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**The Phillips Curve and Underlying Inflation**

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## The Phillips Curve and Underlying Inflation

Hitoshi MIO \*

### Abstract

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 (i) 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 (ii) 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

JEL classification: C43, E31, E52

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## 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<sup>1</sup>.

In the 1970s, two shift parameters, namely the *supply 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, has 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 experience supply shocks frequently (for example, Gordon [1975], 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). Hinted by 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 trimmed mean CPI<sup>2</sup>, 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 (i) because supply shocks hit broad sectors, it is not appropriate to restrict the proxy for the supply shock to the relative price changes

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<sup>1</sup> In this paper, the term *inflation inertia* is defined as a broad concept containing inflation expectations.

<sup>2</sup> I simply call this the trimmed CPI.

of a fixed commodity basket, and (ii) the inflation inertia corresponds to the underlying inflation rate from which the supply shock effect has been eliminated<sup>3</sup>.

The outline of this paper is as follows. Following the introduction, Chapter II summarizes the key features of the methods for controlling the supply shock in the estimation of the Phillips curve. Chapter III presents the empirical results of the estimation and compares the performance. Chapter IV discusses the background of the empirical findings, and Chapter V concludes.

## II. Specification of the Phillips Curve and the Supply Shock

### (1) General Specification of the Phillips Curve

The general specification of the Phillips curve is given as Eq.(1)<sup>4</sup>.

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

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<sup>5</sup>.

In the recent literature, little attention seems to have been paid to the relationship between lagged inflation and the supply shock<sup>6</sup>. Although the subsequent analyses

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<sup>3</sup> 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 Nakata[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.

<sup>4</sup> 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.

<sup>5</sup> 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 affect the error term, and performs estimation using the output gap lagged one year as the instrumental variable.

<sup>6</sup> As I will point out in Chapter IV, however, some of the traditional research including Gordon[1975] is found to discuss this issue.

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 sections summarize the key features of alternative methods for controlling the supply shock in estimating the Phillips curve.

## (2) 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<sup>7</sup>. 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], Okun [1981]). The second is that the exogenous relative price changes of intermediate commodities, such as crude oil, can be regarded as 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 U.S. and Japan using the Gordon method. In the U.S., 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)”<sup>8</sup> for both dependent variable and lagged inflation, and adding the changes in import prices to the right hand side of the equation, is dominant.<sup>9</sup>

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<sup>7</sup> Following Gordon[1997, footnote 2] who argues that he is one of the originators of this method, I call this the Gordon method.

<sup>8</sup> The CPI ex. fresh foods is computed by removing fresh fish and shellfish, fresh vegetables, and fresh fruits from the headline CPI.

<sup>9</sup> 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 chapters since the changes in import prices are overwhelmingly larger than the changes in domestic (general) prices in Japan.

Table 1: Recent Examples from the U.S. and Japan Using the Gordon Method

	Countries	Dependent variable	Proxy on the right hand side of the equation
Gordon [1990]	U.S. etc.	GNP deflator	relative price of food, energy, and import goods, price control "Nixon" dummy, oil shock dummy
Fuhrer [1995]	U.S.	CPI ex. food and energy	relative price change of crude oil
Gordon [1997]	U.S.	CPI-U-X1etc	relative price of food, energy, and import goods, price control "Nixon" dummy
Staiger, Stock and Watson [1997]	U.S.	headline CPI	relative price of food, energy, and price control "Nixon" dummy
Fair [2000]	U.S.	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

### (3) 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 which uses the asymmetry (or skewness) of the cross-sectional price change distribution as a proxy for the supply shock<sup>10</sup>. As in the previous section, 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 after outperforms the former. Therefore, they conclude that the menu cost model is relevant.

In spite of their argument, it is difficult to conclude that the menu cost model has achieved a consensus among economists<sup>11</sup>. However, once we accept their view that

<sup>10</sup> I simply call this the price change distribution.

<sup>11</sup> Reviewing the literature which tries to reconcile the 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 were widely accepted during the late 1970s and the beginning of the 1980s, coincident with the diffusion of the Lucas-Phelps supply function (see Barro[1976], Hercowitz[1981], Parks[1978], Vining and Elwertowski[1976]).

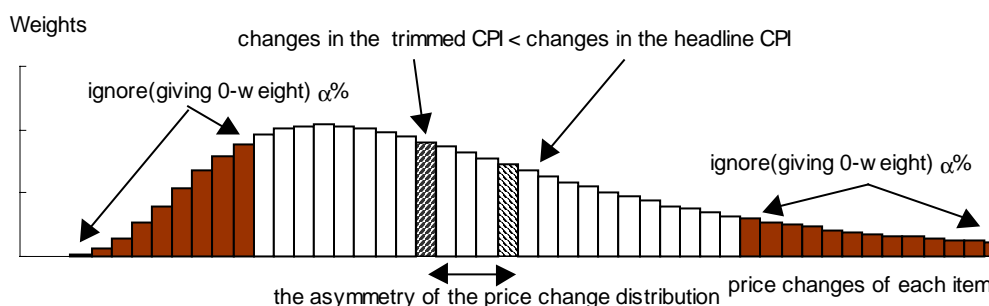
On the contrary, two theories recently suggest that supply shocks to sectors create this correlation. The first is Ball and Mankiw[1995], which assumes that the existence of the menu cost makes the smooth relative price adjustment difficult. The second is Balke and Wynne[2000], which states that this 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 provide the traditional understanding for the macroeconomic consequence of exogenous oil price changes.



supply shocks can potentially hit broad sectors, it might be natural to reexamine the relevance of the traditional Gordon method which assumes that sectors which face supply shocks are fairly limited and can be determined *a priori*. Hinted by their proposal, I estimated the Phillips curve using trimmed mean CPI for the calculation of the the asymmetry (or skewness) of the cross-sectional price change distribution as a proxy for supply shock.<sup>12</sup>

The steps to compute the trimmed CPI are as follows: calculate the price change of each item, find items which 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)<sup>13</sup>. Trimmed CPI tends to be unaffected by large relative price changes in some limited items. Consequently, when some limited sectors face large supply shocks, 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<sup>14</sup>.

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



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 been matured by any means (see Ball and Mankiw [1999], Jaramillo [1999]).

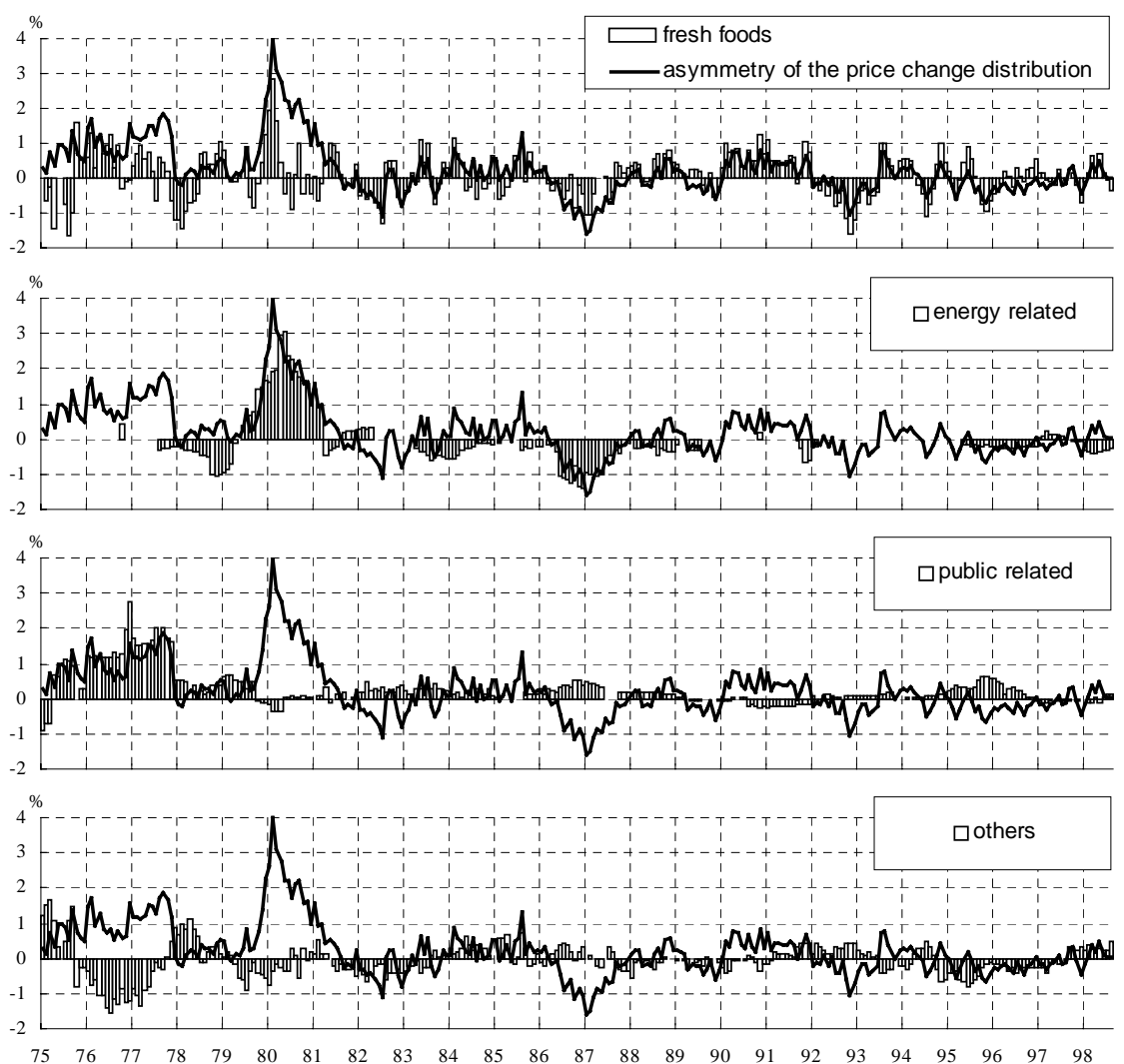
<sup>12</sup> See Nishizaki and Watanabe[1999] for another example using the BM method in Japan.

<sup>13</sup> I use 88 items of the Japanese CPI for the computation of the trimmed CPI. See Shiratsuka[1997], Mio and Higo[1999] for the details of the items used. Based on Mio and Higo [1999], this paper adopts 30% trimmed CPI (i.e., trimming 15% off from each tail of the price change distribution) for the following analysis. In addition, the changes in the headline CPI in this paper is the 0% 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% trimmed CPI and the changes in the headline CPI (arithmetic mean) generally in use virtually show no difference in practice.

<sup>14</sup> See the Appendix for more details about the derivation and the interpretation of the asymmetry of the price change distribution.

There is some evidence that supply shocks may hit broad sectors. Figure 2 presents some items which are located in the tails of the price change distribution and their contribution to the asymmetry of the price change distribution<sup>15</sup>. It turns out that broad items are located in the tails and contribute to creating the asymmetry of the price change distribution. Surprisingly, since 1975, 87 of the 88 items are located in the 15% tail of the price change distribution at least once.

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



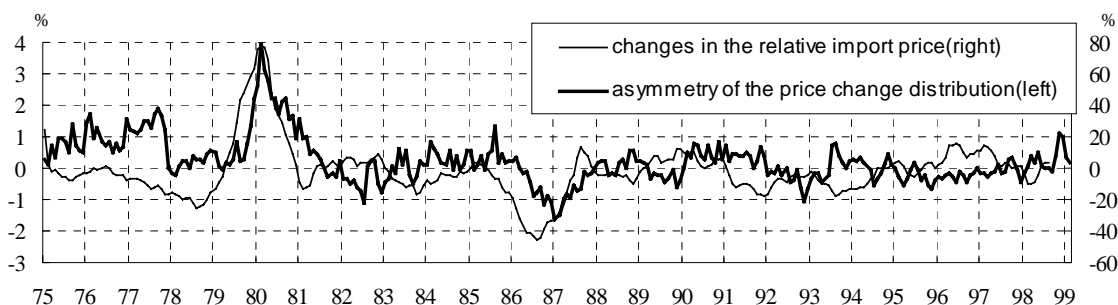
Note: See Mio and Higo[1999] for the detail of the items.

As a consequence, as Figure 3 presents, the relative import price used for the Gordon method and the asymmetry of the price change distribution used for the BM

<sup>15</sup> See the Appendix for the calculation.

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.

Figure 3: Two Proxies for the Supply Shock



In the next chapter, 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<sup>16</sup>.

Table 2: Alternative Methods for Controlling the Supply Shock

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

### III. Estimation Results

In this chapter, 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.

### (1) Estimating Four Specifications

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

Gordon-A type

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

Gordon-AB type

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

BM-A type

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

BM-B type

$$\dot{Trim}30_t = \alpha + \sum_{i=1}^l \beta_i \dot{Trim}30_{t-i} + \sum_{j=1}^m \gamma_j GDPGAP_{t-j} + \varepsilon_t \quad (5)$$

where

$CPIttl$ : headline CPI

$CPIexf$ : CPI ex. fresh foods

$Trim30$ : 30% trimmed CPI

$GDPGAP$  :output gap<sup>19</sup>

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<sup>16</sup> The inflation rate used in the B-type is often called the *core inflation rate*.

<sup>17</sup> Since I consider that present output gap does not affect inflation rate, I do not use present output gap for the explanatory variable. This also avoids the endogeneity problem due to the correlation between  $GDPGAP_t$  and  $\varepsilon_t$ . See Footnote 5.

<sup>18</sup> Names for each specification correspond to those presented in Table 2.

<sup>19</sup> See Watanabe [1997] for the computation of the output gap. He first estimates a Cobb-Douglas 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., output gap is defined as (potential output-actual output)/potential output), the summation of the parameter estimates

*SKEW*: asymmetry of the price change distribution

= changes in the headline CPI- 30% trimmed CPI ( $\dot{CPI}ttl - Trim30$ )

*RIMP*: relative import price

= domestic wholesale import price index / headline CPI

*l*: length of lagged inflation ( $l=1\sim3$ )

*m*: length of the output gap ( $m=1\sim3$ )

*n*: length of the supply shock ( $n=0\sim3$ )

*Dots* (•) above variables indicate year-to-year changes<sup>20</sup>.

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

$$\begin{aligned}\dot{CPI}ttl_t &= \alpha + \sum_{i=1}^n \beta_i \dot{CPI}ttl_{t-i} + \sum_{j=1}^m \gamma_j GDPGAP_{t-j} + \sum_{k=0}^n \theta_k SKEW_{t-k} + \varepsilon_t \\ \dot{CPI}ttl_t - SKEW_t &= \alpha + \sum_{i=1}^n \beta_i \left( \dot{CPI}ttl_{t-i} + \frac{\theta_i}{\beta_i} SKEW_{t-i} \right) + \sum_{j=1}^m \gamma_j GDPGAP_{t-j} + \varepsilon_t \\ Trim30_t &= \alpha + \sum_{i=1}^n \beta_i Trim30_{t-i} + \sum_{j=1}^m \gamma_j GDPGAP_{t-j} + \varepsilon_t\end{aligned}$$

This means that Eq.(5) can be interpreted as a special case of Eq.(4). in the sense that Eq.(5) is the coefficient constrained version of Eq.(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 4 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.<sup>21</sup>

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for the output gap coefficients,  $\Sigma \hat{\gamma}$ , is expected to be negative.

<sup>20</sup> 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.



<sup>21</sup> For Eq.(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.

Next, focusing on coefficients of the output gap term, in Eqs.(4) and (5) the null hypothesis that the coefficient is zero is rejected, regardless of the length of the lagged inflation. In contrast, in Eqs.(2) and (3), the null is not rejected for various lag specifications. None of the specifications has consecutive coefficients which are significant.

Coefficients of the changes in the relative import price in Eqs.(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.

Table 3: Results of Estimated Phillips Curves for Various Lag Specifications

	$\beta_1$	$\beta_2$	$\beta_3$	$\gamma_1$	$\gamma_2$	$\gamma_3$	$\theta_0$	$\theta_1$	$\theta_2$	$\theta_3$	h-alt	adjusted R2	
Eq.(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	
Eq.(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	
Eq.(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
Eq.(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	

 indicates significant at 5% level  
 indicates significant at 10% level

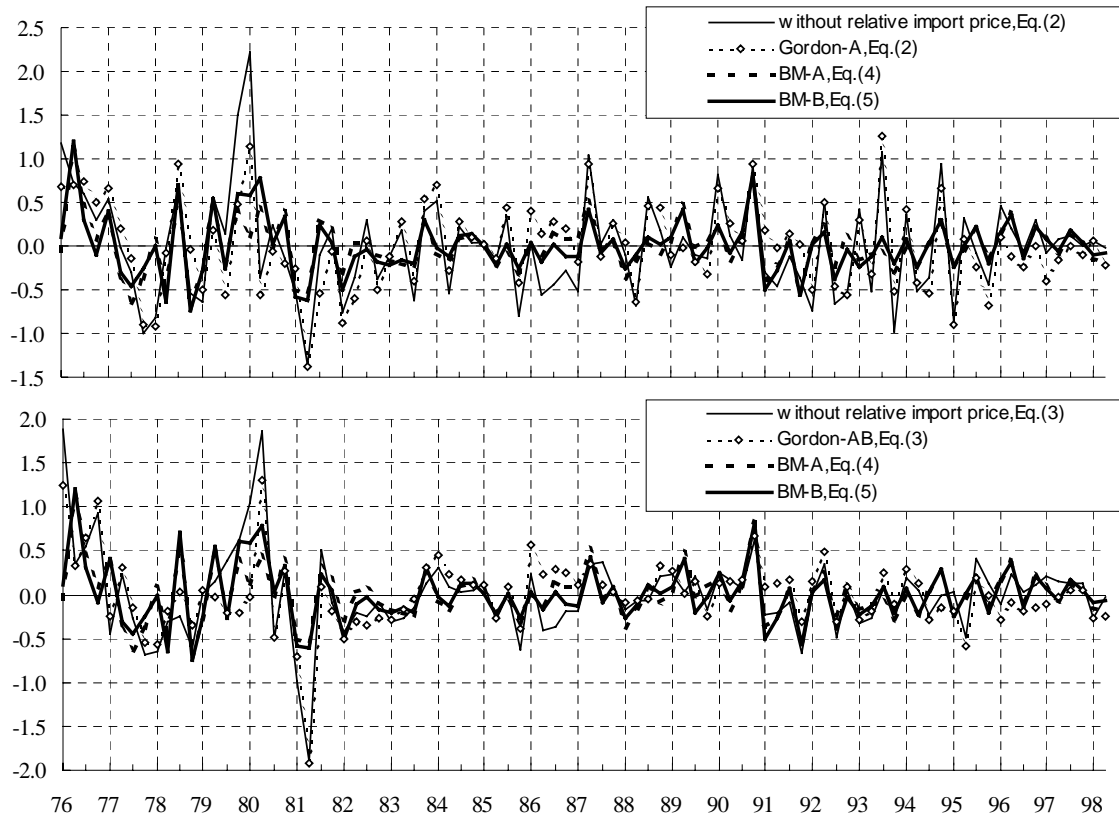
Estimation method: OLS  
 Estimation period: 1975:1Q to 1998:2Q

Checking residuals for various specifications in Figure 4,<sup>22</sup> it turns out, however, that adding the relative import price to the right hand side of the equations contributes to

<sup>22</sup> The length of the lagged inflation ( $I$ ) and output gap ( $m$ ) are set to three and one, respectively, for all four specifications. See Footnote 25.

eliminate a big spike in residual around the year 1980, but not to the other big spikes. These results suggest 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.

Figure 4: Residuals for Various Specifications



## (2) Relationship Between the Inflation Inertia and Supply Shock

In this section, I examine the relationship between inflation inertia and the supply shock. There are two distinctive features in the estimated coefficients of Eq.(4). First, as the length of the lagged inflation increases, the length of the lagged supply shocks which are statistically significant also increases<sup>23</sup>. Second, when the lengths of the lagged inflation and the supply shock term are equal ( $l=n$ ), the coefficient for  $\theta_0$  nearly equals one and coefficients for the corresponding lagged inflation and the supply shock have almost the same absolute values but the opposite sign ( $\beta_n \cong -\theta_n$ ). This

<sup>23</sup> In contrast, as I mentioned above, only the current change in the relative import price is significant for the Gordon type Eqs.(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.



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 section<sup>24</sup>. These findings suggest that the underlying inflation from which supply shock effects have been eliminated by the BM method might be a good proxy for the inflation inertia.

### (3) Predictive Power and Stability of the Estimated Coefficients

In this section, 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<sup>25</sup>.

First, I compute the recursive root mean square error (RMSE) for four specifications. Each specification is first estimated for the period 1985:1Q (all estimation periods begin in 1976:1Q) and a dynamic one- to four-quarter-ahead prediction is made beginning in 1985:2Q. This process is repeated through the estimation period ending in 1997:2Q and 50 one- to four-quarter-ahead predictions are derived. Finally, RMSEs are calculated using these predictions and the actual values<sup>26</sup>.

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.

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<sup>24</sup> See No.25 and No.34 in Table 2, 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 that these linear restrictions are satisfied cannot be rejected at the 1% level.

<sup>25</sup> This specification is the most preferable for the BM method in terms of the significance of the estimates of coefficients and adjusted  $R^2$ . However, the estimates for  $\beta_3$  are considerably small for all specifications so the results of the following analyses are basically not affected by the length of the lagged inflation.

<sup>26</sup> 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, Eq.(2),n=0	Gordon-AB, Eq.(3),n=0	BM-A, Eq.(4),n=3	BM-B, Eq.(5)
1 quarter ahead	0.735 <i>87.5</i>	0.654 <i>66.7</i>	0.402 <i>2.4</i>	0.392
2 quarters ahead	0.995 <i>102.6</i>	0.949 <i>93.2</i>	0.506 <i>2.9</i>	0.491
3 quarters ahead	1.269 <i>102.5</i>	1.227 <i>95.9</i>	0.626 <i>-0.1</i>	0.626
4 quarters ahead	1.490 <i>106.5</i>	1.469 <i>103.7</i>	0.700 <i>-2.9</i>	0.722

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

Next, the parameter stability to changes in the estimation period for each specification is examined. Extending the estimation period to 1998:2Q, 54 estimates are obtained for each coefficient. Table 6 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.

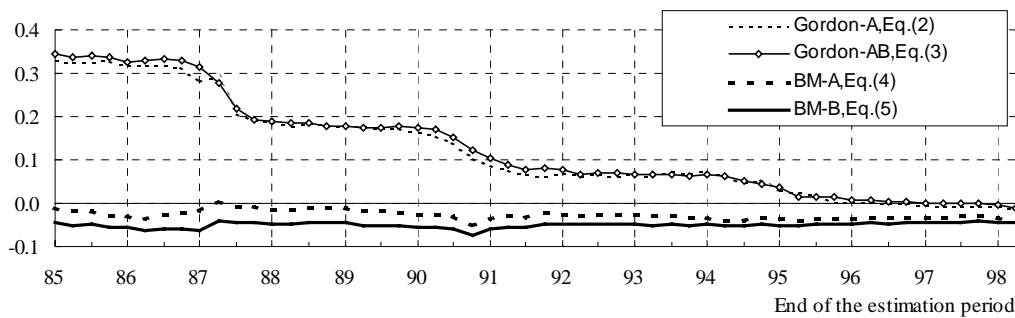
Table 5: CVs for the Estimated Coefficients (54 samples)

		Gordon-A, Eq.(2),n=0	Gordon-AB, Eq.(3),n=0	BM-A, Eq.(4),n=3	BM-B, Eq.(5)
constant	$\alpha$	2.274 <i>2037.0</i>	1.423 <i>1236.9</i>	0.199 <i>87.1</i>	0.106
lagged inflation	$\beta_1$	0.036 <i>40.9</i>	0.049 <i>92.2</i>	0.025 <i>-0.7</i>	0.026
	$\beta_2$	0.309 <i>365.4</i>	0.211 <i>218.0</i>	0.087 <i>30.4</i>	0.066
	$\beta_3$	0.348 <i>288.9</i>	0.249 <i>178.3</i>	0.128 <i>42.9</i>	0.089
output gap	$\gamma_1$	0.901 <i>644.1</i>	0.885 <i>631.0</i>	0.383 <i>216.1</i>	0.121
supply shock	$\theta_0$	0.176	0.222	0.015	
	$\theta_1$			0.038	
	$\theta_2$			0.074	
	$\theta_3$			0.144	

Note: The figures in italics indicate the percentage deviation from the benchmark performance of Eq.(5). Negative figures indicate that the performance is superior to that of Eq.(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 1987:2Q for Eq.(4), and remain fairly stable even when the estimation period is extended.

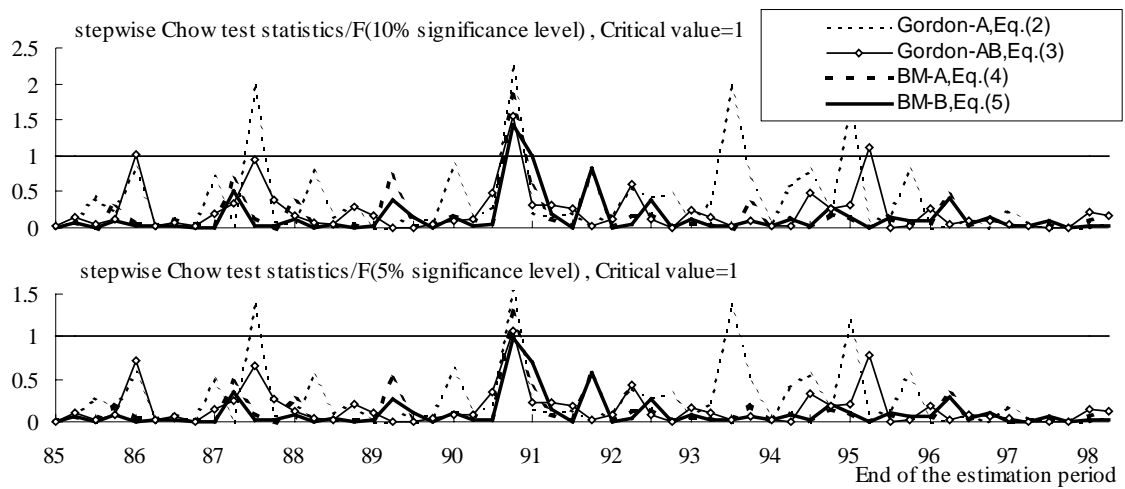
Figure 5: Estimated Coefficients for the Output Gap



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 Eqs.(2) and (3), test statistics are considerably larger than those of BM-type Eqs.(4) and (5), and test statistics beyond the criterion in several points in time. This indicates that the null of no structural break is more likely to be rejected for Gordon-type specifications. Only Eq. (5) does not seem to have any break point during the estimation period<sup>27</sup>.

<sup>27</sup> 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  $F$ -criterion 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 rather choose to show a rough ordinary  $F$ -criterion.

Figure 6: Recursive  $F$ -statistics and the Stepwise Chow Criterion



#### IV. Discussions

Empirical results shown in the previous chapter 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 chapter, I discuss the background for these results.

##### (1) 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 around 1980 and is highly significant. But eventually, this amendment probably reduces the robustness of the other parameter estimates in other periods<sup>28</sup>.

<sup>28</sup> 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

Combining this finding with the empirical results shown in the previous chapter 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.

## (2) 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.

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 mark-up pricing.

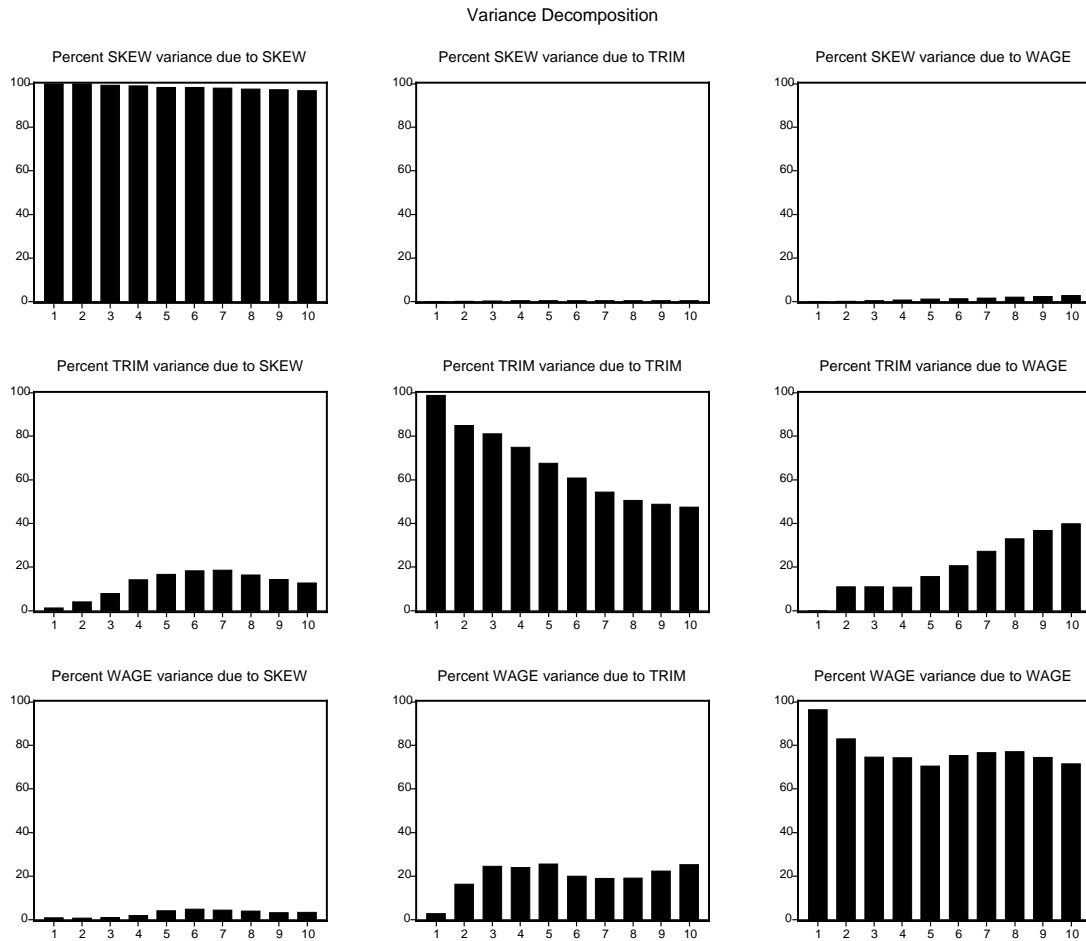
If the underlying inflation rate from which the supply shock effect has been eliminated functions as a good proxy for inflation expectations, interdependence between changes in the nominal wage and the underlying inflation rate should be found. In contrast, little interdependence between the changes in the nominal wage and the asymmetry of the price change distribution which 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*.

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the supply shock coefficient is reversed from positive to negative after 1976.

Figure 7: Variance Decomposition Based on the Estimated VAR Model



Note: The estimation period for VAR is 1973:1Q to 1998:2Q. 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, T=sample size. Changes in the estimation period, lag order, and recursive order generally do not affect the result.

where

*WAGE*: change in nominal wage rate

*Trim30*: 30% trimmed CPI

*SKEW*: asymmetry of the price change distribution.

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 which face supply shocks are unaffected by actual and temporary price changes of those due to

supply shocks<sup>29</sup>.

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 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 section) 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.

The following equation is estimated for the test.

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

diff: headline CPI (log level) – 30% 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% 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<sup>30</sup>.

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

<sup>30</sup> 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
$\psi$	-0.051 (-3.148)***	-0.048 (-2.980)***	-0.042 (-2.723)***	-0.042 (-2.745)***	-0.043 (-2.808)***
$\delta_1$		-0.115 (-1.961)	-0.151 (-2.645)	-0.186 (-3.149)	-0.201 (-3.451)
$\delta_2$			-0.266 (-4.669)	-0.288 (-5.016)	-0.325 (-5.455)
$\delta_3$				-0.125 (-2.177)	-0.153 (-2.606)
$\delta_4$					-0.124 (-2.153)
adjusted R2	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 1% level. Assuming that the cointegration vector is known, the criterion for hypothesis testing is simply computed by Dickey-Fuller's  $\tau$  distribution using MacKinnon's equation.

## V. Conclusion

In this paper, I examined methods of controlling 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: (i) 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 (ii) 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<sup>31</sup>. 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.

It is worth noting that the Phillips curve augmented by lagged inflation remains “clean little secret” of macroeconomics<sup>32</sup>, although it has been faced with 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]<sup>33</sup>, 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 which attempt to derive the structural Phillips curve relationship<sup>34</sup>. Investigating the Phillips curve is still a fascinating concern, for which macroeconomists and policymakers should account.

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<sup>31</sup> See Footnote 11.

<sup>32</sup> Blinder[1997]. Also see Stock and Watson [1999] which argues the advantage of the Phillips curve in terms of the prediction of the inflation rate.

<sup>33</sup> His original statement 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.” (Sargent[1976, p.637])

<sup>34</sup> 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 Eq.(A-1):

$$SKEW_t = \dot{CPI} \, ttl_t - \dot{Trim}30_t = \sum_{i \in N} w_{i,t} \pi_{i,t} - \sum_{i \in M(t)} w_{i,t} \pi_{i,t} / \sum_{i \in M(t)} w_{i,t} \quad (A-1)$$

where

*SKEW*: asymmetry of the price change distribution

*CPI**ttl*: headline CPI

*Trim30*: 30% trimmed CPI

*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*<sup>*C*</sup>(*t*): set comprised of items excluded from the trimmed CPI at time *t*

*w*<sub>*i,t*</sub>: weight for the *i*<sub>th</sub> item at time *t*

*π*<sub>*i,t*</sub>: changes in the price of the *i*<sub>th</sub> 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:

$$\dot{CPI} \, ttl_t = \sum_{i \in N} w_{i,t} \pi_{i,t} = \sum_{i \in M(t)} w_{i,t} \pi_{i,t} + \sum_{i \in M^C(t)} w_{i,t} \pi_{i,t} \quad (A-2)$$

Substituting Eq.(A-2) into Eq.(A-1) yields Eq.(A-3):

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

Eq.(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 5) is calculated by Eq.(A-4):

$$CONT_{i,t} = \frac{w_{i,t}}{\sum_{i \in M(t)} w_{i,t}} \times \left( \pi_{i,t} - \dot{CPI} \, ttl_t \right) \quad \text{for } i \in M^c \quad (A-4)$$

where

*CONT*<sub>*i,j*</sub>: contribution of *i*<sub>th</sub> item to the asymmetry of the distribution.

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