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Abstract

This paper examines inflation dynamics in recent Japan utilizing the estimation of the hybrid New Keynesian Phillips Curve. The result of the estimation with the observed inflation rate and the one with the expected inflation rate estimated through the Kanoh (2006)-type modified Carlson-Parkin procedure are examined. In addition, the underlying points in dispute including the validity of the pure forward-looking (non-hybrid) NKPC are considered. The result of our empirical study leads us to the following conclusions. First, the forward-looking term seems a certain effective element to the inflation dynamics. Second, it is apparent that the backward-looking element has the unignorable impact on inflation process. Third, our results imply the incompleteness of the pure forward-looking NKPC that focuses only on expected future inflation. Fourth, the estimated flattening of the NKPC suggests that the today's difficulty in conducting monetary policy by the central bank.

Key words: New Keynesian Phillips Curve; inflation dynamics; inflation expectation;
JEL Classification Code: C52, E31, E52.

1. Introduction

The dynamics of inflation is a crucial topic of empirical economics in both theory and practice. In other words, to study the evolution of aggregate price and inflation is one of the prominent issues in macroeconomics, and a clear understanding of the inflationary process is necessary in effective planning of a monetary policy. The so-called New Keynesian Phillips Curve (NKPC), which is established by microeconomic foundations with the New Keynesian DSGE (Dynamic Stochastic General Equilibrium) framework, is the most useful tool to study modern issues of monetary policy. To put it another way, the shift in recent emphasis from the traditional Phillips Curve to the New Keynesian Phillips Curve is due to the inability of the former to grasp the developments of today's inflationary processes in several countries. Actually, it is often reported that some countries with lively economic activities are accompanied by relatively low levels of inflation that cannot be explained by the traditional theory.

Recently, literature on the New Keynesian Phillips Curve continues to increase. For instance, Galí and Gertler (1999), and Galí, Gertler, López-Salido (2001), and Sbordone (2002) insist that real marginal cost is the significant factor to analyze inflation dynamics in the U.S. and the Euro area. Galí, Gertler, and López-Salido (2005) describe the importance of the lagged inflation term in their models considering the gradual response of inflation to the monetary policy shocks. Zhang and Clovis (2010) conclude that further lags of inflation are necessary in the hybrid-type NKPC to rule out serial correlation. Rudd and Whelan (2005b) find that the New Keynesian pricing model cannot explain the importance of lagged inflation in standard inflation regression, and that forward-looking element plays a very limited role in describing inflation process. From the aspect of indexation, Smets and Wouters (2003) and Giannoni and Woodford (2005) utilize the partial dynamic inflation indexation. Woodfood (2003) studies the aggregate inflation by focusing on short-run nominal rigidity. Further, some of the recent studies deal with the flattening of the NKPC. For instance, Kuester, Müller, and Stölting (2009) insist that the NKPC looks flatter than its actual slope by considering the estimated pass-through of marginal costs.

Managing "expectation" is an essential concern for monetary policy in today's world. Actually, the central banks monitor the inflation expectation of private sector, while the firm should set its price as a mark-up over a weighted average of current and expected nominal marginal costs in the framework of New Keynesian economics. Furthermore, New Keynesian Phillips Curve includes the forward-looking element as the expected inflation term, which is one of the sources of hot discussions on inflation. In this sense, the empirical study incorporating inflation expectation is worth conducting. Brissimis and Magginas (2008) estimate NKPC with inflation forecasts given by FOMC's Greenbook and the SPF (Survey of Professional Forecasters) concluding that expected inflation is the main determinant of current inflation. Gábriel (2010) reports the significant effect of changes in inflation expectations on prices and wages by the SVAR analysis for three European countries. Oral (2013) uses some different quantification procedures of qualitative data such as Carlson-Parkin method, balance method, regression method in order to estimate Turkish consumer inflation predictions, and rejects the "pure" backward and forward looking expectations hypotheses using the regression method.

Following the trend of recent studies described above, this paper proceeds to examine the inflation dynamics in Japan since 2004 through the estimation of the hybrid New Keynesian Phillips Curve, which allows for a backward-looking component as well as a forward-looking factor. Concretely, the result of the estimation with the observed inflation rate and the one with the estimated expected inflation derived through the Kanoh (2006)-type Carlson-Parkin methodology are compared. In addition, the underlying points in dispute including the validity of the pure forward-looking (non-hybrid) NKPC are considered. In addition, since we should take a critical stance toward NKPC estimation through

GMM in terms of some problems such as weak identification and bias, the Hansen's test for over-identification, the C-test for each instrumental variable's orthogonality, and the tests utilizing Cragg-Donald F-statistics and Stock and Yogo critical values are implemented.

The reminder of this paper is organized as follows. Section 2 explains the basic formulation of the New Keynesian Phillips Curve. Section 3 makes a brief explanation of the basic Carlson-Parkin probability approach and Kanoh (2006)-type modified Carlson-Parkin methodology for the inference of expected inflation. Section 4 examines the results of GMM estimations, and Section 5 presents the concluding remarks.

2. The Structure of New Keynesian Phillips Curve

2.1 The Basic Formulation of New Keynesian Phillips Curve

The New Keynesian Phillips Curve describes the link between inflation and economic activities based on the firms' price-setting behaviours, marginal costs, and various economic activities. Concretely, it incorporates two significant factors: (i) The forward-looking character of inflation which depends on the firm's price-setting manner with their expectations of demands and costs in the future, (ii) The linkages between inflation, real economic activity, and marginal cost.

The NKPC can be derived by the following procedure.[1] The business sector is assumed to be a continuum of monopolistic competitor indexed by $i \epsilon [0,1]$, and produces a differentiated good $Y_t(i)$ with a nominal price $P_t(i)$. Firm i faces an isoelastic demand curve given by $Y_t(i) = \left(\frac{p_t(i)}{P_t}\right)^{-\varepsilon} Y_t$. The production function for firm i is given by a special type of Cobb-Douglas technology: $Y_t(i) = A_t \overline{K}_t(i)^{\alpha} N_t(i)^{1-\alpha}$, where A_t is a technological factor, $\overline{K}_t(i)$ is the fixed firm specific capital stock, and $N_t(i)$ is the employment.

Households are assumed to be paid the nominal wage W_t, and each firm faces the same nominal cost of production. The Dixit-Stiglitz-type aggregate price P_t and output Y_t are represented by:

$$P_t = \left[\int_0^1 P_t^{1-\varepsilon}(i)di\right]^{\frac{1}{1-\varepsilon}}, \qquad (1)$$

$$Y_t = \left[\int_0^1 Y_t^{\frac{\varepsilon-1}{\varepsilon}}(i)di\right]^{\frac{\varepsilon}{\varepsilon-1}}, \qquad (2)$$

where ε is the constant price elasticity of demand. In this model, because investment and foreign trade are abstracted, output Y_t equals consumption C_t.

Without any price frictions, firms would set price level $P_t^*(i)$ which maximizes real profit at any given time. The optimization framework gives the markup equation: $P_t^* = \mu + mc_t$, where $\mu = \log(\frac{\varepsilon}{\varepsilon-1})$ represents the fixed markup and mc is the log nominal marginal cost. In this framework, firms set nominal prices in the Calvo (1983)-type staggered fashion facing constraints on the frequency of price adjustment. With this specification, the probability that a firm resets the price in any period t is $1-\theta$, denoting θ as a measure of the degree of price rigidity. Since this

[1] See Goodfriend and King (1997), Galí, Gertler, and López-Salido (2001), or Scheufele (2010) for an explicit derivation.

probability is time-independent, the mean lag (or duration) of price adjustment becomes $\frac{1}{1-\theta}$. Therefore, a measure $1-\theta$ of producers reset their prices, while a fraction θ remains unchanged. By applying the property of law of large numbers and log linearization of the price index around the steady state of zero inflation, we have the following expression for the evolution of log price P_t as a convex combination of the log of lagged price level P_{t-1} and the log of newly optimized price P_t^*:

$$P_t = (1-\theta)P_t^* + \theta P_{t-1}. \qquad (3)$$

All firms that reset price in period *t* choose the same value of P_t^* since there are no firm-specific state variables. In addition, with the given technology, factor prices, and the constraint on price adjustment, and the reset probability $1-\theta$, a firm which resets its price in period *t* tries to maximize the expected discounted profits. Considering these elements, the Calvo-type optimized reset price can be described as[2]

$$P_t^* = (1-\beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^k E_t\left[mc_{t,t+k}^{n}\right], \qquad (4)$$

where β is a subjective discount factor and $mc_{t,t+k}^{n}$ means the logarithm of nominal marginal cost at time *t+k* of a firm which last change its price at time *t*. This specification implies that firms which reset prices in period *t* will take into consideration the each expected future stream of nominal marginal cost expressed in percent deviation from the steady state value with the chance that newly reset price might be subject to the adjustment constraints in the future. Thus, prices are expected to remain unchanged for an extended period, and firms place more weight on expected marginal costs when they set current prices as θ increases.

The next problem is to find a plausible expression of marginal cost in equation (4) as an observable measure. If we assume a simple Cobb-Douglas production function, we have

$$Y_t = A_t K_t^{\alpha} N_t^{1-\alpha}, \qquad (5)$$

where Y_t is production, A_t refers to technology, K_t denotes capital, and N_t is labor. A Cost minimization with this technology implies that the real marginal cost equals the real wage divided by the marginal product of labor. Therefore, the real MC at time *t+k* for a firm which optimally sets price at time *t* is given by:

$$MC_{t,t+k} = \frac{\frac{W_{t+k}}{P_{t+k}}}{(1-\alpha)(\frac{Y_{t,t+k}}{N_{t,t+k}})} \qquad (6)$$

where $Y_{t,t+k}$ represents output, $N_{t,t+k}$ indicates employment, and α is the curvature of the production function for a firm which has set its price in period *t* at the optimal value P_t^*. From the aspect of the fact that the real MC of individual firm is unobservable, it is helpful to define the average marginal cost depending only on aggregates:

$$MC_t = \frac{\frac{W_t}{P_t}}{(1-\alpha)(\frac{Y_t}{N_t})} = \frac{S_t^n}{1-\alpha}, \qquad (7)$$

where $S_t^n \equiv \frac{W_t N_t}{P_t Y_t}$ is the labor share (or real unit labor costs).[3] Letting lower case letters describe percentage deviations from each steady-state value, it becomes

$$\widehat{mc}_t = \hat{S}_t. \qquad (8)$$

Making the assumption of Cobb-Douglas technology with isoelastic demand curve following Woodford (1996), Galí, Gertler, and López-Salido (2001), and Sbordone (2002), we have the log-linear connection between $MC_{t,t+k}$ and MC_t:

[2] The fixed markup (μ) is disappeared because all variables are expressed in deviation from steady state.

[3] Equation (7) is derived as $MC_t = (W_t/P_t)(1/(\partial Y_t/\partial N_t))$.

$$\widehat{\mathrm{mc}}_{t,t+k} = \widehat{\mathrm{mc}}_{t+k} - \frac{\varepsilon\alpha}{1-\alpha}(\mathrm{P}_t^* - \mathrm{P}_{t+k}), \qquad (9)$$

where $\widehat{\mathrm{mc}}_{t,t+k}$ and $\widehat{\mathrm{mc}}_{t+k}$ are the deviation in logarithm of $\mathrm{MC}_{t,t+k}$ and MC_{t+k} from their steady-state values.[4] Combination of equations (3), (4), and (9) gives the basic formulation of (marginal-cost-based) New Keynesian Phillips Curve (NKPC):[5]

$$\pi_t = \beta E_t[\pi_{t+1}] + \lambda\widehat{\mathrm{mc}}_t, \qquad (10)$$

where

$$\lambda \equiv \frac{(1-\theta)(1-\beta\theta)(1-\alpha)}{\theta[1+\alpha(\varepsilon-1)]}. \qquad (11)$$

The slope coefficient λ is decreasing in θ (the frequency of price adjustment). Thus, a smaller fraction of firms resetting their prices implies inflation will less sensitive to the evolutions of marginal cost. Since it is also decreasing in α (the elasticity of substitution between factor inputs or the curvature of the production function) and ε (the elasticity of demand), the larger α and ε lead the more sensitive marginal cost to the deviation of price from the average level.

2.2 The Hybrid Model of the New Keynesian Phillips Curve

The basic New Keynesian Phillips Curve expressed in equation (10) postulates relatively low persistence of inflation. It is, however, not always consistent with actual inflation dynamics or not data coherent due to price rigidities. An alternative formulation of the NKPC considering this fact proposed by Galí and Gertler (1999) and Galí, Gertler, and López-Salido (2001) incorporates the backward-looking component or lagged dependence of inflation, as well as the forward-looking element.[6] The derivation of this "hybrid model" starts with the modification of the Calvo-type contract by introducing two kinds of firms. A subsample of firms $1-\omega$ has forward-looking price-setting behavior, while the remaining fraction ω set their prices with a backward-looking rule of thumb. Therefore, the aggregate price level is given by the equation:

$$\mathrm{P}_t = \theta\mathrm{P}_{t-1} + (1-\theta)\overline{\mathrm{P}}_t^*, \qquad (12)$$

where $\overline{\mathrm{P}}_t^*$ represents the index of prices at time *t* such that

$$\overline{\mathrm{P}}_t^* = \omega\mathrm{P}_t^b + (1-\omega)\mathrm{P}_t^f, \qquad (13)$$

where P_t^b is the price for backward-looking rule of thumb and P_t^f is the price for forward-looking firms which behave just as basic Calvo-type sectors. Thus, the behavior of forward-looking firms can be described as

$$\mathrm{P}_t{}^f = (1-\beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^k \mathrm{E}_t\,[\mathrm{mc}_{t+k}]. \qquad (14)$$

Galí and Gertler (1999) assume that backward-looking firms follow a rule of thumb behavior based on recent aggregate pricing. In this sense, $\mathrm{P}_t{}^b$ can be expressed as:

$$\mathrm{P}_t{}^b = \overline{\mathrm{P}}_{t-1}^* + \pi_{t-1}. \qquad (15)$$

[4] In the case of linear technology or constant returns to labor ($\alpha = 0$), all firms are confronted with the same marginal cost.

[5] Real marginal cost can be expressed as a related variable of the output gap. Following this condition, the output-gap-based New Keynesian Phillips Curve can be derived. For the concrete discussions, see Walsh (2010), Galí (2008), and Woodford (2003).

[6] This kind of specification is regarded as a "hybrid-type" NKPC in the sense that it incorporates both forward- and backward-looking components.

Since forward-looking firms set prices as the markups over their marginal costs and fix prices probably more than one period, their decisions over prices are based on expected future streams of marginal costs. On the other hand, backward-looking firms fix prices by referring to the equilibrium levels in the previous period.

Totally, combination of equations (10) through (15) derives the reduced-form specification of the (marginal-cost-based) hybrid NKPC:

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E_t[\pi_{t+1}] + \lambda \widehat{mc}_t, \qquad (16)$$

where

$$\lambda \equiv \frac{(1-\omega)(1-\theta)(1-\beta\theta)(1-\alpha)}{\emptyset[1+\alpha(\varepsilon-1)]}, \qquad (17)$$

$$\gamma_f = \beta\theta\emptyset^{-1}, \qquad (18)$$

$$\gamma_b = \omega\emptyset^{-1}, \qquad (19)$$

$$\emptyset = \theta + \omega[1 - \theta(1-\beta)]. \qquad (20)$$

This hybrid specification can be regarded as a special case of the basic formulation of NKPC described by equations (10) and (11) with a backward-looking element ($\omega \neq 0$).

3. Inference of Inflation Expectation

3.1 Inflation Expectation and Survey Data

Inference of inflation expectation based on the data obtained from the survey enables us to consider the formation of expectation by the public without any particular models (for example, rational expectation hypothesis). Specifically, there are two typical patterns of survey data on inflation expectations, in short, “qualitative” and “quantitative” types. In the case of “qualitative” survey, respondents would answer in a qualitative manner to the question, for example, “Do you think that price level (or inflation) go up (or down) during one year from now?” The data on inflation forecast given by this kind of survey is usually presented in the form of a qualitative statistic indicating whether the majority of the polled respondents anticipate inflation to rise, to remain constant, or to decline in the future. Therefore, this type of survey examines a general tendency of the expectation by the public. On the other hand, respondents give an answer to the question in a quantitative manner in the case of “quantitative” survey. It seems desirable to acquire point forecast of inflation expectation, “quantitative” survey may face with some defects since this kind of direct measure is likely to be disturbed by measurement or sampling errors. From this point of view, it is preferable to utilize “qualitative” survey with a method of quantifying qualitative data.

3.2 The Carlson-Parkin Methodology

As we have seen in the previous section, a method of quantifying qualitative survey data is required to study the inflation expectation. However, there are some problems with respect to the data obtained from a qualitative survey. For instance, the respondents only indicate whether prices (or inflation) will “rise”, “fall” or “remain unchanged” for a certain periods ahead in some surveys, and the data do not have a mean value since they are qualitative. To cope with these problems, several techniques such as Carlson-Parkin method, balance method, regression method, and some others have been developed.

The Carlson and Parkin (1975) methodology[7] is a typical way of taking probability approach for the inference of expected inflation. It assumes that the qualitative answer given by the respondent follows an individual probability distribution that is statistically independent and normally distributed with finite mean and variance. The respondent is supposed to report the mean of the distribution. The Carlson-Parkin method postulates that respondents standing at time *t* form an inflation expectation for time *t+1* when they answer the survey. The joint probability distribution $f(\mathrm{x}_{t+1}|\Omega_t)$ is able to be derived by the aggregation of their individual subjective probability distributions where Ω_t is the information set at time *t* and x_{t+1} is the future change of prices in percentage at time *t* for the period *t+1*. This distribution is assumed that it has finite first and second order moments, and can be expressed as $E[\mathrm{x}_{t+1}|\Omega_t] = \pi^e_{t+1}$ where π^e_{t+1} is the inflation expectation for the period *t+1*. Furthermore, it is assumed that there exists an interval $(-\delta_t, \delta_t)$ around 0 ($\delta_t > 0$) such that the participants of the survey report 'no change' in prices if the expected price change lies within this interval. With this δ_t, threshold, respondents are supposed to report the expectation of price change in the following manner:

"prices up" if $\pi^e_{t+1} > \delta_t$. (21)

"prices down" if $\pi^e_{t+1} < -\delta_t$. (22)

"no change" if $-\delta_t \leq \pi^e_{t+1} \leq \delta_t$. (23)

The report by the respondents can be interpreted as the result of an individual probability distribution over the possible future values of the variable in question and as a sampling from some aggregate distribution. Thus, the percentage (or ratio) of the responses of "prices up" denoted by "UP_t" and "prices down" denoted by "DOWN_t" can be transformed into the associated population values:

$$\mathrm{UP}_t = 1 - \Phi\left(\frac{\delta_t - \mu_t}{\sigma_t}\right) \quad (24)$$

$$\mathrm{DOWN}_t = \Phi\left(\frac{-\delta_t - \mu_t}{\sigma_t}\right), \quad (25)$$

where Φ is the cumulative distribution function of the standard normal distribution, μ_t and σ_t are the mean and the standard deviation of the aggregate distribution of inflation expectation. By considering the these two equations, we have

$$a_t = \Phi^{-1}(1 - \mathrm{UP}_t) = \left(\frac{\delta_t - \mu_t}{\sigma_t}\right) \quad (26)$$

$$b_t = \Phi^{-1}(\mathrm{DOWN}_t) = \left(\frac{-\delta_t - \mu_t}{\sigma_t}\right), \quad (27)$$

where Φ^{-1} is the inverse function of Φ. μ_t and σ_t are solved as:

$$\mu_t = -\delta_t\left(\frac{a_t + b_t}{a_t - b_t}\right) \quad (28)$$

$$\sigma_t = 2\delta_t\left(\frac{1}{a_t - b_t}\right) \quad (29)$$

if we have δ_t. One simple way to obtain the plausible value of δ_t is to assume constant δ (i.e. $\delta_t = \delta$) and

$$\sum_{t=1}^{T} \pi_t = \sum_{t=1}^{T} \mu_t \quad (30)$$

[7] The explanation described below is not always same as the original theory given by Carlson and Parkin (1975). The explanation in this section is in line with the basic Carlson-Parkin method based on Henzel and Wollmershäuser (2006), Hori and Terai (2005), Oral (2013), and Scheufele (2011). These papers slightly modify the original Carlson-Parkin model in order that the procedure can be well adapted to empirical analysis.

where π_t is the observed inflation rate. With this assumption, we have

$$\delta = -\frac{\sum_{t=1}^{T} \pi_t}{\sum_{t=1}^{T} \left(\frac{a_t + b_t}{a_t - b_t}\right)}. \qquad (31)$$

Substituting this δ into (28) and (29), we obtain μ_t (expected inflation) and σ_t (standard deviation).

3.3 Kanoh (2006)-type Carlson and Parkin Procedure

Some problems are pointed out to the basic Carlson-Parkin methodology. For instance, there is a chance that the thresholds are asymmetric between the expectations of "prices up" and "prices down" although the basic model assumes they are symmetric. By modifying the basic model, Kanoh (2006)[8] (in Japanese) proposes the procedure that realizes the two kinds of threshold, namely, δ_1 for "prices up" and δ_2 for "prices down". The modifications by Kanoh (2006) are as follows.

The respondents are supposed to express an expectation of price change in the manner:

"prices up" if $\pi_{t+1}^e > \delta_1$. (32)

"prices down" if $\pi_{t+1}^e < \delta_2$. (33)

"no change" if $\delta_2 \leq \pi_{t+1}^e \leq \delta_1$. (34)

For the inferences of the mean and variance of the expectation series, the assumption

$$\sigma_t^{\ 2} = \sum_{t=1}^{T} (\pi_t - \bar{\pi})^2 \qquad (35)$$

is appended. The equations (28) and (29) are altered as:

$$\mu_t = \left(\frac{a_t \delta_2 - b_t \delta_1}{a_t - b_t}\right) \qquad (36)$$

$$\sigma_t = \left(\frac{\delta_1 - \delta_2}{a_t - b_t}\right), \qquad (37)$$

if we assume $\delta_{1t} = \delta_1$ and $\delta_{2t} = \delta_2$ for constant δ_1 and δ_2. With some manipulation with these elements, we have[9]

$$\delta_1 = \frac{1}{T}\left(\sum_{t=1}^{T} \pi_t + \sum_{t=1}^{T} \frac{a_t}{a_t - b_t} \sqrt{\frac{\sum_{t=1}^{T} (\pi_t - \bar{\pi})^2}{\sum_{t=1}^{T} \left(\frac{1}{a_t - b_t}\right)^2}} \right) \qquad (38)$$

$$\delta_2 = \frac{1}{T}\left(\sum_{t=1}^{T} \pi_t + \sum_{t=1}^{T} \frac{b_t}{a_t - b_t} \sqrt{\frac{\sum_{t=1}^{T} (\pi_t - \bar{\pi})^2}{\sum_{t=1}^{T} \left(\frac{1}{a_t - b_t}\right)^2}} \right) \qquad (39)$$

where $\bar{\pi}$ is the average rate of observed inflation. Plugging (38) and (39) into (36) and (37), we obtain μ_t and σ_t, respectively.

3.4 Application of the "Consumer Confidence Survey" to the Estimation of Expected Inflation

"Consumer Confidence Survey" conducted by the Economic and Social Research Institute, Cabinet Office, Government of Japan[10] is one of the applicable sources of empirical study based on the Carlson-Parkin approach.

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[8] Kanoh (2006) proposes some models for the inference of inflation expectations. The model applied in this paper is one of them.

[9] Kanoh (2006) gives only the verbal explanation of his modification without any concrete derivation process of equations (38) and (39). However, with some calculations with given assumptions and conditions, we are able to have these equations for δ_1 and δ_2.

Figure 1: Example of the Survey Result of "Price Expectations a Year Ahead"

(Unit:%)

	Go down			Stay the same	Go up			Don't know
	greater than or equal to -5%	less than -5% to greater than or equal to -2%	less than -2%	about 0%	less than 2%	greater than or equal to 2% to less than 5%	greater than or equal to 5%	
2012 Jul	1.7	2.6	4.4	19.2	19.1	30.0	16.2	6.9
Aug	1.3	2.1	5.6	21.5	22.1	26.6	14.0	6.8
Sep	1.1	1.9	5.0	18.5	23.2	29.2	14.9	6.2
Oct	0.8	2.5	4.4	17.0	25.4	31.0	13.6	5.3
Nov	0.7	1.9	5.6	20.4	25.0	27.7	13.3	5.3
Dec	0.7	2.4	6.3	20.8	24.1	26.2	13.6	5.8

(Source: http://www.esri.cao.go.jp/en/stat/shouhi/shiken_summary_e.html)

Monthly sequential data are available from April 2004. Concretely, the qualitative data obtained from the section "price expectations a year ahead" in the "Consumer Confidence Survey" can be used to our empirical study of inflation perceptions and expectation. The survey is conducted on monthly basis, and the participants are asked to exhibit their assessment of the general situation or expectation of Japan's economy. The survey is conducted on monthly basis, and the participants are asked to exhibit their assessment of the general situation or expectation of Japan's economy.

In the item "price expectations a year ahead", respondents give their a-year-ahead expectations of price level by "go down", "stay the same", "go up", or "don't know" as indicated in Figure 1,[11] an example of the survey result. We apply the data acquired from the "Consumer Confidence Survey" to the inference of expected inflation by utilizing the Carlson-Parkin procedures.

4. Empirical Results

This section is for our estimations of the hybrid NKPC by utilizing the Japanese quarterly data spanning the period 2004:2 to 2013:3. The start of our observation is set at 2004:2 because the data of "Consumer Confidence Survey" is available from April 2004. Our data set is constructed by the following variables.[12]

Df: GDP deflator (quarterly, first preliminary estimates, seasonally adjusted)

Cp: consumer price index (monthly, excluding fresh food, whole Japan, total)

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[10] See "http://www.esri.cao.go.jp/en/stat/shouhi/shouhi_kaisetsu-e_fy2013.html#" in datails.

[11] The points that we should take notice of the "Consumer Confidence Survey" are as follows. (a) survey of "price expectations a year ahead" is conducted on the three categories – "all households", "excluding one-person", and "one-parson". (b) From May 2004 to February 2007, the survey was conducted by using telephone in months other than June, September, December, and March. On the other hand, the survey used direct-visit and self-completion questionnaires in June, September, December and March. (c) From April 2013, the way of the survey has been altered to mail survey. In addition, the number of sample households has been enlarged from 6720 to 8400. Therefore, discontinuity of the survey data exists between March and April in 2013.

[12] The data on "GDP deflator," and "compensation of employees" are obtained from the Economic and Social Research Institute, Cabinet Office's website (in English) "http://www.esri.cao.go.jp/index-e.html". The "consumer price index," "employee," and "employed person," are retrieved from the "Portal Site" of Official Statistics of Japan administered by the Ministry of Internal Affairs and Communications, Statistics Bureau, Director-General for Policy Planning (Statistical Standards) & Statistical Research and Training Institute (in English) "http://www.e-stat.go.jp/SG1/estat/eStatTopPortalE.do".

Cn: compensation of employees (quarterly, chain-linked estimates, first preliminary estimates, seasonally adjusted, billion yen)

Ee: employee (monthly, whole Japan, total, seasonally adjusted)

Ep: employed person (monthly, whole Japan, total, seasonally adjusted)

Wp: nominal wage per capita (= Cn / Ee)

Lp : labor productivity (= Yr / Ep)

Uc: unit labor cost (= Wp / Lp)

Ls: labor share (or , real unit labor costs) (= Uc / (Df /100))

Lc: trend component of Ls obtained by the Hodrick-Prescott filter[13] setting the penalty parameter = 1600

Lg: proxy variable for $\widehat{\mathrm{mc}}(=\hat{\mathrm{S}})$ = log(Ls) − log(Lc)

μ_t: estimated expected inflation rate by applying the basic Carlson-Parkin Method or Kanoh (2006)-type procedure

The monthly data on "consumer price index"[14], "employee", and "employed person" were converted into quarterly series by taking three-months averages. As to the inflation measure, the moving average $\pi_t^* = \frac{1}{4}(\pi_t + \pi_{t-1} + \pi_{t-2} + \pi_{t-3})$ where π_t is the inflation rate at time t as the change from the previous quarter of the consumer price index is adopted. One problem is how we have the proxy for the marginal cost in equation (16) (and (8)). We utilize "Lg" as $\widehat{\mathrm{mc}}$. The trend component estimated by the Hodrick-Prescott filter is regarded as the proxy for the steady-state value. Another problem that we confront is the correlation due to the causal relationship between the variables. Unobservable expected inflation $E_t\pi_{t+1}$ is replaced by actually observed π_{t+1} under the assumption of rational expectation in our first estimation, and by the estimated expected inflation rate, μ_t, which is based on the basic Carlson-Parkin method and Kanoh (2006)-type procedure in our second inference. Thus, we set $E_t[\pi_{t+1}] = \pi_{t+1} + \mathrm{u}_{t+1}$ (u: expectational error) for the first estimation, and we utilize μ_t instead of $E_t[\pi_{t+1}]$ for the second task. However, this treatment may cause the correlation between the error term and the explanatory variables. To deal with this problem, GMM (Generalized Method of Moments) is adopted.

The reduced-form coefficient λ expressed in equation (17) is a function of $\beta, \omega, \theta, \alpha$, and ε, but we cannot estimate all these structural parameters because of the identification restriction. One plausible strategy is as follows. Let us define $\varphi \equiv \frac{1-\alpha}{1+\alpha(\varepsilon-1)} \in (0,1)$ as a function of α and ε. Next, suppose the special case of constant φ, in other words, the case of constant returns to scale or constant marginal costs across firms.[15] If we take advantage of this assumption following Galí, Gertler, and López-Salido (2001) and Maturu, Kisinguh, and Maana (2007), we can regard φ as 1. Plugging $\varphi = 1$ into equation (17), we have

$$\bar{\lambda} \equiv (1-\omega)(1-\theta)(1-\beta\theta)\emptyset^{-1}. \qquad (40)$$

With this specification, we are able to estimate the parameters β, ω, and θ. The corresponding orthogonality condition for our estimation is constructed as:

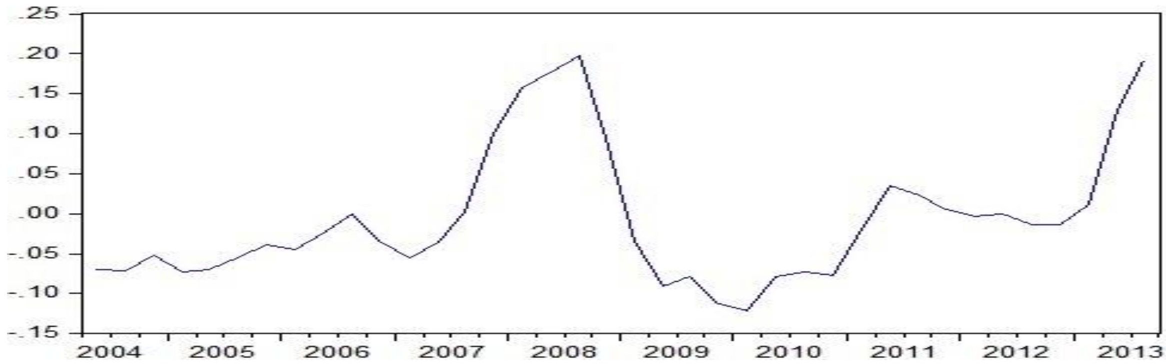
$$E_t[\{\pi_t - \omega\emptyset^{-1}\pi_{t-1} - \beta\theta\emptyset^{-1}\pi_{t+1} - \emptyset^{-1}(1-\omega)(1-\theta)(1-\beta\theta)\widehat{\mathrm{mc}}_t\}Z_t] = 0, \qquad (41)$$

[13] See Hodrick and Prescott (1997) for a concrete discussion.

[14] Seasonally non-adjusted series of consumer price index were converted into seasonally adjusted series by Eviews (Ver. 8) applying X-12-ARIMA with in-line specification of ARIMA as (0 1 1) (0 1 1). In Short, the spec file for X-12-ARIMA was adjusted as close as possible to the one applied to the indices of industrial production by the Ministry of Economy, Trade and Industry. See the section 9 of "Current Survey of Commerce - Notes for use –", at "http://www.meti.go.jp/english/statistics/tyo/syoudou/pdf/h2snotee.pdf".

[15] In this case, capital is assumed to be mobile freely across firms.

Figure 2: Expected Inflation by the Kanoh (2006)-type Carlson-Parkin Procedure (changes from the previous month)



(Notes: $\widehat{\delta_1}$ = -0.05031229, $\widehat{\delta_2}$ = -0.22750368, $\hat{\sigma}$ = 0.124973.)

where Z_t denotes the vector of instrumental variables.

Instrumental variables dated *t-1* and earlier are adopted to construct Z_t because of the following two reasons: (i) The public may not utilize all the current information when they form their expectations, (ii) Certain level of measurement errors of $\widehat{\mathrm{mc}}$ may exist, but the errors may not be correlated with lagged instruments (as the past information). The instrumental variables included in our Z_t are listed in Tables 1-2 and 2-2 with the results of the orthogonality C-Tests.

The inferences of the expected inflation rate are implemented by applying the basic Carlson-Parkin method and the Kanoh (2006)-type Carlson-Parkin procedure explained in section 3. The qualitative data obtained from the "Consumer Confidence Survey" is used to our task. For simplicity, the ratio of "don't know" reported in the result is merged into the one of "stay the same". The total of the ratios of "go down", "stay the same", "go up", and "don't know" sometimes exceeds 100% due to the round-off errors of each category. To cope with this problem, the total sum of the ratios is adjusted to just 100%, and the ratios of each category are accordingly adjusted. Furthermore, the observed inflation rate (as the change from the previous month) based on the seasonally adjusted consumer price index is utilized in the process of estimating μ_t, expected inflation rate. In addition, the estimated monthly μ_t is converted into quarterly series for our estimation of NKPC. The estimation result of expected inflation rate by the basic Carlson-Parkin method is unfavorable since the estimated $\hat{\delta}$ (threshold), has the negative sign ($\hat{\delta} = -0.00219432$). This is inconsistent with the assumption ($\delta > 0$), but this problem is often reported in previous studies. On the other hand, expected inflation by the Kanoh (2006)-procedure has $\widehat{\delta_1} = -0.05031229$ and $\widehat{\delta_2} = -0.22750368$. Since the ideal combination is $\widehat{\delta_1} > 0$ and $\widehat{\delta_2} < 0$, the estimated $\widehat{\delta_1}$ is unfavorable. However, the estimated series by the Kanoh (2006)-procedure can be regarded as a comparatively applicable to our estimation of NKPC since at least one of the two thresholds is in line with the assumption. Figure 2 reports the estimated expected inflation rates by applying the Kanoh (2006)-type Carlson-Parkin procedure.

Our specification of the hybrid NKPC allows us to estimate both reduced-form and structural parameters. The results of the estimations are summarized in the tables listed below. The estimated standard errors of the GMM estimations are computed through the weighting matrix using Bartlett kernel with Newey-West HAC (Heteroscedasticity and Autocorrelation Consistent) covariance estimate (fixed bandwidth = 4) to deal with the possibility of serial correlation.

Table 1-1 displays the result of estimation using actual π_{t+1} as a proxy for $E_t[\pi_{t+1}]$ under the assumption of rational expectation. Concerning the diagnostic tests, the null hypotheses of over-identification for GMM estimations for reduced-form and structural parameters cannot be rejected by the Hansen's tests, supporting the validity of the moment conditions. (See J-statistics and p-values in notes under the Table 1-1.) As to the reduced-form parameters, the estimate

Table 1-1: GMM Estimation with Rational Expectation

variable	coefficient	standard error	p-value
reduced-form parameter			
γ_b	0.411717	0.151597	0.0104
γ_f (observed)	0.586351	0.225231	0.0137
λ	0.008263	0.008941	0.3621
structural parameter			
ω	0.582355	0.347031	0.1028
θ	0.836057	0.189281	0.0001
β	0.991926	0.417099	0.0233
duration (in quarters)	6.099681		

Notes (reduced-form parameter): J-statistic = 1.501746, p-value (J-statistic) = 0.471954, Included observations = 36 (after adjustments). Estimation weighting matrix: HAC (Bartlett kernel, Newey-West fixed bandwidth = 4.0000), Standard errors and covariance computed using HAC weighting matrix (Bartlett kernel, Newey-West fixed bandwidth = 4.0000), Convergence achieved after 12 weight iterations.

Notes (structural parameter): J-statistic = 1.501841, p-value (J-statistic) = 0.471932, Included observations = 36 (after adjustments). Estimation weighting matrix: HAC (Bartlett kernel, Newey-West fixed bandwidth = 4.0000), Standard errors and covariance computed using HAC weighting matrix (Bartlett kernel, Newey-West fixed bandwidth = 4.0000), Convergence achieved after 44 coefficient and 14 weight iterations.

Table 1-2: Orthogonality C-Test for Instrumental Variables

Test instruments	Difference in J-stats			Restricted	Unrestricted
	Value	d.f.	p-value	J-statistic	J-statistic
reduced-form parameter estimation					
Inflation (-1)	1.160500	1	0.2814	1.501746	0.341247
MC (-1)	1.021021	1	0.3123	1.501746	0.480725
MC (-2)	1.501178	1	0.2205	1.501746	0.000568
MC (-3)	1.496288	1	0.2212	1.501746	0.005458
structural parameter estimation					
Inflation (-1)	1.160727	1	0.2813	1.501841	0.341115
MC (-1)	0.504656	1	0.4775	1.501841	0.997186
MC (-2)	1.501273	1	0.2205	1.501841	0.000568
MC (-3)	1.496385	1	0.2212	1.501841	0.005457

Table 1-3: Weak Instrument Diagnostics (reduced-form parameter estimation)

Cragg-Donald F-stat		0.782215
Stock-Yogo TSLS critical values (relative bias)	5%	11.04
	10%	7.56
	20%	5.57
	30%	4.73
Stock-Yogo critical values (size)	10%	16.87
	15%	9.93
	20%	7.54
	25%	6.28
Moment selection criteria	SIC-based	-5.665292
	HQIC-based	-3.629162
	Relevant MSC	-9.111948

for the coefficient γ_b on lagged inflation is significant. Also, γ_f on future inflation is significant. The fact that the estimated value of the latter coefficient is larger than that of the former implies the forward-looking behaviour is comparatively predominant over inflation dynamics in the period we concern. In addition, the sum of γ_b and γ_f is very close to 1, the theoretical value. The coefficient λ on the marginal cost is not significant, and it might imply that marginal cost is not an effective indicator of inflation in recent period. From another aspect, λ is the slope coefficient of NKPC. Thus, the NKPC we focus on is very flat since the estimated value of λ is very small (and insignificant).

The structural parameter ω, the degree of backwardness in price setting, is not significant at the conventional level. This result is not in line with the significance of γ_b in reduced-form estimation. With respect to θ, which is for the measure of price stickiness (or for the fraction of firms that keeps price constant), is significantly estimated. The average duration of a price remaining fixed (in quarters) corresponding to the estimate of θ is 6.099681. In other words, the frequency in price adjustment is about 18.3 months so far as our estimation period is concerned. The estimated value of the discount factor β is 0.991926, and this is virtually the same as the theoretical value, 0.99.[16]

On the other hand, Table 1-2 reports the results of the instrument orthogonality C-tests for each instrumental variable. In short, the tests which detect whether each instrumental variable satisfies the orthogonality condition are implemented one by one. The results suggest that the null hypotheses of respective instrumental variable's orthogonality to the error term cannot be rejected at the conventional level for all cases. Further, to investigate the weak identification problem raised by some studies including Mavroeidis (2004), we utilize the Cragg and Donald (1993) statistic and Stock and Yogo (2005) critical values.[17] In Table 1-3, the Cragg-Donald F-statistic is smaller than Stock and Yogo (2005) critical values for both relative bias and size. It suggests that the set of instrumental variables would not always be strong enough in our estimation of reduced-form parameters.[18] Thus, the results of the tests for instrumental variables are complicated. Namely, each of the instruments would function well, nevertheless, the set of them is weaker than the desirable level.

Table 2-1 indicates the result of second estimation with μ_t, which is derived through the Kanoh (2006)-type Carlson-Parkin procedure. With regard to the diagnostic tests, the null hypotheses of over-identification for GMM estimations cannot be rejected by the Hansen's tests. (See J-statistics and p-values in notes under the tables.) Concerning the reduced-form parameters γ_b and γ_f, both of them are sufficiently significant although the total sum of the values cannot be close to the theoretical value. The values of both coefficients, however, are very close one another indicating their similar impacts in shaping inflation dynamics. The significance of the coefficient estimated on λ shows that the impact of marginal cost on inflationary process works in a certain level. At the same time, the estimated small value of λ implies the very flat NKPC.

With regard to the structural parameter, estimated coefficient of the backward-looking price setting (ω) is significant. What is more, the estimated θ is apparently larger than the one in the case of rational expectation assumption leading to the comparatively longer average duration of price adjustment around 17.583654 quarters. This value suggests that price remain unchanged for roughly 52.75 months. This long duration might be a reflection of the prolonged Japanese recession in the sample period we concern. Lastly, the estimate of β, the discount factor, is about 0.44. This considerably small value might be derived by the conservative inflation expectation by the public during the recession.

Table 2-2 reports the results of the instrument orthogonality C-tests. The test statistics suggest that the null hypotheses of each instrumental variable's orthogonality cannot be rejected at the conventional level for all cases. On the other hand, the Cragg-Donald F-statistic is smaller than two kinds of Stock and Yogo (2005) critical values in Table 2-3. It suggests that the set of instrumental variables would not be strong enough in the estimation of reduced-form parameters. Thus, we have mixed results, as a similar case of reduced-form parameters.

By comparing the estimation result with the observed rate of future inflation rate and the one with the estimated future rate given by Kanoh(20006)-type Carlson-Parkin procedure, we find significantly estimated reduced-form coefficient γ_b (on lagged inflation) in both cases. The significances of the structural parameters ω (the degree of backwardness in price setting) in the first case and θ (the measure of price stickiness) in both cases are consistent with the results of the

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[16] For instance, Christiano, Eichenbaum, and Evans (2005) regard this as $\beta = 1.03^{-0.25}$. This can be interpreted as $\beta = 1.03^{-0.25} \approx 0.99$. Erceg, Henderson, and Levin (2000), Giannoni and Woodford (2003), Steinsson (2003), Walsh (2003), and Christiano, Eichenbaum, and Evans (2005) also assume β = 0.99.

[17] See Cragg and Donald (1993), Stock, Wright, and Yogo (2002), and Stock and Yogo (2002) in details.

[18] Stock and Yogo (2005) critical values cannot be calculated for the structural form parameter estimation since it is regarded as non-linear.

Table 2-1: GMM Estimation with Expected Inflation

reduced-form parameter			
variable	coefficient	standard error	p-value
γ_b	0.314564	0.064525	0.0000
γ_f (expected)	0.375048	0.057353	0.0000
λ	0.019555	0.003627	0.0000
structural parameter			
variable	coefficient	standard error	p-value
ω	0.348399	0.079251	0.0001
θ	0.943129	0.011290	0.0000
β	0.440503	0.066963	0.0000
duration (in quarters)	17.583654		

Notes (reduced-form parameter): J-statistic = 5.986608 , p-value(J-statistic) = 0.816387, Included observations = 34 (after adjustments). Estimation weighting matrix: HAC (Bartlett kernel, Newey-West fixed bandwidth = 4.0000), Standard errors and covariance computed using HAC weighting matrix (Bartlett kernel, Newey-West fixed bandwidth = 4.0000), Convergence achieved after 77 weight iterations.

Notes (structural parameter): J-statistic = 5.986392, p-value(J-statistic) = 0.816405, Included observations = 34 (after adjustments). Estimation weighting matrix: HAC (Bartlett kernel, Newey-West fixed bandwidth = 4.0000), Standard errors and covariance computed using HAC weighting matrix (Bartlett kernel, Newey-West fixed bandwidth = 4.0000), Convergence achieved after 191 coefficient and 78 weight iterations.

Table 2-2: Orthogonality C-Test for Instrumental Variables

reduced-form parameter estimation

Test instruments	Difference in J-stats			Restricted	Unrestricted
	Value	d.f.	p-value	J-statistic	J-statistic
Inflation (-1)	0.257036	1	0.6122	5.986608	5.729572
Inflation (-2)	0.118242	1	0.7309	5.986608	5.868366
Inflation (-3)	0.018903	1	0.8906	5.986608	5.967705
Inflation (-4)	0.470312	1	0.4928	5.986608	5.516296
Expected Inflation (-1)	0.212446	1	0.6449	5.986608	5.774162
Expected Inflation (-2)	0.001590	1	0.9682	5.986608	5.985018
Expected Inflation (-3)	0.933310	1	0.3340	5.986608	5.053298
Expected Inflation (-4)	0.082358	1	0.7741	5.986608	5.904250
MC (-1)	0.564510	1	0.4524	5.986608	5.422098
MC (-2)	0.915092	1	0.3388	5.986608	5.071516
MC (-3)	1.179836	1	0.2774	5.986608	4.806772
MC (-4)	0.396826	1	0.5287	5.986608	5.589782

structural parameter estimation

Test instruments	Difference in J-stats			Restricted	Unrestricted
	Value	d.f.	p-value	J-statistic	J-statistic
Inflation (-1)	0.257042	1	0.6122	5.986392	5.729350
Inflation (-2)	0.118238	1	0.7310	5.986392	5.868153
Inflation (-3)	0.018920	1	0.8906	5.986392	5.967471
Inflation (-4)	0.470292	1	0.4929	5.986392	5.516100
Expected Inflation (-1)	0.212477	1	0.6448	5.986392	5.773915
Expected Inflation (-2)	0.001591	1	0.9682	5.986392	5.984801
Expected Inflation (-3)	0.933273	1	0.3340	5.986392	5.053118
Expected Inflation (-4)	0.082374	1	0.7741	5.986392	5.904018
MC (-1)	0.564505	1	0.4525	5.986392	5.421886
MC (-2)	0.915042	1	0.3388	5.986392	5.071350
MC (-3)	1.179752	1	0.2774	5.986392	4.806639
MC (-4)	0.396864	1	0.5287	5.986392	5.589528

Table 2-3: Weak Instrument Diagnostics (reduced-form parameter estimation)

Cragg-Donald F-stat		1.923592
Stock-Yogo TSLS critical values (relative bias)	5%	19.40
	10%	10.78
	20%	6.22
	30%	4.59
Stock-Yogo critical values (size)	10%	32.88
	15%	17.95
	20%	12.86
	25%	10.22
Moment selection criteria	SIC-based	-29.27700
	HQIC-based	-19.34475
	Relevant MSC	-9.571888

reduced-form γ_b in that the backward-looking factor poses certain impact on inflation dynamics. On the other hand, each γ_f (on future inflation) is significantly estimated in both cases. In this context, the combination of the significances of lagged and expected (or future) inflation terms casts doubt on the validity of the pure forward-looking-type (non-hybrid) NKPC. Further, small estimated values of λ in two types of estimation imply a very flat NKPC in recent Japan. The flattening of the NKPC suggests that inflation is less responsive to the movements in measures of aggregate economic activities such as output gap, and this topic is related to the credibility implication of monetary policy. From this viewpoint, our result implies the today's difficulty in conducting monetary policy by the central bank.

5. Concluding Remarks

This paper examines inflation dynamics in Japan since 2004 utilizing the estimation of the hybrid variant of the New Keynesian Phillips Curve (NKPC). Concretely, the result of the estimation with the observed inflation rate and the one with the estimated expected inflation derived through the Kanoh (2006)-type modified Carlson-Parkin methodology are compared. In addition, the underlying points in dispute including the validity of the pure forward-looking (non-hybrid) NKPC are considered.

The result of our empirical study leads us to the following conclusions. First, the forward-looking term seems a certain effective element to the inflation dynamics in recent Japan since the coefficients on the observed future inflation and on the estimated expected inflation are respectively estimated with significance in our two kinds of estimation. Second, it is apparent that the backward-looking element has the unignorable impact on inflation process as we found estimated sufficiently significant reduced-form coefficients on lagged inflations, and this aspect is also supported by the results of structural form estimations. Third, our results imply the incompleteness of the pure forward-looking (non-hybrid) NKPC that focuses only on expected future inflation by the significantly estimated coefficients of the backward-looking term as well as the forward-looking one as described in the previous conclusions. It gives us the policy implication that the discussion of monetary policy has to lay adequate stress on backward-looking perspective in addition to the forward-looking view. Fourth, the estimated flattening of the NKPC suggests that the today's difficulty in conducting monetary policy by the central bank.

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