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Summary

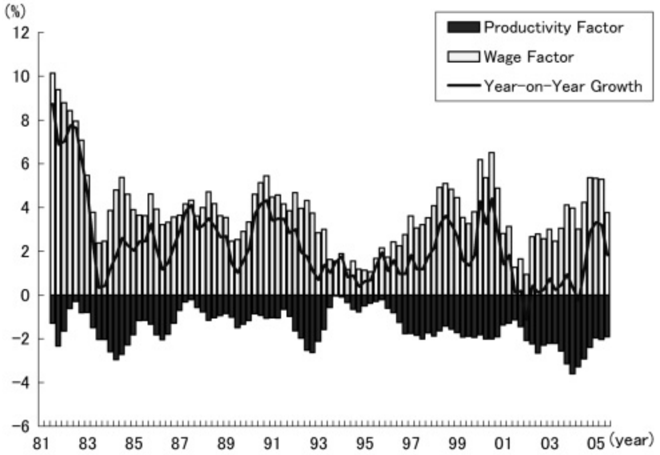
1. Price developments are gathering more attention. In an attempt to capture inflation, unit labor cost, output gap and inflation expectations are often regarded as useful indicators against a backdrop of the huge amount of research on the Phillips curve. In recent years, the New Keynesian Phillips Curve (NKPC, sticky price model) assuming sticky prices is considered one of the standard tools for analyzing inflation developments for conducting monetary policy. In the model, changes in expectations on future inflation could effect current inflation, justifying a modern–style monetary policy in which central banks are inclined to commit to expectations in the market.
2. More recently, a new NKPC assuming sticky wages as well as sticky prices is proposed by Erceg, Henderson, and Levin (2000). In the "sticky price–wage model," the "real wage gap" as well as the "output gap" are explanatory variables in the inflation equation.
3. As a result of estimating the sticky price–wage model in the U.S. and Japan, in the case of the GDP deflator as a price indicator, both coefficients of the real wage gap in the sticky price–wage models in the U.S. and Japan are statistically significant, suggesting the validity of sticky price–wage model in both countries. When using the core CPI as the price indicator for Japan and the PCE deflator for the U.S., we found that Japan's coefficient of the real wage gap is not significant, in contrast to the coefficient being significant in the U.S. As for inflation expectations, while the importance of forward–looking factors and backward–looking factors are almost the same in the U.S., the forward–looking factor is dominant in Japan.

1. Introduction

The Japanese and U.S. economies are entering a more important phase of inflation dynamics. The Japanese economy finally emerged out of a prolonged deflation last year and the Bank of Japan (BOJ) is moving closer to normalizing its monetary policy framework from the quantitative easing monetary policy to interest rate targeting. In the U.S., although the avoidance of deflation in 2003 is still fresh in our memory, inflation pressure has been building with the core PCE deflator, which is considered to be a reference price indicator for monetary policy, rising to about 2 percent in the past few quarters. Recent inflation developments in both countries require us to explore the source of inflation and the degree of inflation pressure more closely than before.

There is no question that comprehensive judgments are needed for capturing future inflation pressures because of the complexity of inflation dynamics. However, some indicators exist which are often used for capturing inflation developments in central banks around the world, one of which is unit labor cost (hereafter ULC). ULC represents the labor cost per output and is computed as nominal labor compensation over real GDP, or (by dividing both numerator and denominator by employees) nominal wage over labor productivity. ULC decreases if labor productivity improves with a constant nominal wage and increases if the nominal wage rises with constant labor productivity.

Figure 1: Factor Decomposition of ULC Growth in the U.S.

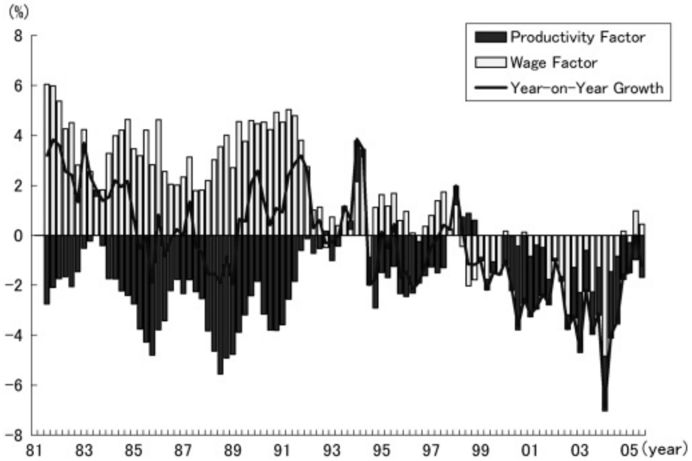


Note: ULC=Nominal wage/labor productivity. Three quarters' moving average of GDP is used in the calculation of labor productivity (real GDP/employees).
Source: U.S. Department of Labor, Bureau of Labor Statistics (BLS),
U.S. Department of Commerce, Bureau of Economic Analysis (BEA).

At the moment, ULC has increased in the U.S. and stopped decreasing in Japan, reflecting the recent changes in inflation developments in both countries. In the U.S., ULC growth rose rapidly in 2004 and is recently hovering around 2 percent, a high level comparable to the 1980s and 1990s (**Figure 1**). ULC growth can be divided into two factors, which are the wage factor and the productivity factor. In the U.S., since the year–on–year rates of growth both in GDP and in nominal wage have continued to post positive growth over the period since the 1980s to date, the productivity factor has continued to contribute negatively to ULC growth, while the wage factor has worked the other way around. In the past few quarters, the high rate of growth in nominal wage is pushing up the rate of ULC growth.

On the other hand, Japan's ULC growth had been negative for a long time since the late 1990s, although recently it is moving upward to the neighborhood of zero percent (**Figure 2**). While the wage factor had contributed positively to ULC growth until the mid–1990s, companies' restructuring efforts after the late 1990s turned the wage factor's contribution negative (Note 1). Recently, with completion of restructuring in companies and their positive attitudes toward new hiring of permanent employees, ULC growth has come to show a traditional pattern consisting of positive contribution by wages and negative contribution by productivity.

Figure 2: Factor Decomposition of ULC Growth in Japan



Note: ULC=Nominal wage/labor productivity. Three quarters' moving average of GDP is used in the calculation of labor productivity (real GDP/employees). Nominal wage is calculated as payrolls' nominal compensation/payrolls.
Source: Cabinet Office.

The focus of attention upon ULC growth in an attempt to capture inflation pressure stems from the theory that the rise in labor costs prompts businesses to raise the prices of their goods or services (Note 2). For example, in the model of a perfect competitive market in which prices are flexible, under the assumption of Cobb–Douglas production function ($Y_t = A_t K_t^{\alpha_k} L_t^{\alpha_l}$, Y : output, K : capital, L : labor, A : technology coefficient, α_k : capital income share of output, α_l : labor income share of output), Eq. (1) can be obtained from an optimal condition for firms.

$$P = \frac{1}{\alpha_l} ULC \quad (1)$$

When ULC rises, the price level (P) also rises by the degree of the reverse of labor income share of output multiplied by ULC. Although the relationship between the price level and ULC depends on the assumption of market conditions and the degree of flexibility in prices, the basic relationship between them is retained. In an imperfect competitive market with flexible prices, the relationship between prices and ULC is modified so as to multiply markup ratio by the right–hand side of Eq. (1). In an imperfect competitive market with price rigidities, the relationship is represented in a more complicated manner as a supply curve referred to as the New Keynesian Phillips Curve (hereafter NKPC). Research on the Phillips curve, which will be explained in detail in Section 2, ranges from Phillips' (1958) evidence of the relation between the growth in nominal wage and unemployment rate to the neoclassical Phillips curve involving inflation expectations and to the NKPC with sticky prices and sticky wages in recent works. Since the 1970s, general equilibrium models have been constructed under the assumption of rational expectations for analyzing the effect of monetary policy, where the relationship between the price level and ULC has been exhibited explicitly or implicitly in an elaborated way. Therefore, one can expect to gain insights into inflation dynamics through a theoretical or empirical consideration of the Phillips curve.

In the spirit of NKPC literature, this paper investigates inflation dynamics in the U.S. and Japan from an empirical perspective. Since the purpose of this paper is to gain insights into inflation dynamics for both countries through the estimation of the NKPC, practical estimations such as inflation forecasting shall not be conducted. The rest of the paper is organized as follows. In Section 2, we review what differentiates the NKPC from the traditional neoclassical Phillips curve, and how the NKPC has evolved in literature on the Phillips curve. In Section 3, we shall estimate "sticky price–wage model" proposed in Erceg, Henderson, and Levin (2000) for the U.S. and Japan, and extract critical feature of inflation in the U.S. and Japan. we will then draw policy implications from the estimation results.

2. What is the New Keynesian Phillips Curve?

This section presents the difference between the traditional neoclassical Phillips curve and the New Keynesian Phillips Curve (NKPC) to ascertain the key aspects of the NKPC and what emphasize it in particular. The section will also deal in more depth with the controversial aspects of the NKPC and the process in which they have evolved.

(1) The Neoclassical Phillips Curve

As is widely known, the Phillips curve after Friedman (1968) and Phelps (1967) can be represented as Eq. (2).

$$\pi_t = \pi^e + \gamma x_t \quad (2)$$

where π_t , π^e , x_t are measures of inflation, inflation expectations, output gap, respectively, while γ is positive coefficient of output gap.

Until the 1960s, while it was common to assume adaptive expectations as the form of inflation expectation (π^e), the assumption of adaptive expectations is ad–hoc in the sense that it is not derived from optimizing behaviors of individuals. Lucas (1972a) and Sargent (1971) stressed the importance of constructing rational expectations models based on rational behaviors of individuals and criticized the use of lagged variables as proxies for inflation expectations. Given the inflation expectations formed under the assumption of rational expectations, the Phillips curve would be vertical to the horizontal axis denoting output gap and parallel to the vertical axis denoting inflation. In rational expectations models without uncertainty, since one can predict the effect of monetary policy perfectly, the increase of money supply eventually results in the increase of prices, not having any real effect. The attempt to raise demand by the change in money supply would be in vain in these environments.

On the other hand, since it is well known that monetary policy affects real output in the short run, rational expectations models are necessary in which monetary policy has real effects. The most famous model of that sort is the “Island model” (imperfect information model) constructed by Lucas (1972b). In this model, it is assumed that each producer exists on a different island from one another and therefore each producer cannot distinguish the increase in the relative price from the increase in general prices. In such a world under imperfect information, producers increase their output when their product prices start to rise. However, once producers notice that the increases in their product prices are caused only by the increase in general prices, their output levels return to the initial levels. Thus, in the model, the real effect of the change in money supply in the short run is created by imperfect information. In general, such a neoclassical Phillips curve which has microfoundations under rational expectations are known to be represented as Eq. (3).

$$\pi_t = E_{t-1}\pi_t + \gamma x_t \quad (3)$$

where $E_{t-1}\pi_t$ is expected inflation in period t which was forecasted in period $t\text{-}1$. The tradeoff between inflation and output gap holds only when the inflation expectations are not correct. So long as inflation was expected correctly in advance, the adjustments of money supply by central banks are unable to affect real economy, where what is referred to as “money neutral” holds.

(2) What is the NKPC?

a. The difference between the traditional Phillips Curve and the NKPC

Instead of imperfect information models, rational expectations models appeared in which monetary policy has real effects under Keynesian taste's assumption of the stickiness of prices.

The most popular sticky price setting that underlie the NKPC is Calvo's (1983) price setting (Note 3). The features of the Calvo price setting are as follows: ① all firms cannot reset the price of their product to the optimal level each period. Only a fraction of firms chosen randomly with constant probability can revise prices to the optimal level. The probability (ω) in which firms can reset the price of their products comes randomly independent of the latest price change. Therefore, the probability in which firms cannot change the product prices between the period t and $t+s$ is ω^s. ② Firms set the optimal price dynamically in a long–term perspective, taking into account the possibility that they cannot reset prices for a period in the future. ③ General prices are computed as the weighted average of firms that can reset prices to the optimal level and the others that cannot do so, as Eq. (4).

$$P_t^{1-\theta} = (1-\omega)(p_t^*)^{1-\theta} + \omega P_{t-1}^{1-\theta} \quad (4)$$

Solving optimizing model under the condition above, one gets Eq. (5) as the optimal price.

$$\hat{p}_t^* = (1-\omega\beta)E_t\left\{\sum_{i=0}^{\infty}(\omega\beta)^i\,\hat{\varphi}_{t+i}^n\right\} \quad (5)$$

where $\hat{\varphi}_{t+i}^n$ is a measure of nominal marginal cost, ^ indicates log–linear approximations of variables around steady states.

By Eq. (5), one can understand that the optimal price is determined so that it is equal to expected weighted nominal marginal costs. By log–lenearization of Eq. (4) and Eq. (5), the

NKPC is obtained as Eq. (6). Eq. (6) shows that inflation is affected by expected inflation and real marginal cost ($\pi_t = \hat{p}_t - \hat{p}_{t-1}$).

$$\pi_t = \beta E_t \pi_{t+1} + \tilde{\kappa}\hat{\varphi}_t \quad (6)$$

where β indicates time preference factor, $\tilde{\kappa} = \dfrac{(1-\omega)(1-\beta\omega)}{\omega}$.

Although we cannot compare Eq. (6) with the traditional neoclassical Phillips curve because Eq. (6) does not include the output gap as an explanatory variable, under the assumption of Eq. (7),

$$\hat{\varphi}_t = \gamma x_t, \ \ \gamma > 0 \quad (7)$$

Eq. (6) is transformed into Eq. (8), where $\kappa_t = \gamma\tilde{\kappa}_t$. The reason why Eq. (7) holds is that when a perfect competitive market with flexible nominal wages is assumed, the change of output gap in goods market causes the change of derivative labor demand in the same direction and (assuming that the labor supply curve is an increasing function of real wages) also cause the change of real wages and firms' real marginal cost in the same direction.

$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t \quad (8)$$

Note that in Eq. (8), inflation depends on the expectations of future inflation. It is easier to understand the difference between the neoclassical Phillips curve and the NKPC by comparing Eq. (3) and Eq. (8). While the neoclassical Phillips curve includes expected inflation in period t which was forecasted in period $t\text{-}1$ as an explanatory valuable, NKPC includes expected inflation in period $t+1$, forecasted in period t. Although the difference between the two may only appear as the difference in forecasting date, there is a significant difference in policy implications because by iterating Eq. (8) forward, one gets Eq. (9) which means inflation in period t depends on the expected future output gap.

$$\pi_t = \kappa \sum_{i=0}^{\infty} \beta^i E_t x_{t+i} \quad (9)$$

In other words, since current inflation depends on expected future output gap in NKPC, central banks can affect current inflation by committing to expected future output. While the neoclassical Phillips curve implies that central banks are able to affect real shocks by giving an unanticipated shock, the NKPC suggests that commitments by central banks to people's expectations are crucial to have inflation under control. The attractive feature of the NKPC is that it is derived from optimizing models under rational expectations and that therefore it is does not yield to the Lucas critique (Note 4) despite having advantages of real shocks by monetary policy under the assumption of sticky price instead of imperfect information by Lucas (1972b).

In the NKPC, as described above, since commitment to future expectations can change current inflation, the views on economic phenomenon in the models are totally different from those in the traditional neoclassical Phillips curve. For instance, in the 1990s, the (neoclassical) NAIRU hypothesis explained the combination of extraordinary low inflation and high growth rate which was never seen before by the time–varying NAIRU hypothesis in which the NAIRU declined to the level which enables high growth rate without inflation pressure (Note 5). Meanwhile, given the NKPC, the reduction of the expected future inflation rate can explain the combination of low inflation and high growth rate, where there is no need for the reduction of NAIRU. Even though NAIRU is unchanged, the NKPC hypothesis makes it possible to argue that a well–managed inflation expectations by credible monetary policies allowed the economy to attain low inflation and high growth rate at the same time. The forward–looking models described above are considered to be a background that central banks around the world are placing more emphasis upon dialogue with markets and paying close attention to expectations of future inflation in the market in recent years.

(3) The hybrid NKPC

However, there is a problem that forward–looking characteristics of the NKPC is not consistent with actual data. The reason why NKPC like Eq. (8) lacks power of explanation is that inflation rarely changes to a large extent immediately in the real world. Eq. (9) provides the feature of NKPC in which the movements in inflation rate are not restricted and can change instantly to a large extent, once the expected output gap substantially changes. However, inflation tends to change by inches. Put differently, it is observed that inflation itself has stickiness as well as prices.

Therefore, at least from the point of view of empirical analysis, the hybrid NKPC is considered more desirable than the pure forward–looking NKPC. The hybrid NKPC is represented as Eq. (10) by incorporating lagged variables of inflation.

$$\pi_t = \phi_b \pi_{t-1} + \phi_f E_t \pi_{t+1} + \kappa x_t \quad (10)$$

where ϕ_b , ϕ_f are coefficients of backward–looking and forward–looking components, respectively.

There are several arguments behind the specification. One of them is Gali and Gartler's (1999, hereafter GG) argument that there are two types of firms which set prices in a forward–looking way and in a backward–looking way. GG assumed that while a fraction of firms set prices in a forward–looking way, the others set prices in a backward–looking way so that the optimal price is equal to "the sum of the previous optimal price and the previous inflation." Furthermore, the optimal aggregate prices are calculated by the weighted average of two kinds of firms. Under the assumption, one eventually gets Eq. (10). GG's specification is so influential that it is often used in empirical tests of the NKPC.

Another argument is the existence of indexation rules in which firms that cannot reset price to the forward–looking optimal price adjust their price partially (Woodford (2003), Christiano et al. (2005)). Suppose only a fraction of firms can reset price to the forward–looking optimal level in each period and the others revise the previous price partially in tandem with the past inflation rate during the preceding period. Under the assumptions, the NKPC is represented as Eq. (11), $0 \leq \phi \leq 1$.

$$\pi_t = \phi\pi_{t-1} + \beta E_t[\pi_{t+1} - \phi\pi_t] + \kappa x_t \quad (11)$$

(4) The sticky price–wage Model

As stated, given the poor performance of the NKPC in reality, the hybrid NKPC is commonly used in empirical studies. But in recent years the NKPC based on sticky price settings have been questioned theoretically as well. The NKPC derived from Calvo price setting is referred to as the "sticky price model" in the sense that only prices are assumed to be sticky, while wages are flexible. Actually, wage stickiness is also observed as John Maynard Keynes insisted, so that there have been growing discussions that it is more desirable to assume stickiness of wages as well as prices.

Erceg, Henderson and Levin (2000, hereafter EHL) proposed the "sticky price–wage model," which assumes sticky wages as well as sticky prices. In sticky price–wage model, EHL assumed sticky wages by incorporating the Calvo wage setting in the optimization of the household sector in the same manner as in the sticky price setting in the optimization of the corporate sector. And they eventually showed that the "sticky price–wage model" is represented as Eq. (12) and Eq. (13)

$$\pi_t = \beta E_t\pi_{t+1} + \kappa_p x_t + \mu_p(\varsigma_t - \varsigma_t^*) \quad (12)$$

$$\omega_t = \beta E_t\omega_{t+1} + \kappa_\omega x_t - \mu_\omega(\varsigma_t - \varsigma_t^*) \quad (13)$$

where ω_t , ς_t , ς_t^* are measures of nominal wage growth, real wage, equilibrium real wage, while κ_p , κ_ω , μ_p , μ_ω are positive coefficients.

Inflation and nominal wage growth are determined in the form of contrasting equations which includes the "output gap" originated in sticky prices and the “real wage gap” originated in sticky wage as explanatory variables, where the “real wage gap” is defined as the “real wage minus equilibrium real wage” (Note 6). Taking into account inertia in inflation, assuming indexation rule like Woodford (2003) (Note 7), Eq. (12) and Eq. (13) are rewritten as Eq. (14) and Eq. (15), respectively.

$$\pi_t = \gamma_p \pi_{t-1} + \beta E_t[\pi_{t+1} - \gamma_p \pi_t] + \kappa_p x_t + \mu_p(\varsigma_t - \varsigma_t^*) \quad (14)$$

$$\omega_t = \gamma_\omega \omega_{t-1} + \beta E_t[\omega_{t+1} - \gamma_\omega \omega_t] + \kappa_\omega x_t - \mu_\omega(\varsigma_t - \varsigma_t^*) \quad (15)$$

The sticky price–wage model (or the EHL model) arises from the doubts that the sticky price model might not be appropriate given the lack of assumption of sticky wages (Note 8). The EHL model departs from a simple question that the Calvo price setting needs to be incorporated not only in price decisions but also in wage decisions because they are both considered to be sticky in reality. In this respect, it is interesting to have the inflation equation (Eq. (14), NKPC) and the nominal wage growth equation (Eq. (15)) described in a contrasting manner. Besides, the sticky price–wage model has new characteristics that the coefficient of real wage gap is positive in Eq. (14), in contrast to being negative in Eq. (15).

(5) Empirical research on the NKPC

a. GG and GGLS

Numerous empirical studies on the NKPC have been conducted mainly since the late 1990s. The most influential empirical paper on the NKPC is probably GG (**Figure 3**). GG estimated the hybrid NKPC, that is, the hybrid sticky price model for the U.S. and found that the NKPC fits the data well. GG insisted that ① positive coefficent of real marginal cost in a reduced–form equation is statistically significant, ② the pure NKPC does not hold, ③ firms which set prices in a forward–looking way are dominant (ϕ_f = about 0.7) and the coefficient of forward–looking and backward–looking components total almost 1.

Gali, Gertler and Lopez–Salido (2001, hereafter GGLS) estimated the NKPC in the U.S. and Euro area, respectively, and concluded among others that ① the NKPC holds in the Euro area as well as the U.S., ② forward–looking components in the Euro area is stronger than that in the U.S.

Recently, Dupuis (2004) estimated the hybrid NKPC for the U.S. and came to the same conclusion as previous studies. As for the data between the 2Q in 1972 and the 2Q in 2003, he concluded that ① the degree of stickiness is 0.462 or 0.628 (in the case of marginal cost or output gap as a explanatory variable, respectively), meaning that prices are rigid in 1.9 or 2.7 quarters (the same), ② the ratio of firms which set prices in a backward–looking way is 35% or 54% (the same). Dividing the estimation period into the first interval from the 2Q in 1972 to the 1Q in 1993 and the second interval from the 3Q in 1979 to the 2Q in 2003 (after Volker (Note 9)), the ratio of firms which set prices in a backward–looking way declined from 46 percent in the first interval to 19 percent in the second interval.

Figure 3: Previous Studies on NKPC

	GG (1999)		GGLS (2001)		Dupuis (2004)			
Dependent variable	Rate of growth in GDPdeflator		Rate of growth in GDPdeflator		Rate of growth in PCE deflator			
Estimation period	1960 I ~97 IV (U.S.)	1980 I ~97 IV (U.S.)	1970 I ~98 II (U.S.)	1970 I ~98 II (Euro)	1972 II ~2003 II (U.S.)		1979 III ~2003 II (U.S.)	
Explanatory variable	MC	MC	MC	MC	MC	GAP	MC	GAP
ϕ_b (S.E.)	0.252 (0.023)	0.123 (0.021)	0.347 (0.045)	0.043 (0.115)	0.435 (0.03)	0.463 (0.06)	0.318 (0.05)	0.216 (0.05)
ϕ_f (S.E.)	0.682 (0.020)	0.696 (0.027)	0.584 (0.054)	0.773 (0.064)	0.555 (0.04)	0.535 (0.05)	0.660 (0.05)	0.757 (0.03)
κ (S.E.)	0.037 (0.007)	0.051 (0.006)	0.291 (0.139)	0.214 (0.079)	0.235 (0.08)	0.054 (0.02)	0.242 (0.11)	0.093 (0.02)
J statistics (p-value)	—	—	4.993 (0.661)	8.983 (0.344)	9.67 (0.72)	11.21 (0.59)	8.51 (0.81)	6.45 (0.93)
Instrumental variable (number in parentheses is the number of lagged variables)	Inflation(4) Labor income share (4) Output gap(4) Wage inflation rate(4) Long-short interest rate spread(4) Commodity price inflation (4)		Inflation (4) Labor income share (4) Output gap (4) Wage inflation rate (4)		Inflation (4) Labor income share (4) Wage inflation rate (4) Output gap (8)			

Note: MC shows real marginal cost (computed as labor income share), GAP shows output gap. Euro in GGLS means Euro Area.

b. Empirical studies on the NKPC in Japan

There are few empirical studies on the NKPC in Japan. Fuchi and Watanabe (2002) estimated the hybrid NKPC based on intermediate input data. In this study, the use of labor income share as a proxy of real marginal cost is considered inappropriate because the existence of fixed cost differentiates marginal cost from average cost. Instead, Fuchi and Watanabe estimated marginal cost directly by using intermediate input data which is considered to have less fixed cost. As a consequence, they concluded that the degree of price stickiness was 0.7~0.9, which implies that prices are fixed an average of 3~10 quarters and that Japan's degree of price stickiness is more or less equivalent to the global average. The coefficient of real marginal cost was 0.005~0.189.

Recently, Koga and Nishizaki (2005) made use of the EHL's sticky price–wage model ((Eq. (14), Eq. (15)) to estimate the NKPC of Japan. They used the GDP deflator and the core CPI as price indicators (dependent variables) and HP–filtered output gap and the real wage gap computed by the relationship between prices and ULC as explanatory variables. Since the results revealed that the coefficient of the output gap and the real wage gap in both equations are statistically significant, Koga and Nishizaki concluded that the EHL model fits Japan's data. The coefficients of output gap were 0.049~0.128 or 0.021~0.031 (in the case of GDP deflator or core CPI) and those of the real wage gap were 0.023~0.68 or 0.043~0.083 (the same).

3. The estimations of the NKPC in the U.S. and Japan

In this section, we shall estimate the NKPC in the U.S. and Japan in order to find the difference in characteristics in inflation dynamics between the two countries. Specifically, EHL's sticky price–wage model are examined in both countries.

(1) What is the real wage gap ?

We shall start with the concept and the calculation method of the real wage gap. Given the absence of wage rigidity, real wage is identical to the marginal product of labor when individuals optimize their behaviors. But if nominal wage has stickiness (in which case real wage also has stickiness), real wage is different from the marginal product of labor (or equilibrium real wage). The difference between them is the "real wage gap." Given a Cobb–Douglas production function, since marginal product of labor is proportional to labor productivity, one obtains the relationship below (Y^*, L^*: output, employees in flexible prices).

$$\text{Real wage gap} \cong \log\frac{W}{P} - \log\frac{Y^*}{L^*} \quad \text{(real wage – labor productivity)}$$

$$= \log\frac{WL^*}{Y^*} - \log P \quad \text{(ULC – prices)}$$

$$= \log\frac{WL^*}{PY^*} \quad \text{(labor income share)}$$

(proportional to real marginal cost)

When real wages are sticky (arising from sticky nominal wage), the real wage gap affects the real marginal cost independent of the output gap. Given the output gap, the real marginal cost is represented as a linear combination of the output gap and the real wage gap in the sticky price–wage model, while in the sticky price model the real marginal cost is substituted for the output gap.

Intuitively, the reason why the real wage gap affects inflation is that companies take into account not only the demand for their products but also wages in setting product prices. When the real wage gap is negative, since rising labor productivity does not reflect corresponding wage increase, companies attempt to expand their market share by lowering the product price level than the equilibrium (Note 10). The incentives to lower their product prices continue as long as the real wage gap is negative, which adversely affects inflation. In these circumstances, even if real ULC is pressured to rise against a backdrop of the expanded output gap, inflation pressure is in part offset as long as the level of the real wage gap is negative.

Koga and Nishizaki (2005) estimated the price level ($\tilde{P}$) in accordance with ULC using their long–tem relationship (cointegration) and defined the difference between the actual prices and the estimated prices from ULC as the real wage gap. The procedure is based on the idea that the magnitude of the actual price level ($\tilde{P}_t$) relative to the estimated price level (P_t) in accordance with ULC shows whether wage is relatively high or restrained. Following prior research, the definition of the real wage gap is used. Specifically, estimating

$$\log \tilde{P}_t = \delta + \theta \log ULC_t + v_t$$

When $\tilde{P}_t < P_t$, that is, the actual price is larger than the estimated price in accordance with the wage, the wage is considered to be lower than the long–term equilibrium.
When $\tilde{P}_t > P_t$, that is, the actual price is smaller than the estimated price in accordance with the wage, the wage is considered to be higher than the long–term equilibrium.

Thus, the real wage gap is defined as $\varsigma_t - \varsigma_t^*$ = $\log W_t - \log W_t^*$ = $\log \tilde{P}_t - \log P_t$, where ς , ς^* indicate logarithm of real wage, equilibrium real wage, respectively and W^* is equilibrium real wage.

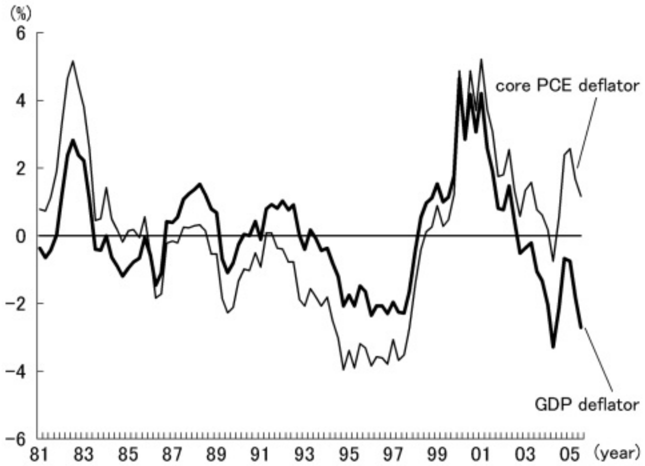
The estimated real wage gap in this definition is described in **Figure 4** and **Figure 5**. Regarding the U.S., we modified ULC which is reported from the Bureau of Labor Statistics (BLS) by using three quarters average of real GDP. As for Japan, nominal wages are represented as nominal compensation of employees (which does not include self–employees) divided by payrolls because nominal wage of total employees does not exist, and calculated nominal compensation of total employees as nominal wage multiplied by total employees. As price deflators, GDP deflators which reflect the overall economy were used for both countries. In addition, the core PCE deflator for the U.S. and the core CPI for Japan, which are considered to be crucial indicators of inflation for monetary policy making are also used. For Japan, energy items are excluded from the commonly used core CPI in light of consistency with the U.S. in which energy items are excluded from the core price index (Note 11).

The real wage gap in the U.S. indicates that the real wage gaps based upon the GDP deflator and the core PCE deflator are moving in an upward direction in the late 2004 to early 2005 (**Figure 4**). The difference between them is that while the GDP deflator–based real wage gap is still in negative territory, the core PCE deflator–based real wage gap is already positive, standing around two percent. As measured by the movements of real wage gap, it is the rising core PCE deflator–based real wage gap that has recently urged the

Federal Reserve (the Fed) to take a more cautious stance on inflation.

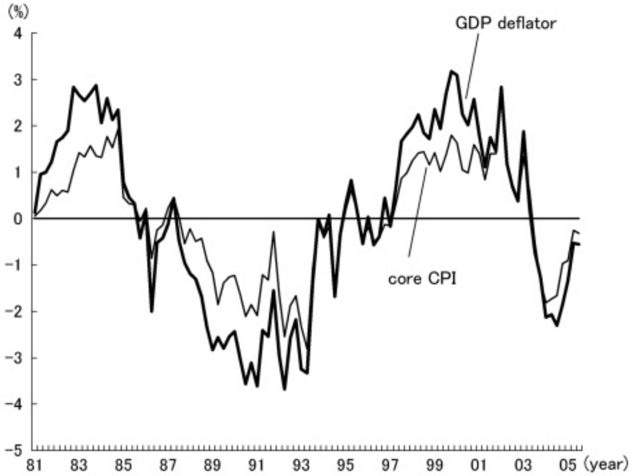
As for Japan, both the GDP deflator–based real wage gap and the core CPI–based real wage gap are about minus 1 percent at present, while the two indicators often showed different movements in the past (**Figure 5**). The reason why the real wage gap has been negative during the past two years is that businesses continued to restrain labor costs despite the increase of demand since 2003. After 2005, it seems that since businesses take a more positive attitude toward hiring, the real wage gap has started to move upward, albeit still negative. Judging from the real wage gap, Japanese economy is on the verge of overcoming deflation pressures which stem from belated wage adjustments. The estimates of the real wage gap in Japan are similar to prior research by Koga and Nishizaki (2005). The difference appears to arise from factors such as the type of wage data, treatments of value–added tax rate change and the difference of estimation periods.

Figure 4: Real Wage Gap in the U.S.



Note: Real wage gap is computed by the difference between actual prices and the prices estimated based on ULC.
Source: BLS, BEA.

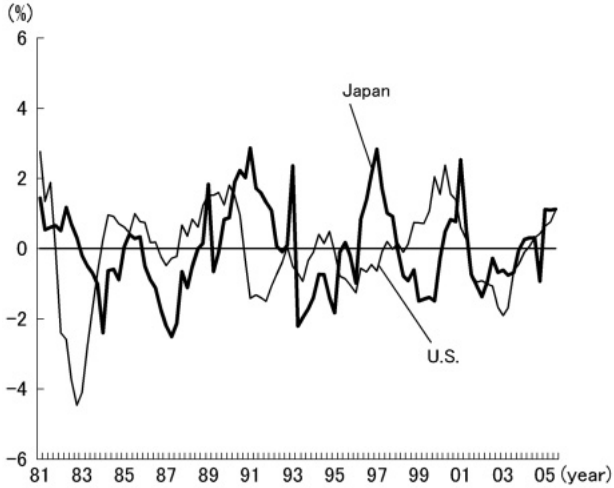
Figure 5: Real Wage Gap in Japan



Note: Real wage gap is computed by the difference between actual prices and the prices estimated based on ULC.
Source: Cabinet Office..

The output gap which is considered to be critical as an explanatory variable in NKPC is described in **Figure 6**. The output gap is calculated by the log–difference between actual real GDP and potential real GDP which is detrended by HP–filter. Since both the U.S. and Japan are continuing to grow at a steady pace, positive output gaps are expanding and serving as positive factors in inflation in both countries.

Figure 6: Output gap in the U.S. and Japan



Note: Detrended by HP filter.
Source: BEA, Cabinet Office.

(2) Estimations of the NKPC in the U.S. and Japan

We shall proceed to the estimations of the NKPC in the U.S. and Japan. The common estimation model for both countries is EHL's sticky price–wage model in which the real wage gap is also used as an explanatory variable as well as the output gap. With μ_p = 0, Eq. (14) is transformed into the sticky price model which does not have the real wage gap, and with γ_p = 0, it turns into a pure forward–looking EHL model. Estimates of these specifications shall be omitted, given the existence of ample prior research.

Very often, expected inflation is substituted by actual inflation in estimations having expectation variables such as Eq. (14), under the assumption of rational expectations ($E_t[\pi_{t+1}] = \pi_{t+1} + u_{t+1}$, u_{t+1} : forecast error). In an attempt to avoid the bias caused by the correlation between explanatory variables and error terms, GMM (Generalized Method of Moments) is used for estimation. In accordance with general methods of prior research, the model shall be estimated via GMM. The orthogonality condition is given as follows (Z_t : a vector of instrumental variables) :

$$E_t\{[\pi_t - \lambda_1\pi_{t-1} - \lambda_2\pi_{t+1} - \lambda_3 x_t - \lambda_4(\varsigma_t - \varsigma_t^*)]Z_t\} = 0$$

where $\lambda_1 = \gamma_p/(1+\beta\gamma_p)$, $\lambda_2 = \beta/(1+\beta\gamma_p)$, $\lambda_3 = \kappa_p/(1+\beta\gamma_p)$, $\lambda_4 = \mu_p/(1+\beta\gamma_p)$.

The estimation period is from 1980 to the third quarter in 2005, because of the availability of retroactive 93–SNA data for Japan. For the U.S., the NKPC is usually estimated from the data since 1960, often along with robustness test from the data since 1980, so that the estimates after 1980 may correspond to robustness tests in prior empirical studies.

The indicators for inflation as dependent variables in the regressions include the GDP deflators for both countries and the core PCE deflator for the U.S. and the core CPI for Japan. The output gap and the real wage gap are what are described in **Figures 4~6**. The instrumental set includes the lagged variables of inflation rate, labor income share, output gap and real wage gap.

a. Estimation results

The estimations were implemented in three ways, depending on the restriction of coefficients: ① no restriction of coefficients (Note 12), ② restriction of λ_1 and λ_2 so as to get the same γ_p from $\lambda_1 = \gamma_p/(1+\beta\gamma_p)$ and $\lambda_2 = \beta/(1+\beta\gamma_p)$, ③ the degree of indexation is 1, that is, $\gamma_p = 1$.

The results are reported in **Figures 7** and **8**. Overall, the estimates of the U.S. EHL model showed good performance to have statistically significant coefficients of output gap (κ_p) and real wage gap (μ_p) in almost all equations. The coefficients of output gap (κ_p) are significant with 5 percent significant level, except the case of core PCE deflator without any restriction of coefficients. The significant coefficients are 0.015~0.025. The coefficients of real wage gap (μ_p) are significant for most equations, regardless of the choice of price deflator. In the case of the GDP deflator, the coefficients are 0.010, smaller than that of the output gap.

Regarding the formation of inflation expectations, in the case of the GDP deflator with no restriction (①), the backward–looking component (λ_1) is 0.478 and the forward–looking component (λ_2) is 0.522, representing that the effect of the forward–looking component is marginally larger than the backward–looking component. For the core PCE deflator, the coefficients (λ_1) and (λ_2) are almost the same, giving no decisive results for inflation expectations.

The degrees of indexation (γ_p) are in line with the theory which indicates $0 \leq \gamma_p \leq 1$ for all equations, with γ_p being almost 1.

Figure 7: Sticky Price–Wage Model in the U.S.

	GDP deflator			Core PCE deflator		
Restriction of coefficients	①None	②Restricted	③$\gamma=1$	①None	②Restricted	③$\gamma=1$
λ_1 (S.E.)	0.478* (0.043)	0.502* (0.006)	—	0.500* (0.060)	0.501* (0.004)	—
λ_2 (S.E.)	0.522* (0.044)	0.499	—	0.501* (0.060)	0.500	—
λ_3 (S.E.)	0.011* (0.003)	0.012* (0.002)	0.012* (0.002)	0.007△ (0.004)	0.007* (0.003)	0.007* (0.003)
λ_4 (S.E.)	0.005* (0.0025)	0.005* (0.002)	0.005* (0.002)	0.003△ (0.001)	0.003* (0.001)	0.002* (0.001)
γ_p	0.953*	0.997*	—	0.992*	0.995*	—
κ_p	0.022*	0.025*	0.024*	0.015△	0.015*	0.015*
μ_p	0.010*	0.010*	0.010*	0.005△	0.005*	0.005*
J statistics (p-value)	7.753 (0.859)	8.295 (0.873)	8.384 (0.907)	7.065 (0.899)	7.086 (0.931)	7.327 (0.948)
Instrumental variable (number in parentheses is the number of lagged variable)	Inflation (4) Labor income share (4) Output gap (4) Real output gap (5)					

Note: * represent significant with significant level of 5% (△ represent significant with 10% level)

For Japan, in the case of the GDP deflator, the coefficients of both output gap (κ_p) and real wage gap (μ_p) are significant for all equations. The coefficients of output gap (κ_p) are 0.086~0.105, larger than those of the U.S. On the contrary, in the case of core CPI, although the coefficients of output gap (κ_p) are significant in two of the three equations, those of real wage gap (μ_p) are all rejected even in a 10 percent significant level, differing from prior research on the NKPC for Japan by Koga and Nishizaki (2005).

Figure 8: Sticky Price–Wage Model in Japan

	GDP deflator			Core CPI		
Restriction of coefficients	①None	②Restricted	③γ =1	①None	②Restricted	③γ =1
λ_1 (S.E.)	0.300* (0.107)	0.474* (0.033)	—	0.312* (0.109)	0.496* (0.015)	—
λ_2 (S.E.)	0.672* (0.117)	0.557	—	0.680* (0.123)	0.511	—
λ_3 (S.E.)	0.049* (0.013)	0.050* (0.011)	0.053* (0.010)	0.009 (0.012)	0.016* (0.007)	0.017* (0.007)
λ_4 (S.E.)	0.015* (0.005)	0.016* (0.006)	0.015* (0.005)	0.000 (0.006)	▲0.001 (0.004)	▲0.001 (0.004)
γ_p	0.740*	0.893*	—	0.731*	0.974*	—
κ_p	0.086*	0.093*	0.105*	0.015	0.031*	0.033*
μ_p	0.026*	0.031*	0.030*	0.003	▲0.002	▲0.003
J statistics (p-value)	8.999 (0.703)	8.282 (0.825)	9.381 (0.806)	15.804 (0.200)	9.351 (0.746)	10.447 (0.729)
Instrumental variable (number in parentheses is the number of lagged variable)	Inflation(4) Labor income share (4) Output gap (4) Real output gap (4)					

Note: * represent significant with significant level of 5% (△ represent significant with 10% level)

As for the formation of inflation expectations, in the case of the GDP deflator without any restrictions upon coefficients (①), the backward–looking component (λ_1) is 0.300 and the forward–looking component (λ_2) is 0.672, revealing that the forward–looking component is dominant in Japan for inflation expectations. In the case of the core CPI, the backward–looking component (λ_1) is 0.312 and the forward–looking component (λ_2) is 0.680, which again confirms the dominance of the forward–looking component.

The degrees of indexation (γ_p) are 0.731~0.974, consistent with the theory which indicates $0 \le \gamma_p \le 1$ for all equations.

b. Policy implications

The estimation results of sticky price–wage model leads to the conclusion below.

First, as far as the data since 1980 is concerned, in the case of the GDP deflator, the coefficients of the output gap and the real wage gap are significant for both the U.S. and Japan. This suggests that the sticky price–wage model is needed, instead of the stick price model, to capture inflation dynamics in the U.S. and Japan. Especially, in the U.S., in the case of both the GDP deflator and the core PCE deflator, the coefficients of the real wage gap are statistically significant, suggesting that it is effective to pay attention to the real wage gap when focusing on the core PCE deflator which is considered a crucial indicator for monetary policy. On the other hand, in Japan, since the coefficients of the real wage gap are not significant, when using the core CPI as a deflator, it would not be appropriate to stick to the evidence obtained from the real wage gap for monetary policy.

Second, while the forward–looking component and the backward–looking component have almost the same effect on inflation expectations in the U.S., the former is dominant in Japan. Although the reason is not necessarily clear, taken together with the evidence of GGLS, interestingly, the U.S. is the least forward–looking country as to inflation expectations among the U.S., Euro area and Japan.

The estimation results should be interpreted roughly because the estimation periods are limited since 1980s, meaning that the estimation period for Japan only includes the Bubble era and the subsequent adjustment period. With that in mind, it appears that the policy implications for the U.S. and Japan can be obtained as follows.

Since the sticky price–wage model fit the data well in the U.S., it is understandable that the Fed has continued the federal fund rate constantly since mid–2003, as the real wage gap widened. And it is commendable that the Fed has continued to post a relatively strong attitude of preventing inflation preemptively, given the backward–looking tendency in inflation expectations when compared with Japan.

In the meantime, since there are some doubts on the validity of the real wage gap in Japan, careful judgments would be necessary to capture the effects of wage developments on inflation. As for inflation expectations, Japan has a stronger tendency to expect inflation in a forward–looking way than in the U.S., so that monetary policy committed to inflation expectations is more important than in the U.S. Taken together with the bitter experience in the past few years that allowed the economy to plunge into deflation by pervasive expectations of deflation, the BOJ should continue to value the policy of committing to future expectations. Indeed, it seems important for the BOJ to commit to expectations to avoid high inflation in the future, just in the same way that they did to emerge out of deflation. Although the estimated results do not indicate what monetary policy would be desirable, judging from the present situation, the BOJ should take a firm attitude of not yielding to political pressure. At the same time, it would also be important for the BOJ to account for their economic diagnosis and clearly present their beliefs on policy strategy. These efforts would enable the BOJ to manage inflation expectations in the market and eventually lead to effective monetary policy.

4. Concluding remarks

In this paper, we presented the developments and discussions of the NKPC theoretically, and estimated the sticky price–wage model (EHL model) for the U.S. and Japan. Since there is no prior research that apply the EHL model to both the U.S. and Japan, we believe the empirical results provide us with some insights on inflation. The challenge remains in the results which are different from prior research and in the point of not identifying more primitive parameters to overcome the Lucas critique. However, it is meaningful that the results suggested that the sticky price–wage model holds both in the U.S. and in Japan in the case of GDP deflator, and that there is a clear difference between the U.S. and Japan when looking at inflation expectations.

Despite the rapid progress of empirical research on the new NKPC during the past decade, the research still dwells upon econometric methods of estimating the sticky price model. Going forward, theoretical modifications of the EHL model or new specifications of sticky wage setting which are different from the EHL would be necessary, especially in Japan where the validity of the EHL model is vulnerable.

From the standpoint of inflation forecasting, some authers like Rudd and Whelan (2005b) argue that the traditional Phillips curve that includes lagged variables of inflation is still more useful than the NKPC. In forecasting inflation, it would be important to gain insight into inflation dynamics by comparing several types of inflation models. The NKPC including the sticky price–wage model are considered critical tools that provide insight into inflation and modern implications on monetary policy.

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Notes

1. The reduction in nominal wages were largely due to the substitution of regular workers for partime workers who are paid less than regular workers.
2. Empirically, Mehra (1991) showed the long–term relationship (cointegration) between prices and ULC for the U.S. in 1960~89 using the Vector Error Correction Model (VECM). In Japan, Tanaka and Kimura (1998) came to the same conclusion as Mehra (1991) for Japan in 1980~98.
3. Other time–dependent sticky price settings include Taylor (1979, 1980), Rotemberg (1982). As for state–dependent price setting, see Dotsey et.al (1999).
4. The critique of reliance on the empirical relationship between variables which may

collapse when policy changes alter people's expectations. Lucas (1976).

5. Gordon (1997, 1998).
6. Variables are represented in percent deviation from its steady state level.
7. Specifically, $\log p_{jt} = \log p_{jt-1} + \gamma\pi_{t-1}$ and $\log w_{jt} = \log w_{jt-1} + \gamma_w \pi^w_{t-1}$.
8. In cases in which nominal wages are inflexible, the proportional relationship between the output gap and the real marginal cost in Eq. (7) collapses.
9. Paul Volker took office as Fed chairman on August 6 th of 1979.
10. Kimura and Koga (2005).
11. Since core prices in the U.S. exclude not only fresh foods but also all foods except alcoholic beverages, Japan's core CPI excluding energy items is not identical to the U.S definition.
12. γ_2 is calculated by $\gamma_p = (\beta / \lambda_2 - 1) / \beta$.

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