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Abstract

We present an empirical analysis on the New Keynesian Wage Phillips Curve (NKWPC), which is derived by Galí (2011) as a micro-founded structural relationship between wage inflation and the unemployment rate under a sticky wage framework using data for Japan and the US. We find that the empirical fit of the NKWPC is generally superior for Japan. We also find that the slope of the NKWPC is much steeper in Japan than in the US. These results suggest that wages are less sticky in Japan than in the US. Inflation indexation plays a key role in the US, but is less important in Japan. Rolling estimations indicate that the NKWPC has flattened over time in Japan. Analysis of recent data indicates that in both countries the role of inflation indexation is quantitatively smaller than before, although this result might be influenced by low and stable inflation rates over the past few decades.

JEL Classification: E24, E31, E32

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1 Introduction

The "Phillips curve" originally referred to the inverse relationship between wage inflation and the unemployment rate (Phillips (1958)), but this relationship has long been regarded as purely observational in nature, with the theoretical background (micro foundations) for the emergence of this relationship not sufficiently addressed in the literature. As a result, it was hard for us to gain theoretical insights as to how the relationship between wage inflation and the unemployment rate is structurally determined. By way of contrast, the Phillips curve relating price inflation to unemployment — the so-called New Keynesian Phillips Curve (NKPC) — has a solid theoretical foundation and has also been empirically examined in numerous previous studies.[1]

However, a recent study by Galí (2011) derives a New Keynesian Wage Phillips Curve (NKWPC) as a micro-founded structural equation under a sticky wage framework. In the framework of the NKWPC, the relationship between wage inflation and unemployment is determined by structural parameters, such as wage stickiness and labor supply elasticity. This framework thus provides theoretical insights into the mechanism of wage determination. If the NKWPC receives good empirical support, the inverse relationship between wage inflation and the unemployment rate can be introduced as a component in dynamic stochastic general equilibrium models (Galí, Smets, and Wouters (2012)). However, empirical evidence on the NKWPC has so far been reported only by Galí and more empirical studies are needed to examine whether the NKWPC can be regarded as an empirically plausible model. With this goal in mind, we provide empirical evidence on the NKWPC using data for Japan and the US. By using both countries' data, we compare the empirical fit of the NKWPC and identify structural differences in wage dynamics between these two countries.

There are some previous empirical studies on structural wage dynamics based on the New Keynesian framework (Sbordone (2006), Koga and Nishizaki (2006)). Following the standard sticky wage framework (Erceg, Henderson, and Levin (2000)), they use the "wage markup" (or real wage gap) as a driving force variable for wage dynamics. The wage markup is defined as the deviation of the actual real wage from the hypothetical level of that real

[1] For example, Galí and Gertler (1999), Sbordone (2002), Galí, Gertler, and López-Salido (2001), Fuchi and Watanabe (2002), and Muto (2009). Muto and Tsuruga (2008) present a survey on empirical studies of the NKPC (written in Japanese).

wage that should be realized in the absence of wage stickiness.[2] However, this theoretical wage markup is difficult to observe in actual time series data, and it is still unclear whether the proxies used in previous studies can indeed be considered good approximations.

Contrary to these previous studies, Galí and our own analysis use data on the unemployment rate, which is directly observable as a time series, based on Galí's theoretical derivation of a linear relationship between the wage markup and the unemployment rate under certain assumptions regarding labor supply behaviors. A great advantage of this approach is the absence of a conceptual gap between the theoretical framework and the data used in empirical analysis. In addition, under a simple autoregressive model of the unemployment rate, the NKWPC can be expressed as a linear relationship between wage inflation and unemployment, which is consistent with the classical Phillips curve. This allows us to interpret the empirical results from a traditional viewpoint.

The rest of this paper is organized as follows. In Section 2, we briefly explain the theoretical background for the NKWPC. In Section 3, we explain the data used in our analysis and provide NKWPC estimation results for Japan and the US. Section 4 concludes the paper.

2 Theoretical foundation of the NKWPC

In this section, we briefly explain the theoretical background for the NKWPC. Galí (2011) extends the standard sticky wage model provided by Erceg, Henderson and Levin (2000, EHL henceforth). In the EHL model, there is a large representative household with the following period utility function[3]:

$$U(C_t, N_t) \equiv \log C_t - \frac{N_t^{1+\varphi}}{1+\varphi}, \tag{1}$$

where C_t is household consumption and N_t is labor input at period t.

The budget constraint is given as follows:

$$P_t C_t + Q_t B_t \leq B_{t-1} + W_t N_t + \Pi_t, \tag{2}$$

[2] If nominal rigidities are absent, the real wage must be equal to the household's marginal rate of substitution between consumption and labor (leisure). The wage markup is defined as the deviation of the real wage from the marginal rate of substitution.

[3] For a more general setup of the utility function, see Section 3.4 of Galí (2011).

where P_t is the aggregate price level, Q_t is the price of a nominal riskless one-period bond, B_t is the purchase of this nominal riskless one-period bond, W_t is the aggregate nominal wage level, and Π_t is a lump-sum component of income (such as dividends from ownership of firms).

A household determines its nominal wage level so as to maximize lifetime utility, given the period utility function. The household is not allowed to re-optimize their nominal wage in every period. Like Calvo (1983)'s sticky price setup, the household can re-optimize their nominal wage only with the probability of $(1 - \theta_w)$.

In the EHL framework, employment is determined by the firm's labor demand, given the level of the real wage. With a standard CES aggregator, firm's labor demand is given as follows:

$$N_{t+k|t} = (W_t/W_{t+k})^{-\epsilon_w} N_{t+k}, \tag{3}$$

where $N_{t+k|t}$ represents the labor demand at period $t + k$ when the nominal wage is last reset in period t.[4]

When a household obtains a chance to re-optimize the level of the nominal wage, it maximizes expected utility during the period in which the level of nominal wage determined in period t will persist. Then the first order condition for the household with respect to the nominal wage is given as follows (W_t^* is the optimal level of nominal wage) [5]:

$$\sum_{k=0}^{\infty} (\beta\theta_w)^k E_t \left\{ \frac{N_{t+k|t}}{C_{t+k}} \left(\frac{W_t^*}{P_{t+k}} - \mathcal{M}^w MRS_{t+k|t} \right) \right\} = 0, \tag{4}$$

where MRS_t denotes the marginal rate of substitution between consumption and labor at period t. Under the period utility (1), MRS_t is given by $MRS_{t+k|t} = C_{t+k} N_{t+k|t}^{\varphi}$. $\mathcal{M}^w$ is the natural level of the wage markup (deviation of the real wage from the marginal rate of substitution) that should be realized if wage stickiness is absent. Under labor demand (3), $\mathcal{M}^w$ is derived as $\mathcal{M}^w = \epsilon_w/(\epsilon_w - 1)$.[6] β is the discount factor.

After log-linearizing (4) around the steady state, EHL shows that the wage dynamics

[4] The labor demand function (3) is derived from firms' optimization problem using a standard CES aggregator (ϵ_w is the constant elasticity for the CES aggregator).

[5] Since EHL assumes perfect risk-sharing among households, the consumption level is identical for each household.

[6] $\mathcal{M}^w$ can be considered the "desired wage markup".

can be expressed in the following form:

$$\pi_t^w = \beta E_t \pi_{t+1}^w - \lambda_w(\mu_t^w - \overline{\mu}^w), \tag{5}$$

where π_t^w is the wage inflation rate ($\pi_t^w \equiv \log W_t - \log W_{t-1}$), μ_t^w is the average wage markup ($\mu_t^w \equiv \log(W_t/P_t) - \log MRS_t$), and $\overline{\mu}^w$ is the natural level of μ_t^w. The parameter λ_w is defined as follows:

$$\lambda_w \equiv \frac{(1-\theta_w)(1-\beta\theta_w)}{\theta_w(1+\epsilon_w\varphi)} > 0.$$

Equation (5) is the structural model of wage dynamics in EHL. However, it is difficult to estimate since the wage markup — the primary determinant of wage inflation — cannot be directly observed in actual time series data.

Galí proposes replacing the wage markup with the unemployment rate by introducing an additional assumption vis-à-vis the household's labor supply decisions. Galí assumes that there are many members in the representative household, and that each member's labor supply decision is based on a comparison of the real wage level and their disutility of labor. Galí also assumes that the unit of labor is indivisible (Hansen (1985)), so each member decides either to work or not to work.

In Galí's framework, there is a continuum of members in the household. Each member is indexed by $j \in [0,1]$ where the disutility of labor for member j is given by j^{φ} (where $\varphi \geq 0$) if he is employed, and is zero otherwise. Then the utility of a household is as follows:

$$U(C_t, N_t) \equiv \log C_t - \int_0^{N_t} j^{\varphi} dj = \log C_t - \frac{N_t^{1+\varphi}}{1+\varphi}, \tag{6}$$

where N_t is employment as determined by the firm's labor demand. Since this period utility function is identical to (1), the household's problem is exactly the same as in EHL. Therefore, the structural model of wage inflation (5) can be applied in Galí's framework.

A household member j compares the marginal utility of acquiring the real wage (measured in consumption units) and the disutility of labor. He supplies labor if and only if the following condition is satisfied:

$$\frac{W_t}{P_t C_t} \geq j^{\varphi}.$$

Let L_t be the index of the threshold member who satisfies the above condition with equality. Then L_t can be considered a measure of the labor supply, since only the members with an index from 0 to L_t desire to supply labor at period t. Then the labor supply function in log-linearized form can be expressed as follows:

$$w_t - p_t = c_t + \varphi l_t, \tag{7}$$

where small case letters represent the logarithms of the corresponding variables. By using the definitions of average wage markup ($\mu_t^w \equiv w_t - p_t - mrs_t = w_t - p_t - c_t - \varphi n_t$) and unemployment rate ($u_t \equiv n_t - l_t$), the following linear relationship between the wage markup and the unemployment rate is derived:

$$\mu_t^w = \varphi u_t. \tag{8}$$

Based on (8), the natural rate of unemployment — defined as the level of unemployment that should be realized if wages are not sticky — is a linear function of the desired wage markup:

$$u^n = \frac{1}{\varphi}\overline{\mu}^w. \tag{9}$$

By substituting (8) and (9) into (5), the basic form of the New Keynesian Wage Phillips Curve (NKWPC) is derived as follows:

$$\pi_t^w = \beta E_t \pi_{t+1}^w - \lambda_w \varphi (u_t - u^n). \tag{10}$$

Like the original wage Phillips curve (Phillips (1958)), wage inflation and the unemployment are inversely related in the NKWPC.[7] However, the NKWPC has a dynamic property in that it includes the one-period-ahead forecast for wage inflation. If we iteratively substitute the expectation term, another expression of the NKWPC can be obtained

[7] Theoretically, the driving force for determining wage inflation in the NKWPC is the deviation of unemployment from its natural level. However, the natural rate of unemployment in the framework of Galí — that is, the unemployment rate in the absence of wage stickiness — is unobservable in practice. Therefore, Galí introduces a benchmark assumption that the natural rate of unemployment is constant, and then he reports that the NKWPC can account for the correlation between US wage inflation and unemployment even under the strong assumption of a constant natural rate of unemployment. In the process of our analysis, we have tried to estimate the NKWPC for the US by using the time series for the natural rate of unemployment estimated by the US Congressional Budget Office, but the fit of the NKWPC was no better than for the case of a constant natural rate. Based on this result, we assume that the natural rate of unemployment is constant (or constant plus random noise), following Galí.

as follows:

$$\pi_t^w = -\lambda_w \varphi \sum_{k=0}^{\infty} \beta^k E_t(u_{t+k} - u^n). \tag{11}$$

Therefore, the NKWPC implies that wage inflation depends on the discounted sum of the current and future unemployment rates.

Equation (10) indicates that the slope of the NKWPC depends on structural parameters. All else equal, the slope is steep when the wage is flexible (the parameter θ_w is small) or labor supply is inelastic (the inverse of labor supply elasticity to real wage φ is large).

In the basic form of the NKWPC (hereafter "basic NKWPC"), the wage is assumed to be fixed if the household does not obtain a chance to revise it. In an alternative specification, Galí takes account of automatic indexation to price inflation into wage contracts. Specifically, Galí assumes that, if the household does not obtain a chance to re-optimize, the nominal wage is set automatically in accordance with the rule:

$$w_{t+k|t} - w_{t+k-1|t} = \gamma \overline{\pi}_{t+k-1}^p + (1-\gamma)\pi^p + g, \tag{12}$$

where $w_{t+k|t}$ is the nominal wage (in log) at period $t+k$ when household last obtains the chance to revise the nominal wage at period t. $\overline{\pi}_t^p$ is the measure of price inflation used for indexation, π^p is steady state price inflation, and g is productivity growth in the steady state. Then the NKWPC is modified as follows:

$$\pi_t^w = \alpha + \gamma \pi_{t-1}^p + \beta E_t(\pi_{t+1}^w - \gamma \pi_t^p) - \lambda_w \varphi (u_t - u^n). \tag{13}$$

where $\alpha \equiv (1-\beta)((1-\gamma)\pi^p + g)$.

In estimating the NKWPC, Galí assumes a simple autoregressive model for determination of the unemployment rate. For example, we assume that the unemployment rate follows an AR(1) model, such as $u_t = \phi_0 + \phi_1 u_{t-1} + \varepsilon_t$ (where ε_t is i.i.d.).[8] Then the closed form of the NKWPC with indexation is expressed as follows:

$$\pi_t^w = \delta + \gamma \pi_{t-1}^p + \psi_0 u_t. \tag{14}$$

[8]We mainly use an AR(1) model for determining the unemployment rate given that its R-squares are quite high (0.986 for Japan and 0.961 for the US between 1980Q1 and 2013Q2) and offers almost as good a fit as an AR(2) model. However, since Galí uses AR(2) model, we also present the results based on an AR(2) model for the purpose of comparison with Galí. The estimated parameters for our AR(2) models satisfy the conditions required for stationarity (see Section 3.5 of Galí (2011)).

where $\delta \equiv \frac{1}{1-\beta}\left\{\alpha + \lambda_w \varphi (u^n - \frac{\beta\phi_0}{1-\beta\phi_1})\right\}$ and $\psi_0 \equiv -\frac{\lambda_w \varphi}{1-\beta\phi_1}$. In the next section, we estimate this reduced-form NKWPC by OLS regression.[9]

3 Empirical study of the NKWPC: Japan and the US

3.1 Data comparison between Japan and the US

In this section, we present an empirical study of the NKWPC using data for Japan and the US (Figure 1). For Japan, we use data on the hourly wage (monthly total wage divided by monthly total working hours) from the "*Monthly Labour Survey*" published by the Ministry of Health, Labour and Welfare and data on the unemployment rate from the "*Labor Force Survey*" published by the Ministry of Internal Affairs and Communications. For the US, we use data on the hourly wage and unemployment rate as used in the main analysis of Galí (2011).[10] For the price index used for inflation indexation, we use the representative measure of core inflation for each country, which is the consumer price index excluding fresh foods for Japan and the consumer price index excluding food and energy for the US. Since Galí uses quarter-to-quarter inflation data as well as year-to-year inflation data, we use both. Since Galí uses quarter-to-quarter inflation data (π_t) as well as its 4-quarter moving average ($\pi_{t-1}^{(4)} = (1/4) * (\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4})$), we use both.

Before estimating the NKWPC, we display the relationship between wage inflation and unemployment for each country as a scatter plot. In the case of the US (Figure 2), the relationship appears to be a circle, rather than a downward sloping line. As reported by Galí the US wage Phillips curve shifted between the 1970s and the middle of the 1980s, so we cannot identify an inverse relationship between wage inflation and unemployment during the sample that includes this period.

[9] In our estimation, we introduce an error term into equation (14). We assume that the error term is uncorrelated with the unemployment and inflation rates. Conceptually, the error term captures (i) measurement errors in wage inflation data and (ii) random variations in the natural rate of unemployment.

[10] Galí compares two different measures of hourly wage which are (i) the average hourly earnings of production and non-supervisory employees from the *Establishment Survey* and (ii) hourly compensation from the *Productivity and Costs* publication of the Bureau of Labor Statistics. Since the latter is highly volatile and seems to be significantly affected by measurement errors, he uses the former measure for his main analysis. For this reason, we also use the former measure in our main analysis. However, since we use compensation-based data for Japan's wage inflation, the latter measure is more directly comparable to Japan's data. Therefore, we also present estimation results using a compensation-based measure of US wage inflation. These results show that our main findings are not affected by the choice of the US wage inflation measure.

In clear contrast, Japan's data shows a remarkably stable inverse relationship between wage inflation and unemployment throughout the sample period from the 1970s onwards (Figure 3), as reflected in a strong correlation coefficient (-0.755). In addition, even if we look at subsample data, we confirm the existence of a downward sloping line for each decade.[11] This kind of clear inverse relationship is quite similar to the original Phillips curve reported by Phillips (1958) based on UK data for 1861-1957.

Since the NKWPC captures the dynamic relationship between wage inflation and unemployment, the static correlation reported above does not directly tell us about the empirical fit of the NKWPC for each country. In the case of the US, Galí has reported that the relationship between wage inflation and unemployment in the scatter plot becomes unstable due to the presence of inflation indexation, and that the NKWPC fits the US data fairly well once inflation indexation is taken into account when estimating the NKWPC. For Japan, although the scatter plot shows a stable inverse relationship between wage inflation and unemployment, it is also possible that the inflation rate has at least some impact on wage inflation. To capture any such impact, we need to estimate the NKWPC while allowing for inflation indexation. With this approach in mind, we now present out NKWPC estimation results for Japan and the US.

3.2 NKWPC estimation results

Following Galí (2011), we estimate the reduced-form of the NKWPC by OLS. Our analysis mainly uses data for the 1980s onwards, since we allow for possible structural changes in the wage setting mechanism after the high inflation experience of the 1970s. However, in Section 3.4, we present estimation results using data from the 1970s. In this section, we use the quarter-to-quarter change in the hourly wage as the measure of wage inflation.

Figure 4 shows estimation results for the closed-form of the NKWPC (equation (14)), assuming that there is no inflation indexation (γ is assumed to be zero in equation (14)). For the US, the coefficient on the unemployment rate is not statistically significant, as is consistent with Galí. In contrast, the coefficient on the unemployment rate is significantly negative for Japan. These results indicate that the basic NKWPC is a good fit for Japanese data, but not for US data.

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[11] Correlation coefficients are -0.828 for the 1970s, -0.842 for the 1980s, -0.835 for the 1990s, and -0.388 for the 2000s.

Figure 5 shows estimation results for the NKWPC with inflation indexation. In this case, the coefficient on the unemployment rate is significantly negative even for the US. In other words, the empirical fit of the US NKWPC is remarkably improved by incorporating inflation indexation. However, in the case of Japan, the coefficient on the inflation rate is statistically insignificant at the 5% level and empirical fit improves only slightly due to the incorporation of inflation indexation. These results suggest that inflation indexation plays quite an important role in the US but is less of a factor in Japan. This finding is consistent with micro-level evidence that automatic price indexation is explicitly incorporated into some US wage contracts but is rarely applied in Japan.[12]

Table 1 and 2 present estimation results for the NKWPC under alternative specifications. These results indicate that the absolute value of the coefficient on the unemployment rate is generally larger in Japan than in the US, which means that the reduced-form NKWPC is much steeper for Japan. This implies that a given change in unemployment has a larger impact on wage inflation in Japan than in the US. However, since the slope of the reduced-form NKWPC depends on the AR coefficient for the unemployment rate model (ϕ_1), we need to adjust this factor when comparing the slopes of the structural-form NKWPC. Table 1 and 2 show the slope of the structural-form NKWPC ($\lambda_w \varphi$ in equation (10) and (13)). These results also suggest that the slope of the structural-form NKWPC is steeper in Japan than in the US.

As we have explained in Section 2, the slope of the structural-form NKWPC mainly depends on two factors: wage stickiness and labor supply elasticity. Based on this framework, the estimation results suggest that (i) the degree of wage stickiness is smaller in Japan, and/or (ii) labor supply elasticity is smaller in Japan. Following Galí, we set alternative values for the parameter φ, which is the inverse of Frisch labor supply elasticity, as $\varphi = 1$ and 5, based on the previous studies. Then we compute the value of θ_w, which represents

[12] According to Kuroda and Yamamoto (2007), in the US economy, the proportion of wage contracts that explicitly incorporate inflation indexation exceeded 60% from the middle of the 1970s to the 1980s, but declined to approximately 20% in the 2000s. They also report that explicit inflation indexation is extremely rare in Japan. This suggests that the proportion of wage contracts incorporating inflation indexation is still lower in Japan than in the US.

the degree of wage stickiness.[13, 14]

The bottom two lines of Table 1 and 2 show the values of θ_w for $\varphi = 1$ and 5. Although the results depend on the specifications of the NKWPC to some degree, in the case of Japan, θ_w ranges from 0.32 to 0.60 when $\varphi = 1$ and from 0.58 to 0.79 when $\varphi = 5$. In contrast, in the case of the US, θ_w ranges from 0.79 to 0.91 when $\varphi = 1$ and from 0.90 to 0.96 when $\varphi = 5$.[15] These results imply that, if labor supply elasticity lies within the range presented in previous studies, the NKWPC is much steeper in Japan because wages are less sticky in Japan.[16] In this respect, Yamamoto (2008) also points out that the slope of Japan's wage Phillips curve, as depicted in a scatter plot diagram, was steeper than those of the US and European countries, especially prior to the collapse of Japan's bubble economy. Based on some previous studies (such as Gordon (1982) and Freeman and Weitzman (1987)), Yamamoto claims that this can be attributed to Japan's relatively flexible nominal wage.

Finally, in order to identify the quantitative importance of unemployment rate in determining wage inflation, we decompose changes in wage inflation based on equation (14). Figure 6 shows that unemployment rate accounts for a significant portion of fluctuations in Japanese wage inflation. In the US, however, changes in the unemployment rate explain only a small percentage of changes in wage inflation. In other words, the unemployment rate clearly plays a greater role in determining the wage inflation rate in Japan than in the US.

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[13] Kuroda and Yamamoto (2008) estimate the labor supply elasticity using Japanese data. They report that the estimated Frisch labor supply elasticity in Japan after the 1990s is in the range of 0.7 to 1.0 for the total for males and females, if they take into account both the extensive and intensive margins. However, they do not make a direct judgment as to whether the labor supply elasticity is higher or lower in Japan than in the US.

[14] Based on the theoretical model, the parameter ϵ_w satisfies $\epsilon_w = (1 - \exp(-\varphi u^n))^{-1}$. The average unemployment rates for 1980–2013 are approximately 3.5% for Japan and 6.5% for the US. If we consider these to be the natural rates of unemployment, ϵ_w is 29.07 or 6.23 for Japan and 15.89 or 3.60 for the US for $\varphi = 1$ and 5, respectively.

[15] These values are somewhat larger than those reported by Galí. Since Galí uses data for 1964 onwards, the difference from our analysis suggests that US wage stickiness has increased after the 1980s.

[16] If we use the hourly scheduled wage as the measure of the nominal wage, the fit of the NKWPC becomes even better than for when the total wage is used (see Table A-1), while the values of θ_w are not significantly different. Therefore, even if we use the scheduled wage, it seems that wages are less sticky in Japan than in the US.

3.3 Estimation results using year-to-year wage inflation data

In Section 3.2, we have used quarter-to-quarter wage inflation data to estimate the NKWPC. However, since quarterly data are highly volatile due to considerable measurement errors, the fit of the NKWPC evaluated in terms of adjusted R-squares was not satisfactory, even in the case of Japan. In this section, to eliminate short-term noise, we instead use year-to-year wage inflation data to estimate the NKWPC.

Table 3 and 4 show that, if we use year-to-year wage inflation data, adjusted R-squares are around 0.7 to 0.8 for the case of Japan, which is better than the results for the US. This implies that the fit of the NKWPC presented in Section 3.2 was largely affected by short-term noise included in quarterly-based wage inflation data, especially for the case of Japan. If we exclude this noisy component, the fit of the NKWPC is generally better in Japan than in US. We also find that the basic NKWPC fits quite well in Japan, and that incorporating inflation indexation does not improve the fit substantially. In contrast, the results for the US show that the basic NKWPC is not empirically supported even if we use year-to-year wage inflation data, and that the incorporation of inflation indexation greatly improves the fit of the NKWPC.

So far we have not made allowance for the potential influence of changes in labor productivity growth on wage inflation. In Galí's model, the long-run trend of labor productivity growth is introduced as a component of the indexation rule (equation (12)). This specification is based on the assumption that labor productivity grows at a constant rate in the long run. Although this assumption is perhaps acceptable in the US, trend labor productivity growth appears to have shifted over time in Japan, as shown in Figure 7. It may therefore be necessary to allow for a trend shift in labor productivity growth when explaining fluctuations in Japanese wage inflation. Here we estimate the NKWPC again by subtracting trend labor productivity growth from wage inflation data.[17] Figure 8 shows that the empirical fit of the NKWPC is still remarkably good for Japan. Therefore, even if we make allowance for shifts in productivity growth, it would appear that changes in the unemployment rate have a significant impact on Japanese wage inflation.

[17] Labor productivity is calculated as real GDP divided by the product of total number of employed persons in "*Labor Force Survey*" and total working hours in "*Monthly Labor Survey*". The trend component is calculated using a Hodrick-Prescott Filter.

3.4 Changes in NKWPC parameters over time

In this section we examine possible variations in NKWPC coefficients over time. Specifically, we use subsample data to identify changes in the parameters of the reduced-form of the NKWPC. In Japan, we have seen in Figure 3 that there is a clear inverse relationship between wage inflation and unemployment, but that this downward-sloping line has been somewhat flatter in recent data. To reflect this observation, we split the sample period at 1995, since which time Japan's unemployment rate has been above 3%, and estimate the reduced-form of the NKWPC using pre-1995 and post-1995 data (year-to-year wage inflation). Figure 9 shows that the absolute value of the coefficient on the unemployment rate is lower for the post-1995 period than for the pre-1995 period. We also find that the coefficient on the inflation rate is lower in the post-1995 period, but is not statistically significant.

Since these results might depend on the choice of subsample period or the choice of wage inflation measure (namely, whether quarter-to-quarter or year-to-year data are used), Figure 10 presents more thorough results of rolling regressions with 20-year windows, using both wage inflation measures. The estimation results for the basic NKWPC show that the absolute value of the coefficient on the unemployment rate shows a downward trend, no matter which wage inflation measure is used. This indicates that the slope of Japan's NKWPC has flattened in recent years. The estimation results for the NKWPC with inflation indexation also show that the absolute value of the coefficient on the unemployment rate has declined. The coefficient on the inflation rate was near unity and statistically significant for the period from the 1970s through the early 1990s, but has subsequently followed a downward trend and lost its statistical significance.

Figure 11 presents the results of rolling regressions for US data, and indicates that the unemployment rate has recently become more influential on wage inflation in the basic NKWPC. This result is consistent with Galí's finding that wage inflation and unemployment have been inversely related since the mid-1980s. The estimation for the NKWPC with inflation indexation show that the coefficient on the inflation rate has trended lower and is no longer statistically significant in recent data.

Among the above empirical results, here we consider possible reasons for the flattening of Japan's NKWPC. Based on Galí's theoretical framework, we can conjecture that the flattening might be caused by (i) an increase in the degree of wage stickiness and/or (ii) an increase in labor supply elasticity. Although it is impossible to judge solely on the basis of our own results, the empirical analysis of Kuroda and Yamamoto (2008) indicates that Japanese labor supply elasticity has held steady or declined since the 1990s.[18] This suggests that the flattening of Japan's NKWPC might be attributable to the recent increase in wage rigidity.[19]

Regarding inflation indexation, our main estimation results based on a long time series show that this element is clearly important in the US, but less so in Japan. However, our subsample estimation results indicate that the role of inflation indexation has declined recently in both Japan and the US. Since the role of inflation indexation is determined exogenously in Galí's framework, it is hard to identify the reason for its decline over time. However, since the 1990s, inflation rates in both countries have been lower and more stable than before, as shown in Figure 12. It therefore seems possible that there is less need to make explicit allowance for fluctuations in the inflation rate during periods when it is low and comparatively stable. In Figure 10, the estimation results including data for the early 1970s show that the inflation rate has a large impact on the wage inflation rate, even in Japan. This result suggests that the inflation rate is perhaps taken into account in wage contracts, either formally or informally. We should therefore stress that our findings regarding the role of inflation indexation might be sensitive to the level of inflation going forward.[20]

4 Conclusion

In this study, we have presented an empirical analysis on the New Keynesian Wage Phillips Curve (NKWPC), which is derived by Galí (2011) as a micro-founded structural relation-

[18] Using data for Japan from the 1990s onwards, they report that labor supply elasticity has been either unchanged or in a declining trend for the extensive and intensive margins combined, either unchanged or in a slight rising trend for the intensive margin only, and in a declining trend for the extensive margin only.

[19] Kuroda and Yamamoto (2003 a, b) present comprehensive empirical results for the emergence of downward nominal wage rigidity in the 1990s, which strengthened wage stickiness in Japan. Yamamoto (2007) also shows that, even in the 2000s, downward nominal wage rigidity is found in regular wages for full-time workers.

[20] The "*Survey on Wage Increase*" published by the Ministry of Health, Labour and Welfare indicates that more than half of all companies viewed the inflation rate as a motivation for revising wages in the 1970s (see Figure A-1), but that the percentage of such companies is much lower in recent years. For the US, the proportion of wage contracts that explicitly incorporate inflation indexation was higher through the early 1980s than it is today. This evidence suggests that, under certain conditions, variations in the inflation rate may have a substantial impact on wage inflation, irrespective of whether inflation indexation is explicitly incorporated into wage contracts.

ship between wage inflation and the unemployment rate under a sticky wage framework using data for Japan and the US. We find that the empirical fit of the NKWPC is generally superior for Japan. We also find that the slope of the NKWPC is much steeper in Japan than in the US. These results suggest that wages are less sticky in Japan than in the US. Inflation indexation plays a key role in the US, but is less important in Japan. Rolling estimations indicate that the NKWPC has flattened over time in Japan. Analysis of recent data indicates that in both countries the role of inflation indexation is quantitatively smaller than before, although this result might be influenced by low and stable inflation rates over the past few decades.

Our analysis has provided empirical evidence on the plausibility of the NKWPC as an equilibrium model of wage determination. Although we find the fit of the NKWPC to be remarkably good — especially for Japanese data — we must also acknowledge the limitations of our partial equilibrium analysis. We have seen still limited amount of DSGE-based analysis of Japanese data, and to the best of our knowledge there is no study that incorporates the NKWPC into a DSGE model for Japan. It is therefore to be hoped that our empirical evidence will lay a platform for future studies to introduce the NKWPC into DSGE models of the Japanese economy. Further analysis of data for other countries is also needed to examine the empirical plausibility of the NKWPC and identify international structural differences in the wage determination process. These issues have been left for future research.

Appendix: NKWPC for the US using compensation-based wage inflation data

In the empirical analysis of Section 3, we have used household-side earnings-based data for the US nominal wage, which is mainly used in Galí (2011). However, firm-side labor compensation data are also available as an alternative measure. Galí does not use compensation-based wage data in his main analysis owing to their high volatility, which implies the presence of large measurement errors. However, since we have used compensation-based data for Japan's nominal wage, it might be better for us to use compensation-based data for the US nominal wage to facilitate a more direct comparison. Therefore, in this appendix, we report estimation results of the NKWPC for the US economy using compensation-based wage data (hourly compensation from the *Productivity and Costs* publication of the Bureau of Labor Statistics).

Figure A-2 shows the relationship between compensation-based wage inflation and the unemployment rate. The scatter plot indicates the absence of a clear inverse relationship between wage inflation and the unemployment rate, which is essentially similar to Figure 2. The historical time series shows that compensation-based wage inflation data are more volatile than earning-based data.

Table A-2 presents estimation results for the NKWPC using the compensation-based quarter-to-quarter wage inflation data. It shows that the adjusted R-squares of the NKWPC are smaller than for the results using earnings-based data. This reflects the high volatility of compensation-based data, as pointed out by Galí. As such, the empirical fit is worse than for Japan's NKWPC using compensation-based data.

However, except for the adjusted R-squares, the estimation results based on compensation-based data are not qualitatively different from those using earning-based data. That is, the basic form of the NKWPC, which does not incorporate inflation indexation, is not empirically supported by the US data. Inclusion of the inflation rate as an additional explanatory variable is crucial, even in the estimation using compensation-based data. Moreover, the structural parameters of the NKWPC, as calculated using the AR coefficients of the unemployment rate, are not substantially different from those calculated by using the earning-based data. As a result, the parameter for wage stickiness (θ_w) does not differ significantly between the estimation results using alternative measures of wage inflation. The estimation results using the compensation-based data also suggest that wages are less sticky in Japan than in the US.

Figure A-3 presents the results of rolling regressions for the reduced-form NKWPC. Compared with the results using the earnings-based data (Figure 10), the standard errors of the parameters are larger, especially in the estimation using quarter-to-quarter wage inflation data, owing to the high volatility of the compensation-based data. However, we can confirm that the impact of the unemployment rate on wage inflation is more pronounced in recent periods, even if we use the compensation-based data. The influence of price inflation on wage inflation has been diminishing over time. These results suggest that our main results reported in Section 3 hold in at least a qualitative sense, even if we use the compensation-based data for US wage inflation.

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Figure 1: Summary of the data

(1) Hourly wage

	Japan	U.S.
Name of Statistical Survey	Monthly Labour Survey (Ministry of Health, Labour and Welfare)	Establishment Survey (Bureau of Labor Statistics)
Data	Monthly total wage / Monthly total working hours Monthly scheduled wage / Monthly scheduled working hours	Average hourly earnings of production and nonsupervisory employees: total private*
Seasonally adjusted or original	Seasonally adjusted	Seasonally adjusted
Data construction	Monthly indices of scheduled wage are seasonally adjusted by X11 default. Quarterly indices are made by averaging monthly indices.	Officially released
Start date	1970/Q1 (total wage) 1979/Q2 (scheduled wage)	1964/Q1

(2) Unemployment rate

	Japan	U.S.
Name of Statistical Survey	Labor Force Survey (Ministry of Internal Affairs and Communications)	Employment Situation (Bureau of Labor Statistics)
Data	Unemployment rate	Civilian unemployment rate*
Seasonally adjusted or original	Seasonally adjusted	Seasonally adjusted
Data construction	Officially released monthly labor forces and unemployed persons are averaged, and quarterly unemployment rates are calculated.	Officially released
Start date	1953/Q1	1948/Q1

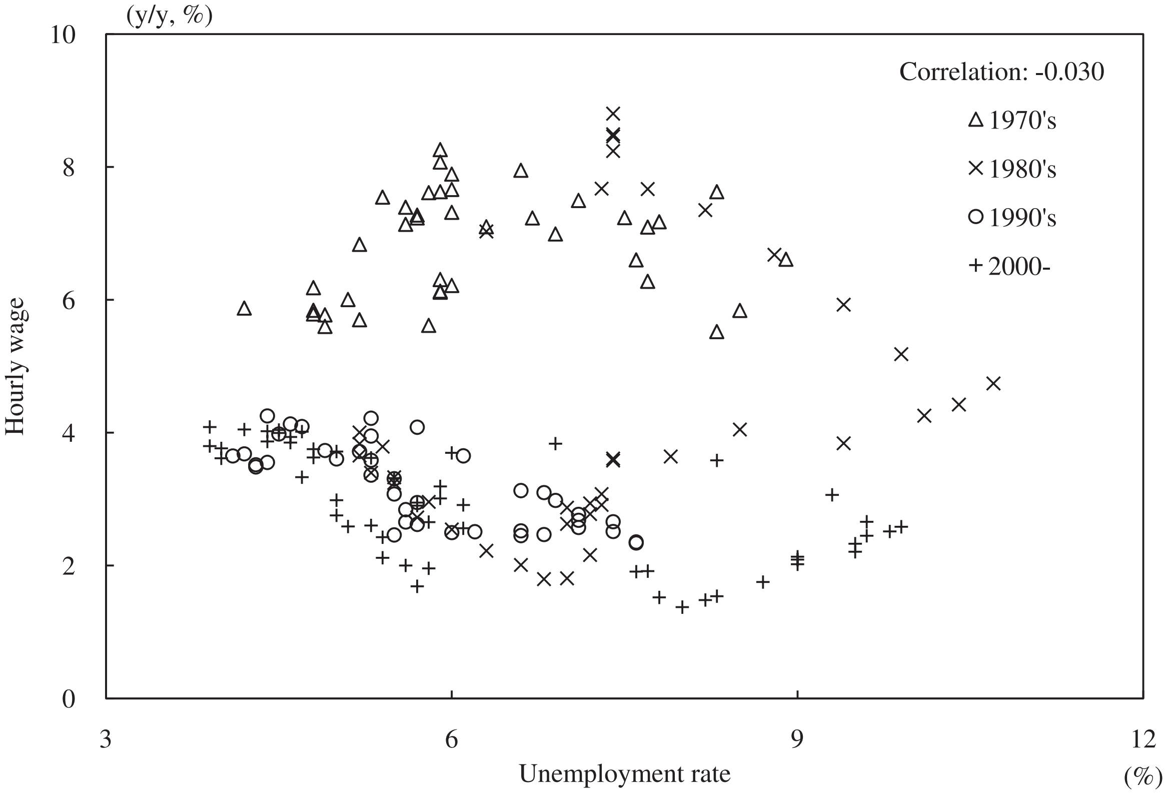
(3) Inflation

	Japan	U.S.
Name of Statistical Survey	Consumer Price Inmdex (Ministry of Internal Affairs and Communications)	Consumer Price Index (Bureau of Labor Statistics)
Data	All items less food	All items less food and energy*
Seasonally adjusted or original	Seasonally adjusted	Seasonally adjusted
Data construction	Impacts of consumption tax introduction in 1989 and hike in 1997 are excluded from original index, and the indices are seasonally adjusted. Quarterly indices are made by averaging monthly ones.	Officially released
Start date	1970/Q1	1957/Q1

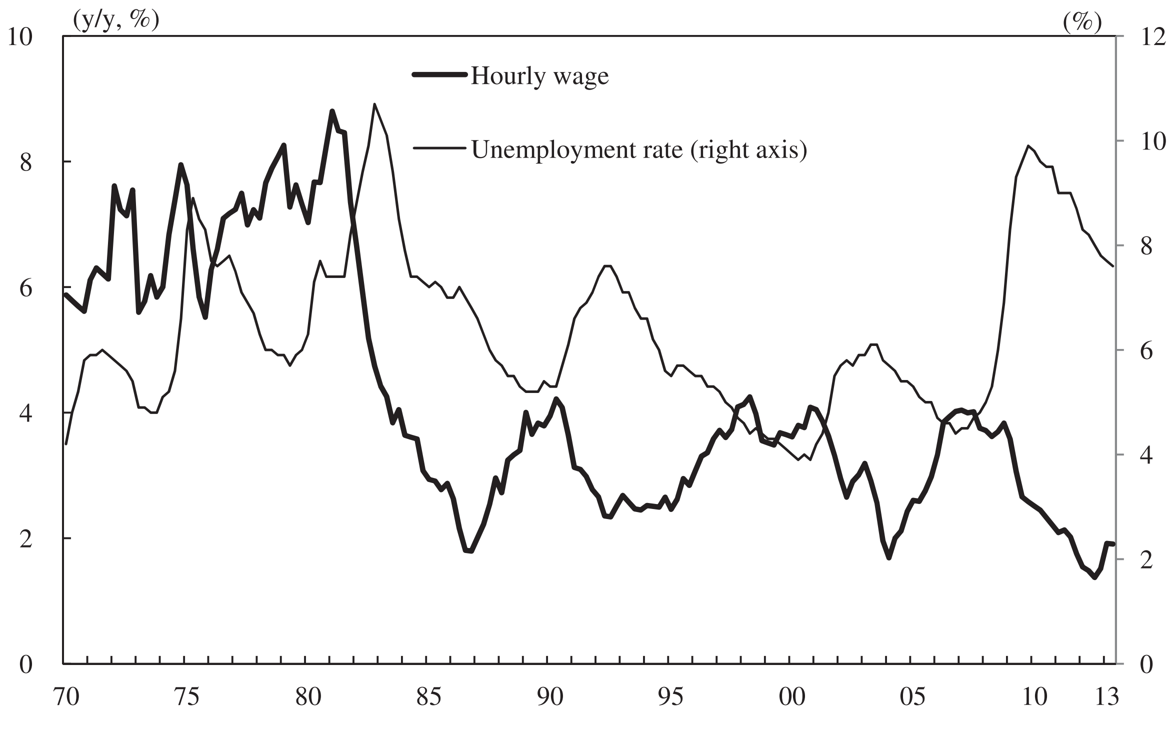
Note: * denotes quarterly time series downloaded from FRED (http://research.stlouisfed.org/fred2/) provided by St. Louis Fed.

Figure 2: Wage inflation and unemployment rate (U.S.)

(1) Scatter plot



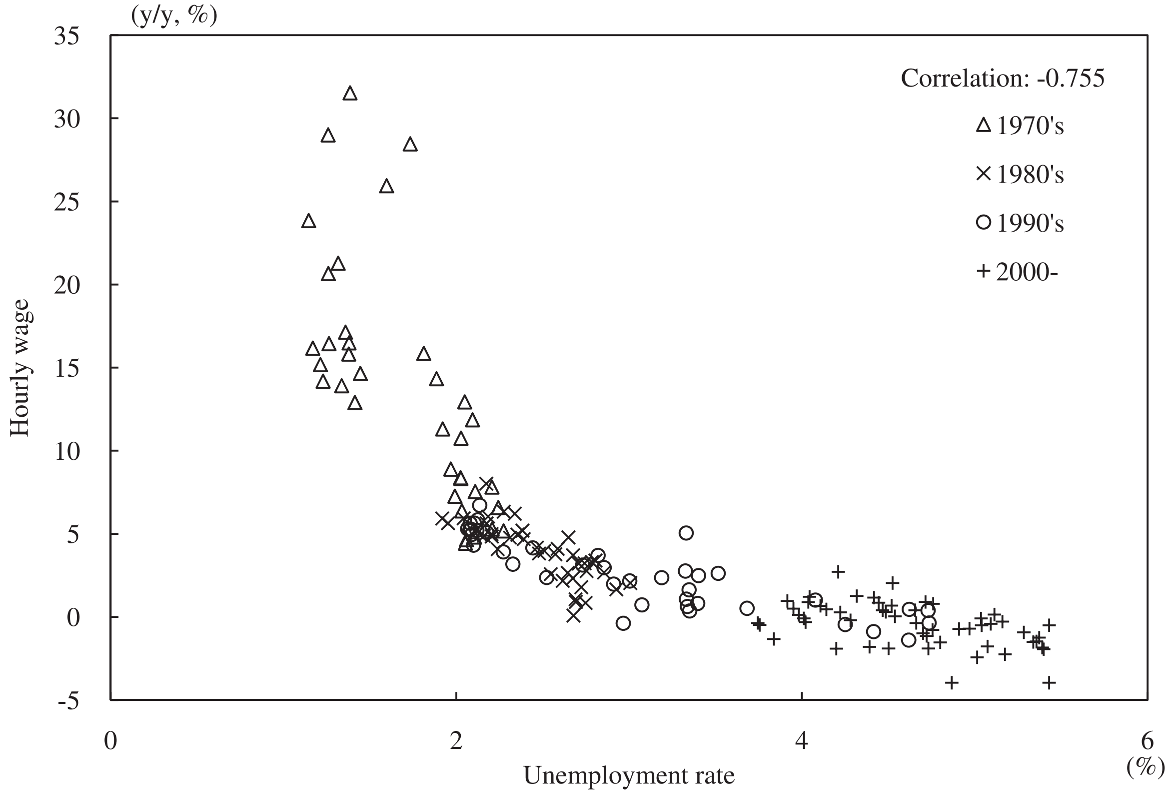
(2) Time series



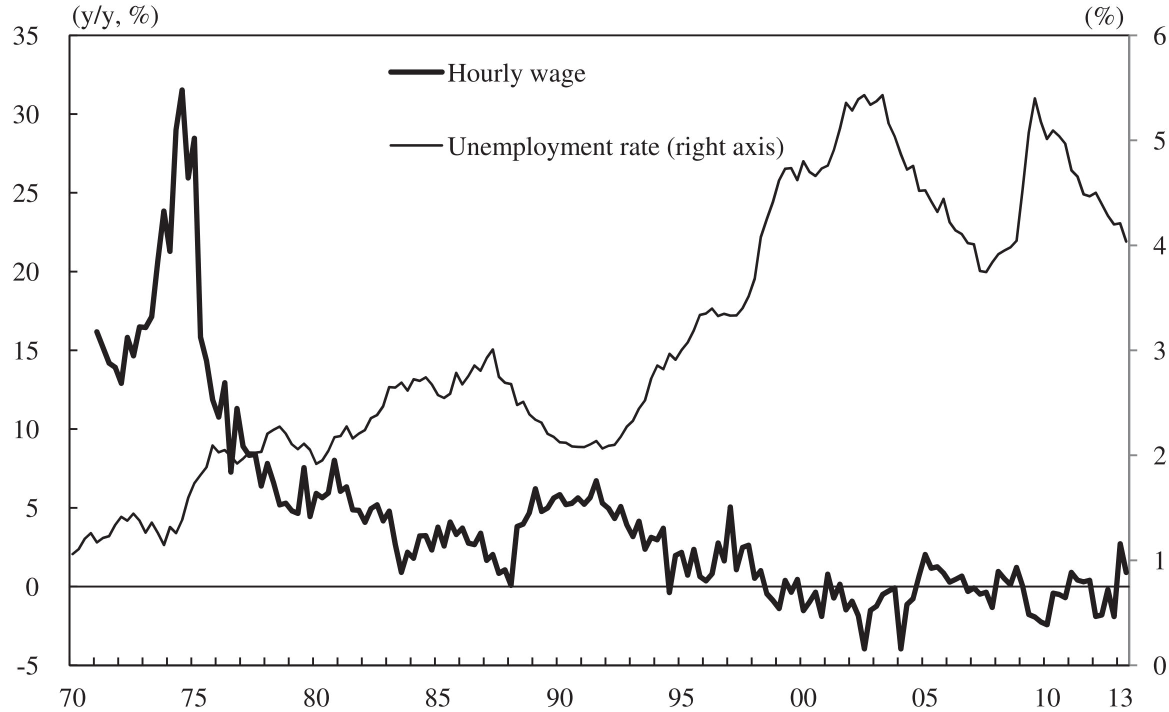
Source: Bureau of Labor Statistics.

Figure 3: Wage inflation and unemployment rate (Japan)

(1) Scatter plot



(2) Time series



Sources: Ministry of Health, Labour and Welfare, Ministry of Internal Affairs and Communications.

Figure 4: Estimation results (Basic NKWPC)

$$\Delta \log(Hourly\ wage_t) = \alpha_0 + \alpha_1 \frac{Unemployment\ rate_t}{100}$$

• Japan

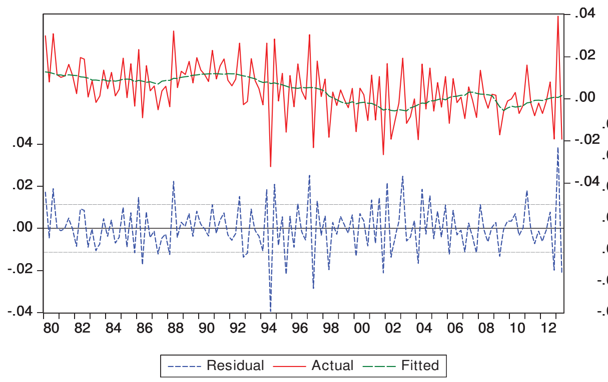
Sample period	α_0	α_1	Adj-R^2
1980Q1-2013Q2	0.023 (6.92)	-0.525 (-5.88)	0.202

• U.S.

Sample period	α_0	α_1	Adj-R^2
1980Q1-2013Q2	0.010 (7.49)	-0.020 (-1.02)	0.000

Note: t-values in parentheses.

• Japan



• U.S.

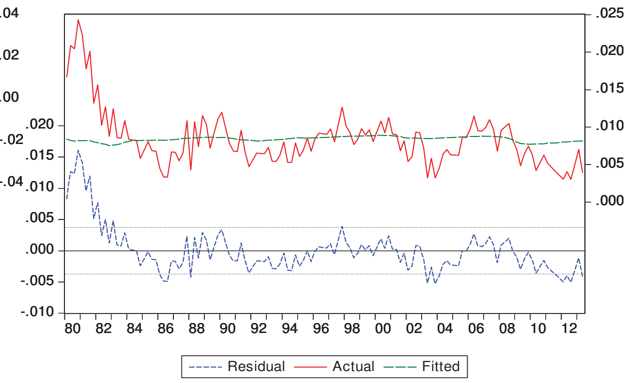


Figure 5: Estimation results (NKWPC with inflation indexation)

$$\Delta \log(Hourly\ wage_t) = \alpha_0 + \alpha_1 \frac{Unemployment\ rate_t}{100} + \alpha_2 \Delta \log(CPI_{t-1})$$

• Japan

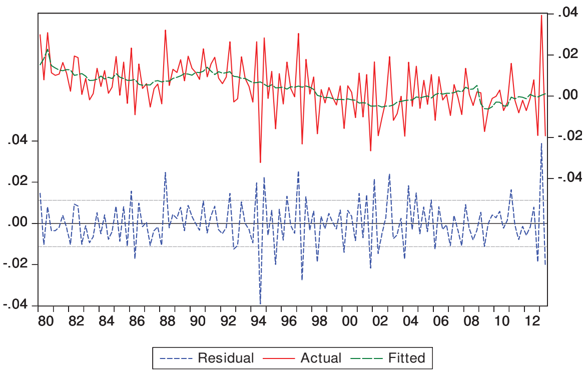
Sample period	α 0	α 1	α 2	Adj-R^2
1980Q1-2013Q2	0.017 (3.52)	-0.389 (-3.19)	0.449 (1.63)	0.212

• U.S.

Sample period	α 0	α 1	α 2	Adj-R^2
1980Q1-2013Q2	0.008 (8.20)	-0.048 (-3.39)	0.433 (11.20)	0.486

Note: t-values in parentheses.

• Japan



• U.S.

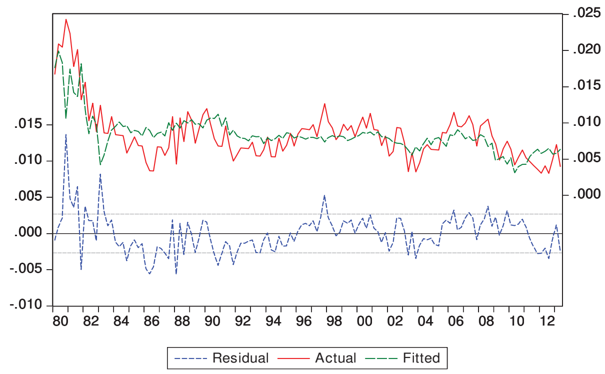
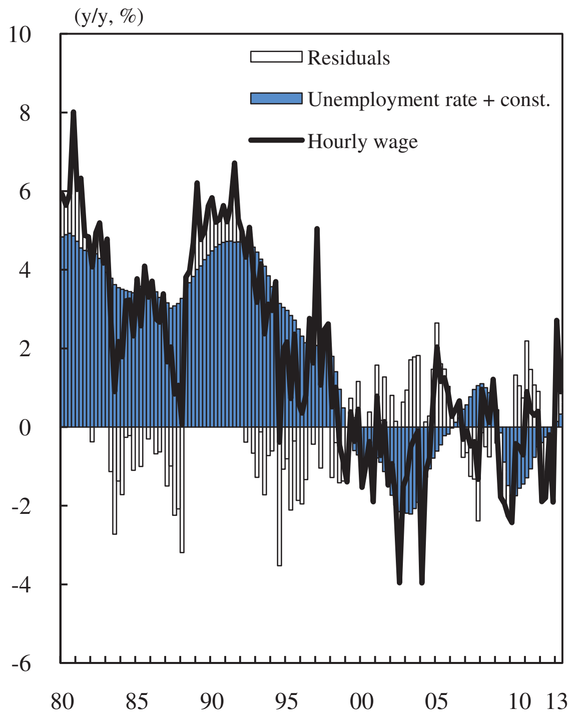


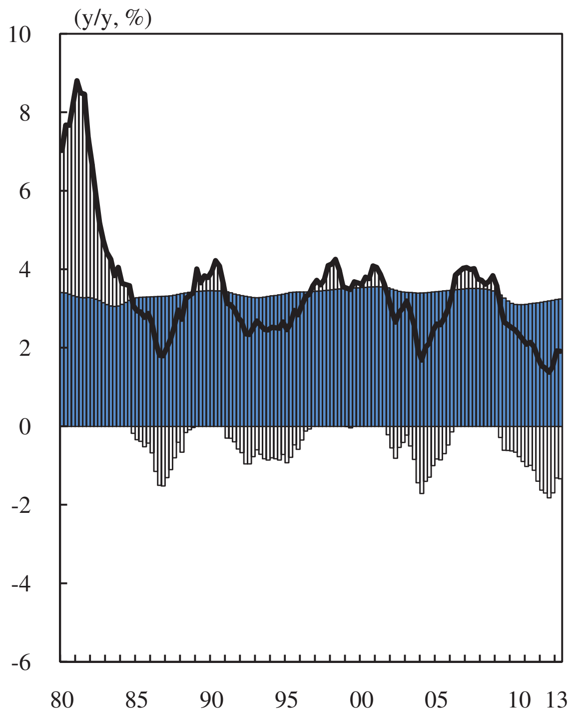
Figure 6: Decomposing wage inflation based on NKWPC

(1) Basic NKWPC

• Japan

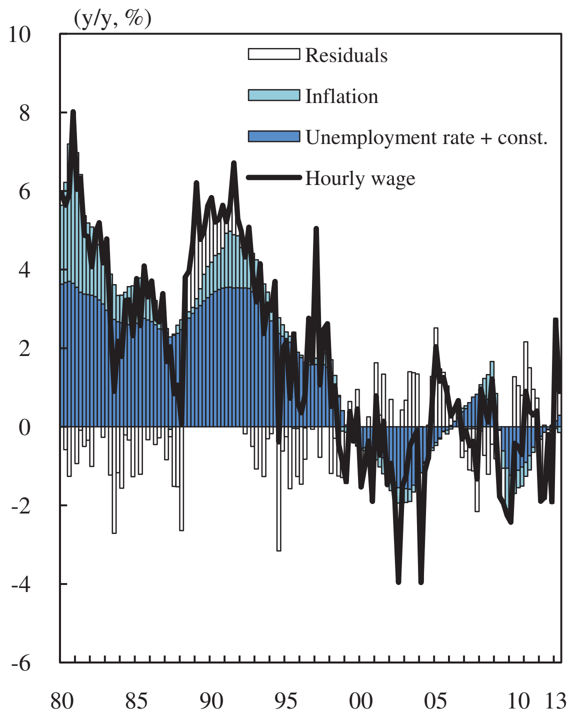


• U.S.

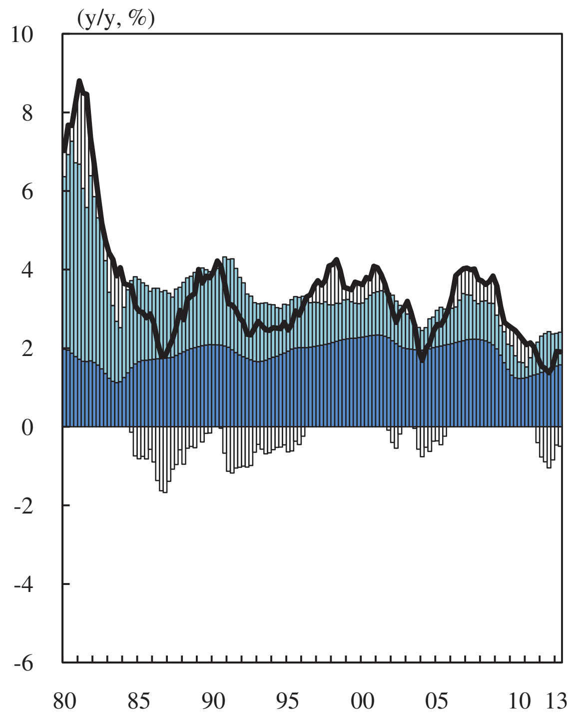


(2) NKWPC with inflation indexation

• Japan



• U.S.

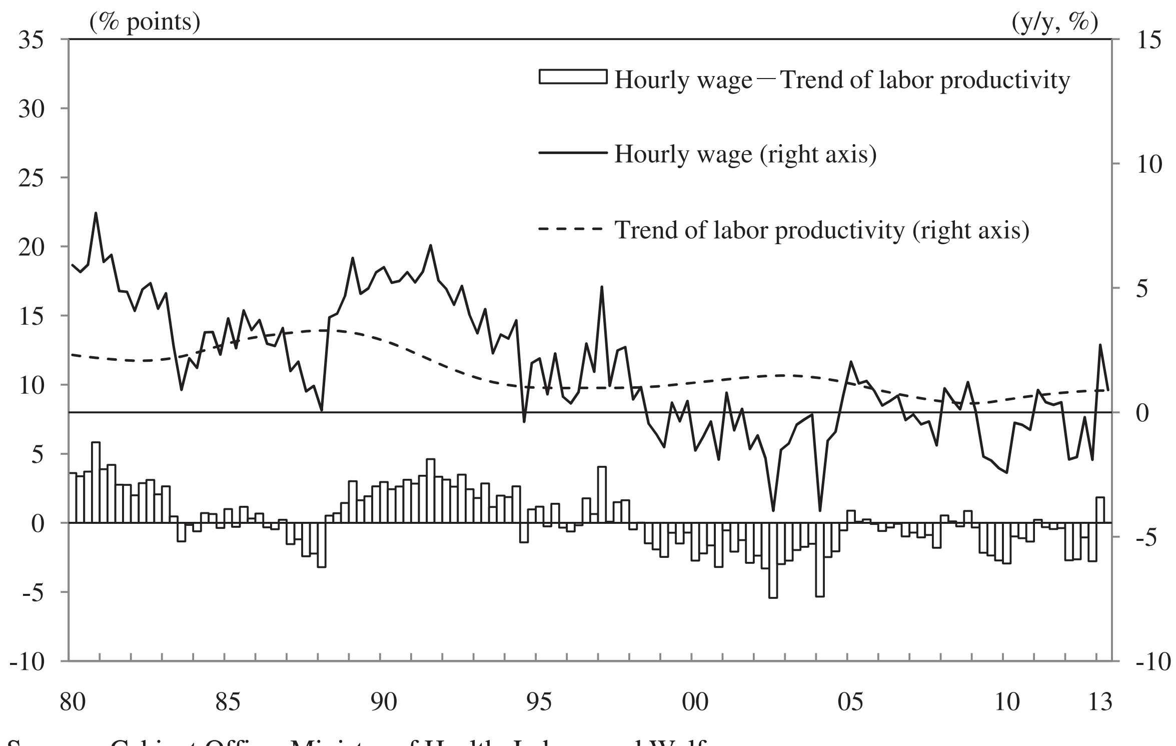


Sources: Ministry of Health, Labour and Welfare, Ministry of Internal Affairs and Communications; Bureau of Labor Statistics.

Figure 7: Wage inflation and labor productivity trend (Japan)

(1) Labor productivity trend

(2) Wage inflation and labor productivity trend



Sources: Cabinet Office, Ministry of Health, Labour and Welfare, Ministry of Internal Affairs and Communications.

Figure 8: Estimation results (Japan, y/y-based, hourly total wage)

– Labor productivity trend is eliminated –

(1) Basic NKWPC

$$\log\left(\frac{Hourly\ wage_t}{Hourly\ wage_{t-4}} \Big/ \frac{Trend\ of\ labor\ productivity_t}{Trend\ of\ labor\ productivity_{t-4}}\right) = \alpha_0 + \alpha_1 \frac{Unemployment\ rate_t}{100}$$

Sample period	α_0	α_1	Adj-R^2
1980Q1-2013Q2	0.055 (13.85)	-1.513 (-14.09)	0.598

Note: t-values in parentheses.

(2) NKWPC with inflation indexation

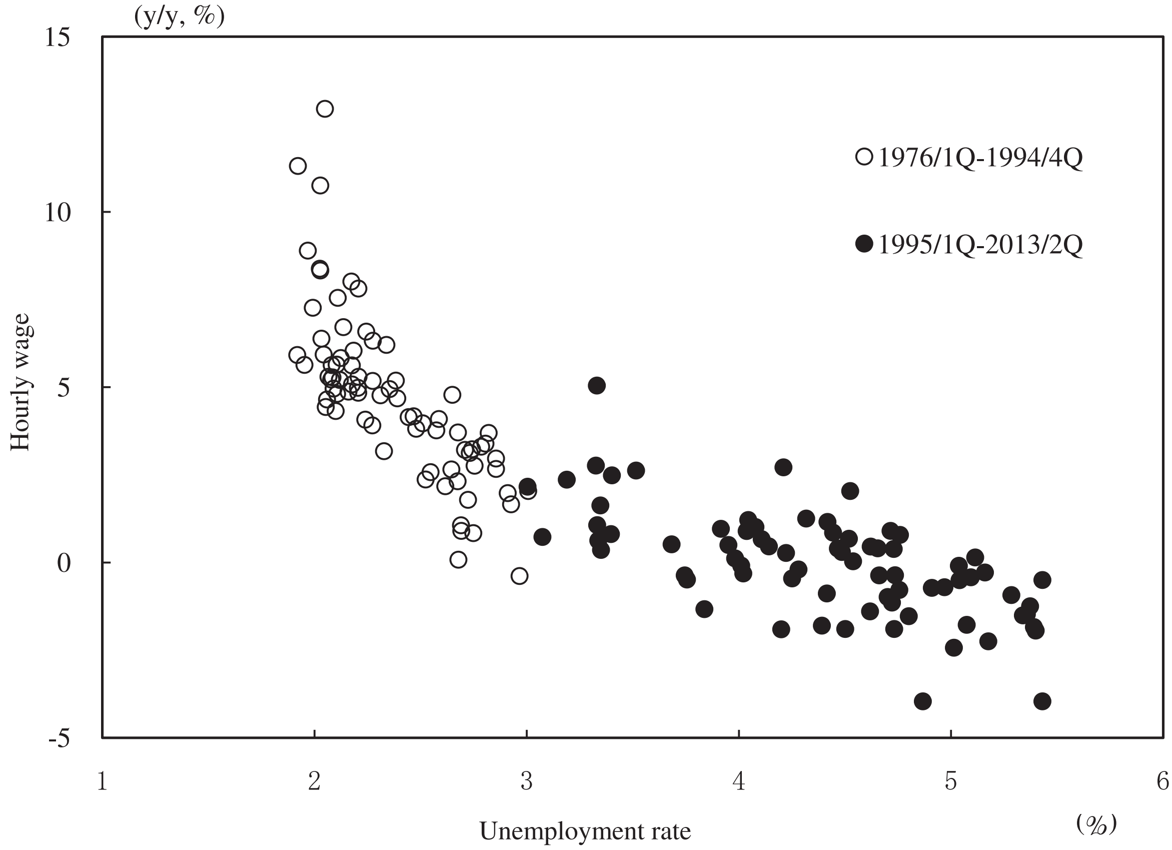
$$\log\left(\frac{Hourly\ wage_t}{Hourly\ wage_{t-4}} \Big/ \frac{Trend\ of\ labor\ productivity_t}{Trend\ of\ labor\ productivity_{t-4}}\right) = \alpha_0 + \alpha_1 \frac{Unemployment\ rate_t}{100} + \alpha_2 \log\left(\frac{CPI_{t-1}}{CPI_{t-5}}\right)$$

Sample period	α_0	α_1	α_2	Adj-R^2
1980Q1-2013Q2	0.031 (5.17)	-0.962 (-6.45)	0.453 (4.93)	0.658

Note: t-values in parentheses.

Figure 9: Subsample estimation of the reduced-form NKWPC for Japan

(1) Wage inflation and unemployment in Japan



(2) Subsample estimation of the reduced-form NKWPC (Japan, y/y-based, hourly total wage)

$$\log\left(\frac{Hourly\ wage_t}{Hourly\ wage_{t-4}}\right) = \alpha_0 + \alpha_1 \frac{Unemployment\ rate_t}{100} + \alpha_2 \log\left(\frac{CPI_{t-1}}{CPI_{t-5}}\right)$$

Sample period	α_0	α_1	α_2	Adj-R^2
1976/1Q～1994/4Q	0.113 (6.53)	-3.397 (-5.22)	0.475 (5.98)	0.724
1995/1Q～2013/2Q	0.062 (5.36)	-1.409 (-5.29)	0.206 (0.78)	0.427

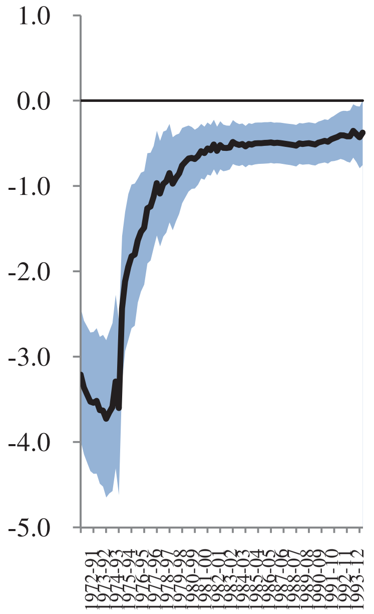
Note: t-values in parentheses.

Figure 10: Rolling estimation of the reduced-form NKWPC for Japan

1. q/q-based estimation

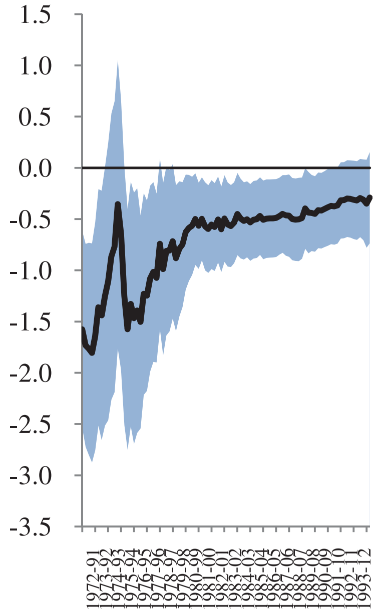
(1) Basic NKWPC

<Coefficient on unemployment rate>

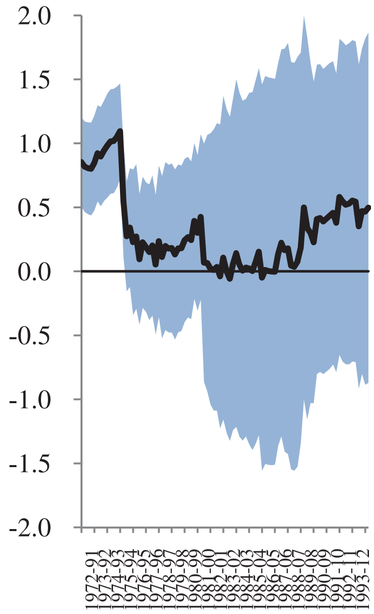


(2) NKWPC with inflation indexation

<Coefficient on unemployment rate>



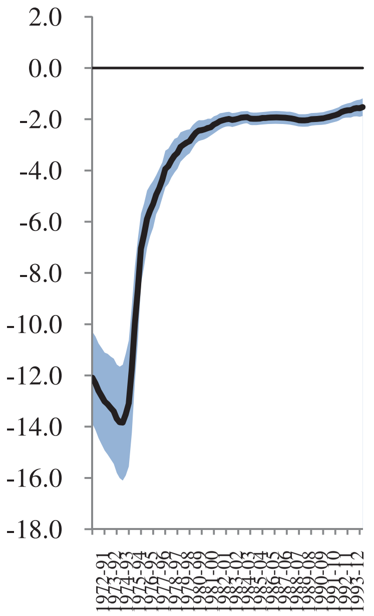
<Coefficient on inflation rate>



2. y/y-based estimation

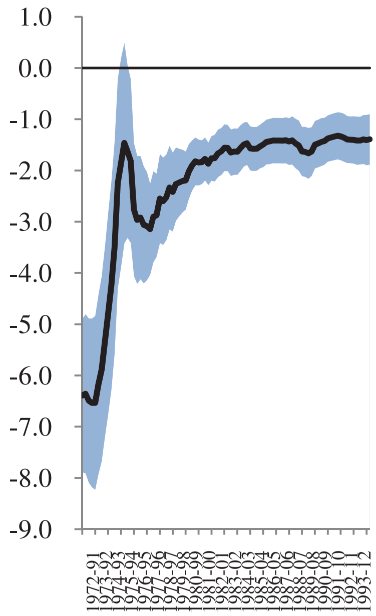
(1) Basic NKWPC

<Coefficient on unemployment rate>

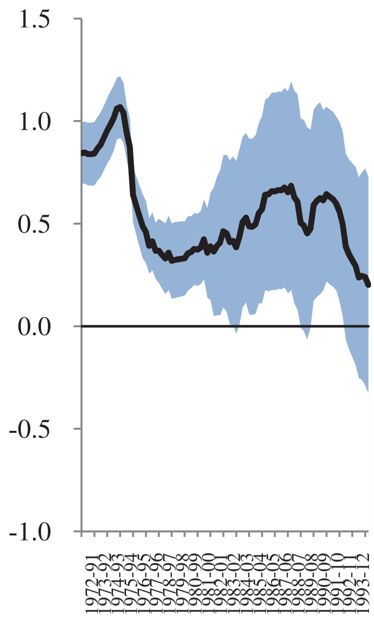


(2) NKWPC with inflation indexation

<Coefficient on unemployment rate>



<Coefficient on inflation rate>



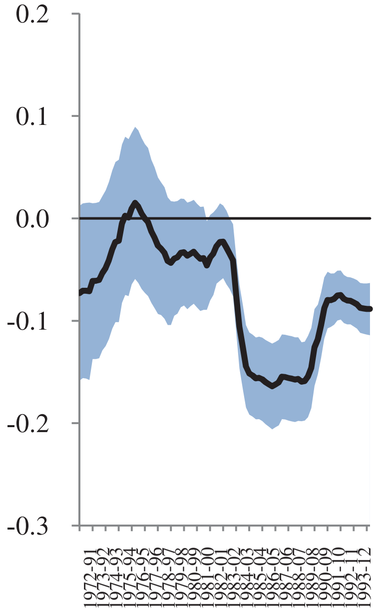
Note: Rollling window is 20 years. Shaded area indicates the range of two standard errors.

Figure 11: Rolling estimation of the reduced-form NKWPC for the US

1. q/q-based estimation

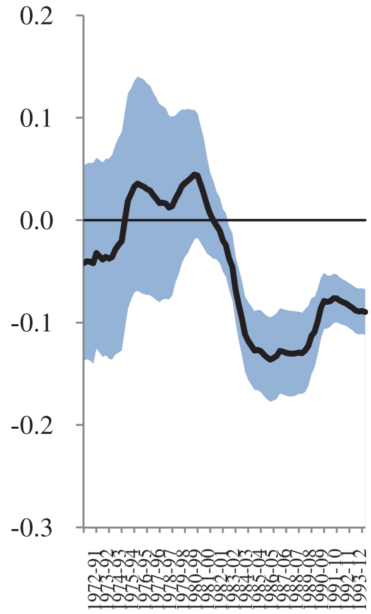
(1) Basic NKWPC

<Coefficient on unemployment rate>

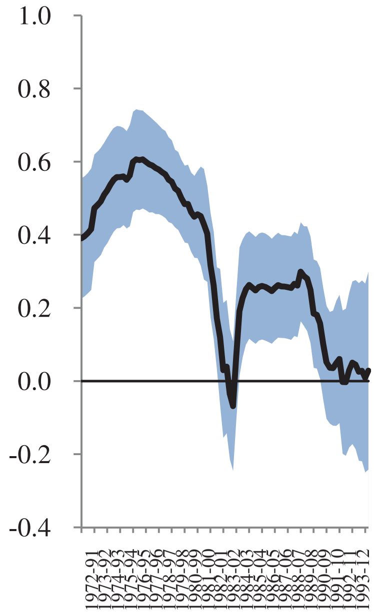


(2) NKWPC with inflation indexation

<Coefficient on unemployment rate>



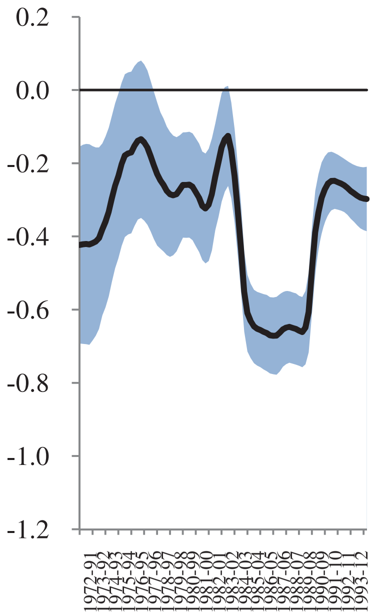
<Coefficient on inflation rate>



2. y/y-based estimation

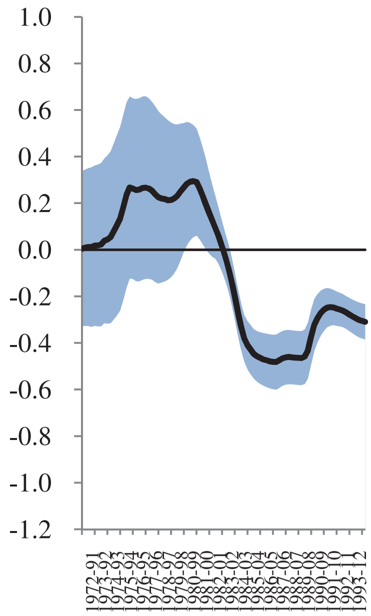
(1) Basic NKWPC

<Coefficient on unemployment rate>

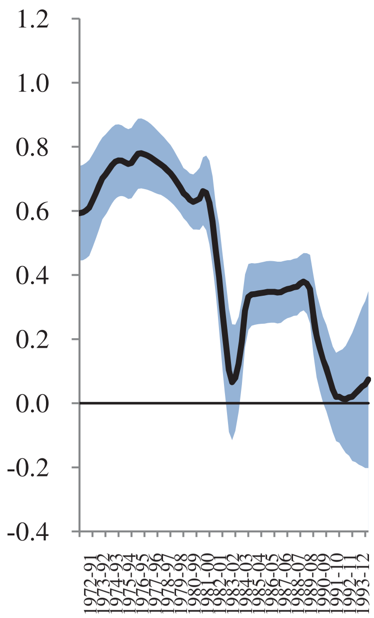


(2) NKWPC with inflation indexation

<Coefficient on unemployment rate>



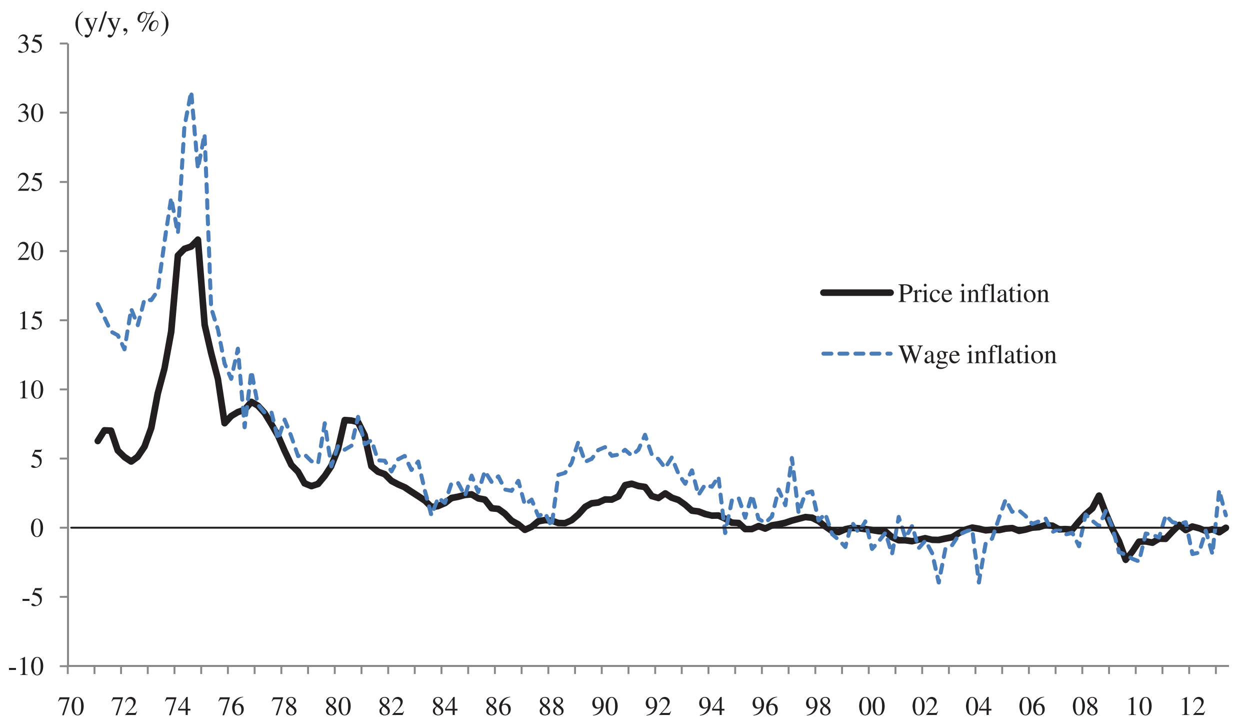
<Coefficient on inflation rate>



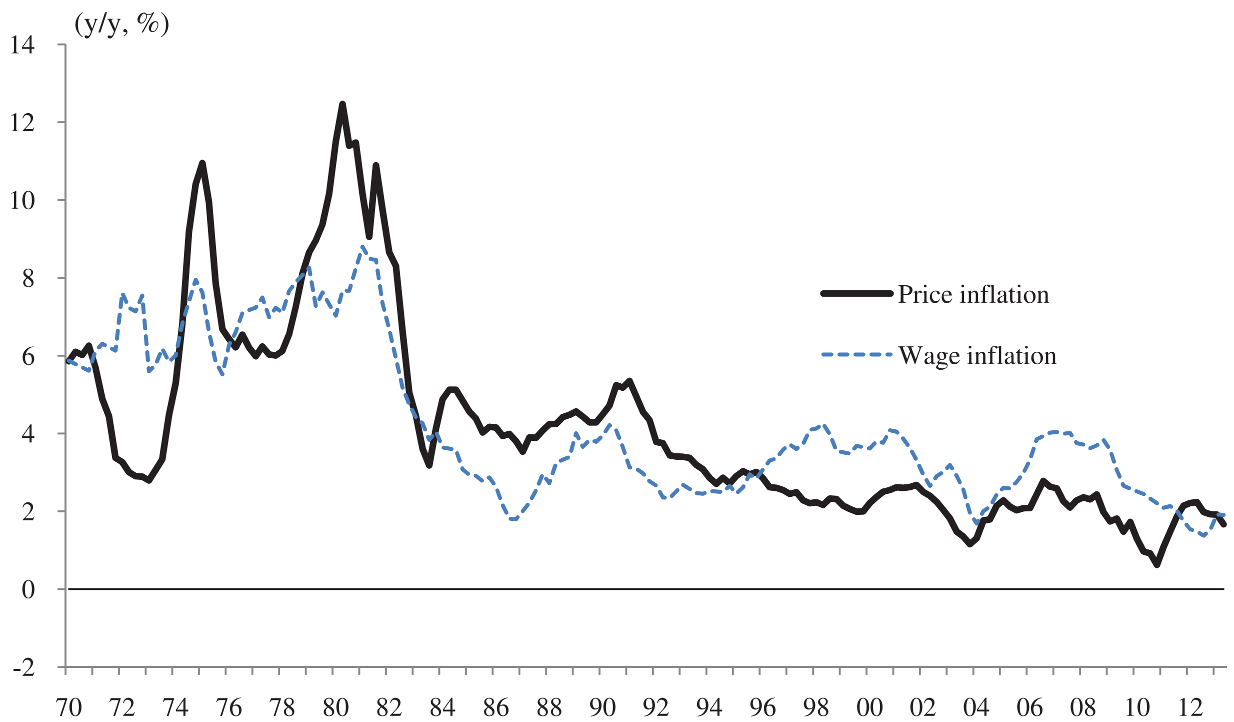
Note: Rollling window is 20 years. Shaded area indicates the range of two standard errors.

Figure 12: Price inflation and wage inflation

1. Japan



2. US



Note: See Figure 1 for data sources.

Table 1: Summary of estimation results (Japan, q/q-based, hourly total wage)

	(1)	(2)	(3)	(4)	(5)	(6)
u_t	-0.525 (-5.88)	-0.389 (-3.19)	-0.446 (-3.31)	-2.390 (-3.28)	-2.204 (-3.00)	-2.436 (-3.35)
u_{t-1}				1.868 (2.58)	1.806 (2.50)	2.044 (2.78)
π_{t-1}		0.449 (1.63)			0.411 (1.52)	
$\pi_{t-1}^{(4)}$			0.065 (0.78)			0.107 (1.30)
$Const.$	0.023 (6.92)	0.017 (3.52)	0.019 (3.57)	0.023 (7.12)	0.018 (3.73)	0.017 (3.25)
$Adj\text{-}R^2$	0.202	0.212	0.199	0.235	0.242	0.239
ϕ_1	0.987	0.987	0.987	1.359	1.359	1.359
ϕ_2	—	—	—	-0.373	-0.373	-0.373
$\lambda_w \varphi$	0.0119	0.0088	0.0102	0.0480	0.0443	0.0489
$\theta_w\ (\varphi = 1)$	0.557	0.603	0.581	0.348	0.334	0.318
$\theta_w\ (\varphi = 5)$	0.762	0.792	0.778	0.580	0.592	0.577

Note: Sample period is 1980Q1-2013Q2 in every case. t-values in parentheses.

Table 2: Summary of estimation results (U.S., q/q-based, hourly total wage)

	(1)	(2)	(3)	(4)	(5)	(6)
u_t	-0.020 (-1.02)	-0.048 (-3.39)	-0.067 (-5.36)	0.183 (1.89)	-0.047 (-0.64)	-0.091 (-1.41)
u_{t-1}				-0.208 (-2.14)	-0.001 (-0.01)	0.024 (0.38)
π_{t-1}		0.433 (11.20)			0.433 (10.77)	
$\pi_{t-1}^{(4)}$			0.128 (14.40)			0.129 (13.96)
$Const.$	0.010 (7.49)	0.008 (8.20)	0.008 (10.06)	0.010 (7.76)	0.008 (8.09)	0.008 (9.89)
$Adj\text{-}R^2$	0.000	0.486	0.610	0.027	0.482	0.608
ϕ_1	0.982	0.982	0.982	1.660	1.660	1.660
ϕ_2	—	—	—	-0.694	-0.694	-0.694
$\lambda_w \varphi$	0.0006	0.0013	0.0019	-0.0066	0.0017	0.0033
$\theta_w\ (\varphi = 1)$	0.908	0.866	0.840	NA	0.848	0.794
$\theta_w\ (\varphi = 5)$	0.958	0.936	0.923	NA	0.927	0.898

Note: Sample period is 1980Q1-2013Q2 in every case. t-values in parentheses.

Table 3: Summary of estimation results (Japan, y/y-based, hourly total wage)

	(1)	(2)	(3)	(4)
u_t	-2.041 (-20.96)	-1.560 (-11.46)	-1.965 (-2.41)	-2.141 (-2.84)
u_{t-1}			-0.076 (-0.09)	0.596 (0.78)
π_{t-1}				
$\pi_{t-1}^{(4)}$		0.396 (4.72)		0.409 (4.78)
$Const.$	0.089 (24.88)	0.069 (12.48)	0.089 (24.78)	0.068 (12.24)
$Adj\text{-}R^2$	0.767	0.800	0.766	0.799

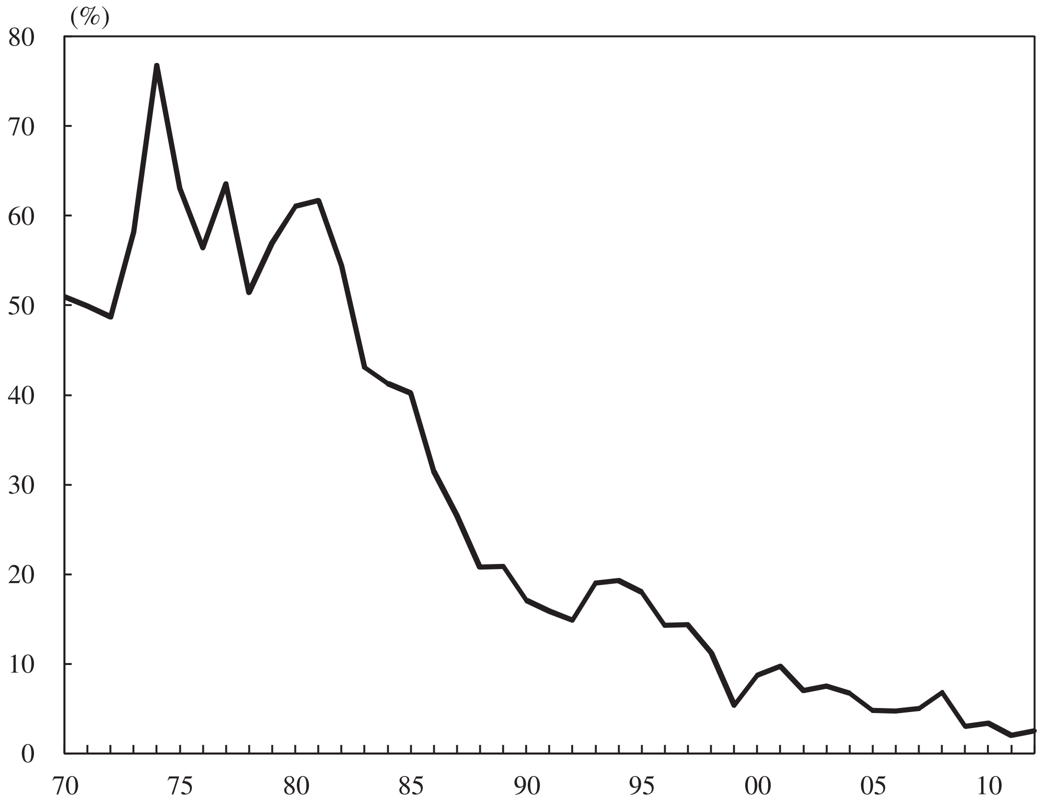
Note: Sample period is 1980Q1-2013Q2 in every case. t-values in parentheses.

Table 4: Summary of estimation results (U.S., y/y-based, hourly total wage)

	(1)	(2)	(3)	(4)
u_t	0.005 (0.07)	-0.191 (-4.49)	1.356 (3.76)	0.266 (1.23)
u_{t-1}			-1.380 (-3.82)	-0.460 (-2.17)
π_{t-1}				
$\pi_{t-1}^{(4)}$		0.529 (17.56)		0.512 (16.63)
$Const.$	0.034 (6.78)	0.028 (10.04)	0.036 (7.45)	0.028 (10.37)
$Adj\text{-}R^2$	-0.008	0.697	0.086	0.706

Note: Sample period is 1980Q1-2013Q2 in every case. t-values in parentheses.

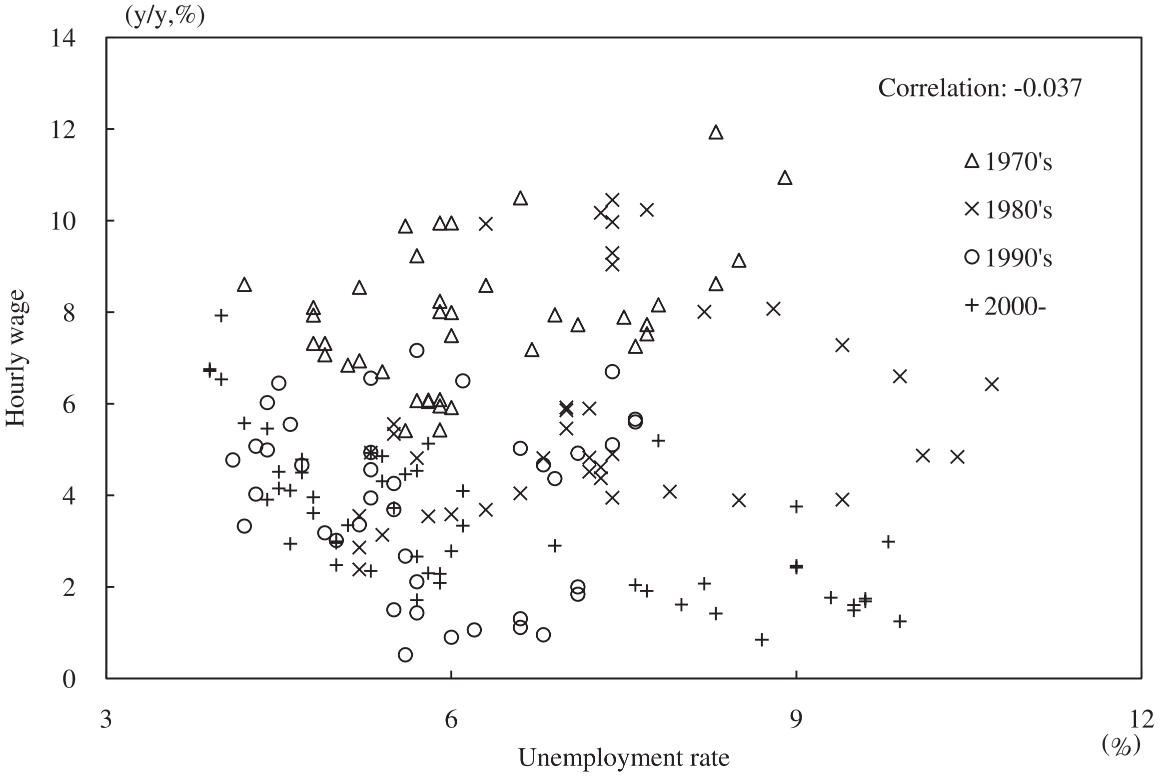
Figure A-1: Proportion of companies viewing inflation as a reason to revise wages



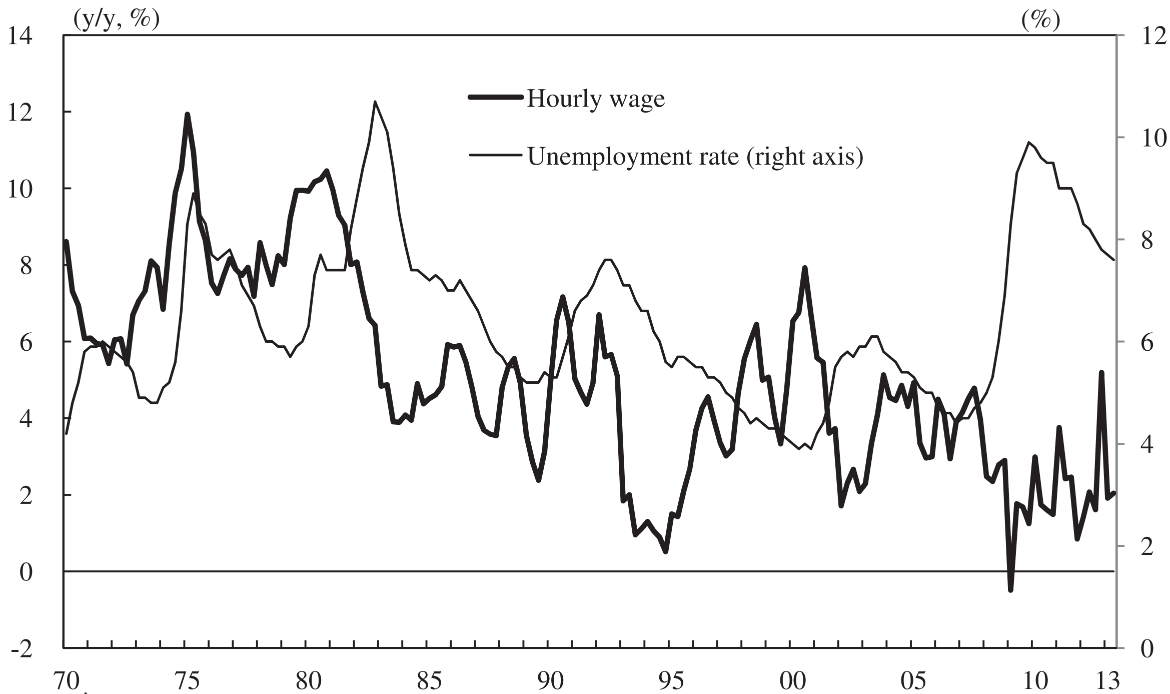
Source: Ministry of Health, Labour and Welfare.

Figure A-2: Wage inflation and unemployment rate (U.S., compensation-based)

(1) Scatter plot



(2) Time series



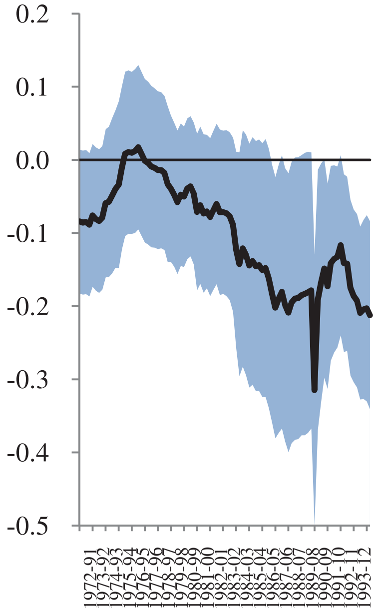
Source: Bureau of Labor Statistics.

Figure A-3: Rolling estimation of the reduced-form NKWPC for the US (compensation-based)

1. q/q-based estimation

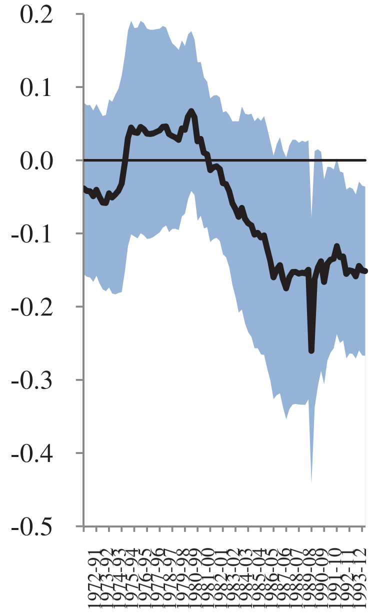
(1) Basic NKWPC

<Coefficient on unemployment rate>

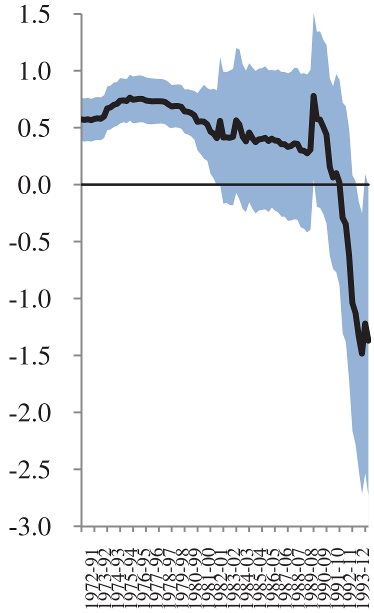


(2) NKWPC with inflation indexation

<Coefficient on unemployment rate>



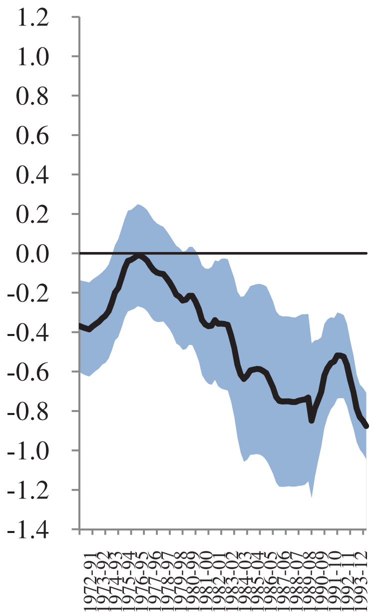
<Coefficient on inflation rate>



2. y/y-based estimation

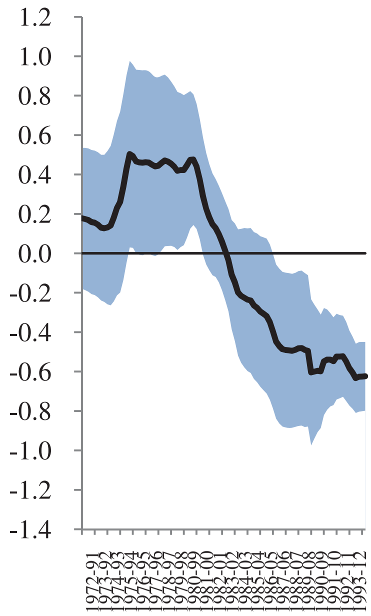
(1) Basic NKWPC

<Coefficient on unemployment rate>

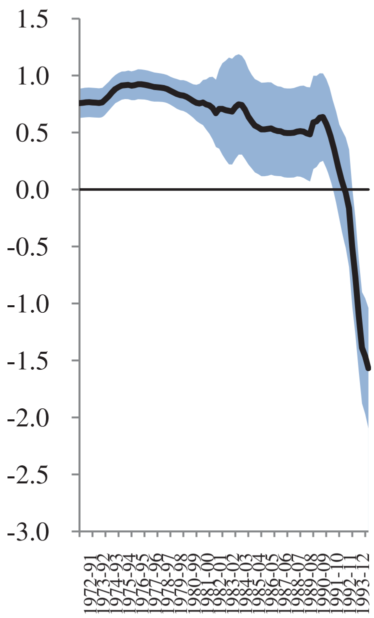


(2) NKWPC with inflation indexation

<Coefficient on unemployment rate>



<Coefficient on inflation rate>



Note: Rollling window is 20 years. Shaded area indicates the range of two standard errors.

Table A-1: Estimation results (Japan, q/q-based, hourly scheduled wage)

	(1)	(2)	(3)	(4)	(5)	(6)
u_t	-0.465 (-7.58)	-0.378 (-4.51)	-0.363 (-3.94)	-1.041 (-2.04)	-0.915 (-1.77)	-1.084 (-2.14)
u_{t-1}				0.577 (1.13)	0.535 (1.06)	0.741 (1.44)
π_{t-1}		0.289 (1.52)			0.278 (1.46)	
$\pi_{t-1}^{(4)}$			0.085 (1.49)			0.100 (1.74)
$Const.$	0.021 (9.40)	0.018 (5.28)	0.017 (4.53)	0.021 (9.43)	0.018 (5.34)	0.016 (4.22)
$Adj\text{-}R^2$	0.298	0.305	0.304	0.300	0.306	0.310
ϕ_1	0.987	0.987	0.987	1.359	1.359	1.359
ϕ_2	—	—	—	-0.373	-0.373	-0.373
$\lambda_w \varphi$	0.0106	0.0086	0.0083	0.0209	0.0184	0.0218
$\theta_w\ (\varphi = 1)$	0.575	0.607	0.612	0.463	0.485	0.456
$\theta_w\ (\varphi = 5)$	0.774	0.794	0.798	0.697	0.713	0.692

Note: Sample period is 1980Q1-2013Q2 in every case. t-values in parentheses.

Table A-2: Estimation results (U.S., q/q-based, hourly total wage, compensation-based)

	(1)	(2)	(3)	(4)	(5)	(6)
u_t	-0.039 (-0.86)	-0.078 (-1.87)	-0.103 (-2.47)	0.040 (0.18)	-0.297 (-1.37)	-0.348 (-1.63)
u_{t-1}				-0.081 (-0.35)	0.222 (1.03)	0.247 (1.17)
π_{t-1}		0.602 (5.30)			0.634 (5.39)	
$\pi_{t-1}^{(4)}$			0.691 (5.87)			0.728 (5.98)
$Const.$	0.013 (4.29)	0.010 (3.65)	0.011 (4.01)	0.013 (4.29)	0.010 (3.46)	0.010 (3.83)
$Adj\text{-}R^2$	-0.002	0.169	0.201	-0.009	0.169	0.203
ϕ_1	0.982	0.982	0.982	1.660	1.660	1.660
ϕ_2	—	—	—	-0.694	-0.694	-0.694
$\lambda_w \varphi$	0.0011	0.0022	0.0029	-0.0015	0.0107	0.0125
$\theta_w\ (\varphi = 1)$	0.877	0.829	0.805	NA	0.658	0.637
$\theta_w\ (\varphi = 5)$	0.942	0.917	0.905	NA	0.821	0.808

Note: Sample period is 1980Q1-2013Q2 in every case. t-values in parentheses.