The International Journal of Economic Policy Studies

Volume 6 | 2011 | Article 6

THE NEW KEYNESIAN PHILLIPS CURVE FOR JAPAN — AN EMPIRICAL ANALYSIS —

Kazuhiko NAKAHIRA
Associate Professor
Department of Business Administration and Information
Tokyo University of Science, Suwa
5000-1 Toyohira,
Chino, Nagano
391-0292, JAPAN
e-mail: nakahira@rs.suwa.tus.ac.jp

ABSTRACT

The aim of this paper is to conduct empirical research on Japanese inflation dynamics through GMM estimations by applying the modified Woodford (2003)-type New Keynesian Phillips Curve (NKPC) which incorporates staggered price and wage setting, by using quarterly data spanning the period 1980:1 to 2010:4. The result of estimation leads our empirical study to conclude that the backward-looking component tends to have a stronger impact on inflation dynamics than the forward-looking one. Further, the investigation of flattening of the NKPC implies that it is rather flat, and that downward nominal wage rigidity is related to this in recent years. Thus, the conduct of monetary policy by the central bank faces a certain difficulty in recent years.

Key words : New Keynesian Phillips Curve; Inflation Dynamics; Monetary Policy; GMM

JEL Classification : E31, E52

THE NEW KEYNESIAN PHILLIPS CURVE FOR JAPAN — AN EMPIRICAL ANALYSIS —

1. INTRODUCTION

New Keynesian Macroeconomics has emerged recently as one of the prominent and influential frameworks for economic research. It has combined the theoretical constituents of Keynesian economics, including monopolistic competition and nominal rigidities, with the ones of new classical concepts like Real Business Cycle approach. Examples of notable features of the New Keynesian methodology are as follows. First, it utilizes the tools of dynamic stochastic general equilibrium (DSGE) model, which incorporates optimizing behaviors of households and firms, and rational expectations. Second, firms are assumed to act as monopolistic competitors to maximize their discounted profits. Third, nominal rigidities are applied as an important factor, and they act as a source of non-neutrality of monetary policy. Fourth, monetary policy rules are incorporated as the endogenous component in the system. Moreover, evaluation of the policy rule and its optimality can be implemented by a welfare-based criterion, along with maximization of the utility of economic agents.

One of the key elements of the New Keynesian approach is the so-called New Keynesian Phillips Curve (NKPC) derived through the New Keynesian DSGE which includes firms' price-setting behaviours, marginal costs, and various economic activities. The NKPC characterizes the relation between inflation and economic activities by indicating two distinct features. Firstly, it depicts the forward-looking character of inflation, which is an outcome of firms' price-setting manner reflecting their expectations of demands and costs in the future. Secondly, NKPC describes the linkages between inflation, real economic activity, and marginal cost.

Taking advantage of the noticeable features described above, there has been plenty of research devoted to the New Keynesian Phillips Curve. Galí and Gertler (1999) and Galí, Gertler, and López-Salido (2005) insist that lagged inflation is one of the key ingredients of the NKPC from the aspect of the delayed or gradual response to monetary policy shocks. Sbordone (2002), and Galí, Gertler, and López-Salido (2001) find that real marginal cost is an important factor to analyze inflation dynamics in the United States and the Euro area, by empirical studies of the NKPC. On the other hand, Mazumder (2010) argues that labor income share is an imprecise proxy for real marginal cost from the aspect of its cyclicality. Zhang and Clovis (2010) show that further lags of inflation are necessary in the hybrid-type NKPC to rule out serial correlation in the Euler equation. Smets and Wouters (2003) and Giannoni and Woodford (2003) utilize partial dynamic inflation indexation to estimate their NKPC. Further, some of the recent studies deal with the flattening of the NKPC. For instance, Kuester, Müller, and Stölting (2009) insist that the NKPC looks flatter than it actually is by considering the estimated pass-through of marginal costs.

This paper proceeds to examine whether the special type of the New Keynesian Phillips Curve (NKPC) provides reasonable approximations of Japanese inflation dynamics. Concretely, empirical study is conducted through the GMM (Generalized Method of Moments) estimation based on the modified Woodford (2003)-type NKPC for the periods before and after the bubble collapse. It is often pointed out that inflation has come to be less responsive to demand pressures in major industrialized countries, and that downward nominal wage rigidity has existed in Japan. In this sense, estimation by utilizing Woodford-type NKPC which incorporates staggered price and wage setting is worth implementing. Further, the slope of NKPC is an important factor to consider the influence of monetary policy. For instance, flattening of NKPC implies that inflation becomes less responsive to aggregate economic activities including output gap. Therefore, flattening of NKPC is examined through the estimation in this study.

The remainder of this paper is organized as follows. Section 2 gives a brief summary of the derivation of four major types of NKPC. Section 3 describes the result of empirical study through GMM estimation, and Section 4 presents the concluding remarks.

2. THE STRUCTURE OF NKPC

In the following section, the brief summary of the derivation for the major four types of NKPC is made by following Walsh (2010), Galí (2008), Woodford (2003), and Erceg, Henderson, and Levin (2000).[1]

2.1 Households

The representative household maximizes the discounted sum of life time utility:

$$E_t \sum_{i=0}^{\infty} \beta^i U(C, N)$$

$$= E_t \sum_{i=0}^{\infty} \beta^i \left[\frac{C_{t+i}^{1-\sigma}}{1-\sigma} + \frac{\gamma}{1-b} \left(\frac{M_{t+i}}{P_{t+i}} \right)^{1-b} - \chi \frac{N_{t+i}^{1+\eta}}{1+\eta} \right] \quad (1)$$

where C_t denotes a composite good, $\frac{M_t}{P_t}$ is the real money balances, N_t refers to the time devoted to market employment, and β is the subjective discount factor ($0 < \beta < 1$). We utilize

[1] For explicit derivations, see Walsh (2010), Galí (2008), Woodford (2003), and Erceg, Henderson, and Levin (2000).

the monopolistic competition model of Dixit and Stiglitz (1977), with a continuum of differentiated goods indexed by $j \in [0,1]$. The Dixit-Stiglitz-type composite consumption good (consumption index) for the household's utility function is defined as

$$C_t = \left[\int_0^1 c_{jt}^{\frac{\theta-1}{\theta}} dj\right]^{\frac{\theta}{\theta-1}}, \ \theta > 1, \tag{2}$$

where C_{jt} denotes good C_t produced by firm j. θ is a constant and common elasticity of substitution between each good ($\theta > 1$). With some manipulations, the aggregated price index, P_t is given by

$$\psi_t = \left[\int_0^1 p_{jt}^{1-\theta} dj\right]^{\frac{1}{1-\theta}} \equiv P_t, \tag{3}$$

where ψ_t is Lagrangian multiplier.

The budget constraint of the household in real terms yields,

$$C_t + \frac{M_t}{P_t} + \frac{B_t}{P_t} = \left(\frac{W_t}{P_t}\right) N_t + \frac{M_{t-1}}{P_t} + (1 + i_{t-1})\left(\frac{B_{t-1}}{P_t}\right) + \Pi_t \tag{4}$$

where W_t denotes the (nominal) wage, $M_t(B_t)$ is the (nominal) holdings of money by the household generated by one-period bonds, i_t refers to the (nominal) interest rate of bonds, and Π_t denotes households' real profits received from firms.

The decision problem by the representative household (or consumer) with regard to consumption, labor supply, money, and bond holdings are expressed as the maximization of (1) subject to (4). The following three conditions derived by this optimization problem and (4) have to hold in equilibrium.

<Euler condition for the optimal intertemporal allocation of consumption>

$$C_t^{-\sigma} = \beta(1 + i_t)E_t\left(\frac{P_t}{P_{t+1}}\right) C_{t+1}^{-\sigma} \tag{5}$$

<intratemporal optimality condition setting the marginal rate of substitution between money and consumption equals the opportunity cost of holding money>

$$\frac{\gamma\left(\frac{M_t}{P_t}\right)^{-b}}{C_t^{-\sigma}} = \frac{i_t}{1+i_t} \tag{6}$$

<intratemporal optimality condition setting the marginal rate of substitution between leisure and consumption equal to the real wage>

$$\frac{\gamma N_t^{\eta}}{C_t^{-\sigma}} = \frac{W_t}{P_t} \tag{7}$$

2.2 Firms

Firms seek to maximize their profits, subject to the following three kinds of constraints.

<production function>

The constant returns to scale type production function which summarizes the available technology is assumed. In this case, output is a function of labor input N_{jt} and an aggregate productivity disturbance Z_t. Capital is ignored for simplicity.

$$c_{jt} = Z_t N_{jt},\ E(Z_t) = 1 \tag{8}$$

<demand curve>

The demand curve which each firm faces is

$$c_{jt} = \left(\frac{p_{jt}}{P_t}\right)^{-\theta} C_t \tag{9}$$

where p_{jt} is the price of good j.

<Calvo-type price adjustment>

The model of price stickiness proposed in Calvo (1983) is adopted. The firms that adjust their price are randomly selected. Each firm may reset its price with probability $1-\omega$ in any given period, independent of the time elapsed since the last adjustment. Therefore, a fraction $1-\omega$ of all firms adjusts (or resets) their price while the remaining fraction ω keeps their price unchanged, and the average duration of a price is $(1-\omega)^{-1}$. In this respect, the parameter ω is a measure of the degree of nominal rigidity. A firm's profit at some future date $t+s$ is affected by the selection of price at time t only if the firm has not got another chance of adjusting the price between t and $t+s$ with the probability ω^s.

The profit maximization problem based on the pricing decision picking P_{jt} is solved to maximize

$$E_t \sum_{i=0}^{\infty} \omega^i D_{i,t+1} \left[\left(\frac{P_{jt}}{P_{t+i}}\right) c_{jt+i} - \varphi_{t+i} c_{jt+i}\right], \tag{10}$$

where $D_{i,t+1} = \beta^i \left(\frac{C_{t+i}}{C_t}\right)^{-\sigma}$ is the stochastic discount factor, and φ_t denotes the real marginal cost. The objective function can be described by the elimination of C_{jt} by using the demand curve:

$$E_t \sum_{i=0}^{\infty} \omega^i D_{i,t+1} \left[\left(\frac{P_{jt}}{P_{t+i}}\right)^{1-\theta} - \varphi_{t+i} \left(\frac{P_{jt}}{P_{t+i}}\right)^{-\theta}\right] C_{t+i}. \tag{11}$$

While each firm produce differentiated products, all firms are assumed to have the same technology and face demand curves with constant and equal elasticity of demand. In addition, it is assumed that all firms adjusting their prices in period t set the same price. The first order condition of the objective function with respect to the optimal price p_t^* chosen by all firms adjusting at time t is

$$E_t \sum_{i=0}^{\infty} \omega^i D_{i,t+1} \left[(1-\theta)\left(\frac{p_t^*}{P_{t+i}}\right) + \theta\varphi_{t+i}\right]\left(\frac{1}{p_t^*}\right)\left(\frac{p_t^*}{P_{t+i}}\right)^{-\theta} C_{t+i} = 0. \tag{12}$$

This can be re-written by using the stochastic discount factor:

$$\left(\frac{p_t^*}{P_t}\right) = \left(\frac{\theta}{\theta-1}\right)\frac{E_t \sum_{i=0}^{\infty} \omega^i \beta^i C_{t+i}^{1-\sigma} \varphi_{t+i}\left(\frac{P_{t+i}}{P_t}\right)^{\theta}}{E_t \sum_{i=0}^{\infty} \omega^i \beta^i C_{t+i}^{1-\sigma}\left(\frac{P_{t+i}}{P_t}\right)^{\theta-1}}. \tag{13}$$

The condition that the real wage equals the marginal rate of substitution between leisure and consumption and the property of (7) imply that

$$\frac{\chi N_t^{\eta}}{C_t^{-\sigma}} = \frac{W_t}{P_t} = \frac{Z_t}{\mu} \tag{14}$$

where $\mu > 1$ is a markup.

By the goods market clearing condition and the production function, we have $C_t = Y_t$ and $N_t = \frac{Y_t}{Z_t}$. Utilizing these elements in (14) and denoting Y_t^f as equilibrium output under flexible prices, we have

$$Y_t^f = \left(\frac{1}{\chi\mu}\right)^{\frac{1}{\sigma+\eta}} Z_t^{\frac{1+\eta}{\sigma+\eta}}. \tag{15}$$

Output derived in the case of sticky price $\omega > 0$ can differ from the output in the flexible-price equilibrium. The average price of the non-price-adjusting firms is the average of all firms that obtained in period *t*—*1* since the adjusting firms were randomly selected from all firms. Therefore, from equation (3), the average price in period t satisfies

$$P_t^{1-\theta} = (1-\omega)(p_t^*)^{1-\theta} + \omega P_{t-1}^{1-\theta}. \tag{16}$$

Equations (13) and (16) can be utilized in order to express the deviations of the inflation rate around its steady-state. Suppose the steady-state involves a zero rate of inflation and $Q_t = \frac{p_t^*}{P_t}$ be the relative price chosen by all price-adjusting firms in period t, the steady-state value should be $Q = 1$. Dividing equation (16) by P_t, we have $1 = (1-\omega)Q_t^{1-\theta} + \omega\left(\frac{P_{t-1}}{P_t}\right)^{1-\theta}$. In terms of percentage deviations around the zero inflation steady-state, this can be re-written as $0 = (1-\omega)\hat{q}_t - \omega\pi_t$, or

$$\hat{q}_t = \left(\frac{\omega}{1-\omega}\right)\pi_t. \tag{17}$$

2.3 Marginal-Cost-Based Forward Looking NKPC

Equation (12) is able to be expressed as

$$\left[E_t \sum_{i=0}^{\infty} \omega^i \beta^i C_{t+i}^{1-\sigma} \left(\frac{P_{t+i}}{P_t}\right)^{\theta-1}\right] Q_t = \mu \left[E_t \sum_{i=0}^{\infty} \omega^i \beta^i C_{t+i}^{1-\sigma} \varphi_{t+i} \left(\frac{P_{t+i}}{P_t}\right)^{\theta}\right]. \quad (18)$$

After some manipulations, we get

$$\hat{q}_t + \hat{p}_t = (1 - \omega\beta) \sum_{i=0}^{\infty} \omega^i \beta^i (E_t \hat{\varphi}_{t+i} + E_t \hat{p}_{t+i}). \quad (19)$$

The left side of equation (19) is the optimal nominal price ($\hat{p}_t^* = \hat{q}_t + \hat{p}_t$), which is set to equal the expected discounted value of future nominal marginal costs. This can be re-written as

$$\hat{q}_t + \hat{p}_t = (1 - \omega\beta)(\hat{\varphi}_t + \hat{p}_t) + \omega\beta(E_t \hat{q}_{t+1} + E_t \hat{p}_{t+1}),$$

and rearrange this yields

$$\begin{aligned} \hat{q}_t &= (1 - \omega\beta)\hat{\varphi}_t + \omega\beta(E_t \hat{q}_{t+1} + E_t \hat{p}_{t+1} - \hat{p}_t) \\ &= (1 - \omega\beta)\hat{\varphi}_t + \omega\beta(E_t \hat{q}_{t+1} + E_t \pi_{t+1}). \end{aligned} \quad (20)$$

Utilizing equation (17) to eliminate $\hat{q}_t$, above equation becomes

$$\begin{aligned} \left(\frac{\omega}{1-\omega}\right)\pi_t &= (1 - \omega\beta)\hat{\varphi}_t + \omega\beta\left[\left(\frac{\omega}{1-\omega}\right)E_t\pi_{t+1} + E_t\pi_{t+1}\right] \\ &= (1 - \omega\beta)\hat{\varphi}_t + \omega\beta\left(\frac{1}{1-\omega}\right)E_t\pi_{t+1}. \end{aligned} \quad (21)$$

By multiplying both sides by $\frac{1-\omega}{\omega}$, we have the following equation:

$$\pi_t = \beta E_t \pi_{t+1} + \tilde{\kappa}\hat{\varphi}_t \quad (22)$$

where $\tilde{\kappa} = \frac{(1-\omega)(1-\omega\beta)}{\omega}$. This is an increasing function of the fraction that firms can adjust each period. $\hat{\varphi}_t$ is real marginal cost expressed as a percentage deviation around its steady-state value. In this sense, this specification can be regarded as the marginal-cost-based forward-looking New Keynesian Phillips Curve.

2.4 Output-Gap-Based Forward Looking NKPC

Equation (21) incorporates real marginal cost ($\hat{\varphi}_t$) as an explanatory factor for inflation, however, real marginal cost can be expressed as a related variable of the output gap. Considering some required conditions, we have

$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t, \quad (23)$$

where $\kappa = \gamma\tilde{\kappa} = \frac{\gamma(1-\omega)(1-\omega\beta)}{\omega}$, and $x_t \equiv \hat{y}_t - \hat{y}_t^f$ is the gap between actual output and flexible-price equilibrium output. This is the output-gap-based forward-looking New Keynesian Phillips Curve.

In the two types of New Keynesian Phillips Curve described above, inflation is determined by current expectations of future inflation and current economic activities. In this point, these are pure forward-looking specifications, and inflation is assumed to jump immediately rather than reacting with delay.

2.5 NKPC with Indexation to Past Inflation

Christiano, Eichenbaum, and Evans (2001, 2005), Smets and Wouters (2002), and Giannoni and Woodford (2003, 2005) assume partial or full indexation of price or wage commitments, and these studies discuss the modification of the Calvo pricing model in line with this kind of indexation. Woodford (2003) proposed the model based on the backward-looking indexation for inflation dynamics with the assumption of efficient labor-market contracting. Woodford (2003) assumes that a randomly selected fraction $1-\omega$ of all prices are reconsidered and set optimally in each period, but the price of each good which is not reset is adjusted by the indexation rule:

$$log\, p_t(i) = log\, p_{t-1}(i) + \gamma\pi_{t-1}, \tag{24}$$

where $0 \leq \gamma \leq 1$ expresses the degree of indexation to the most recently available inflation measure. A new price $p_t(i)$ in period *t* should be set to maximize the following function if we assume that newly optimized prices come into effect instantly

$$E_t\left\{\sum_{T=t}^{\infty} \omega^{T-t} Q_{t,T}\left[\Pi_T^i(p(i)(\tfrac{P_{T-1}}{P_{t-1}})^{\gamma})\right]\right\} \tag{25}$$

where $Q_{t,T}$ is the stochastic discount factor, and Π_T^i denotes the profit function. Choosing the optimal price p_t^*, the overall price index evolves according to

$$P_t = \left[(1-\omega)p_t^{*1-\theta} + \omega\left(P_{t-1}\left(\frac{P_{t-1}}{P_{t-2}}\right)^{\gamma}\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}. \tag{26}$$

A series of manipulations with the above elements yields a log-linear aggregate-supply relation:

$$\pi_t - \gamma\pi_{t-1} = \kappa(\hat{Y}_t - \hat{Y}_t^n) + \beta E_t(\pi_{t+1} - \gamma\pi_t)\,, \tag{27}$$

where $\hat{Y}_t - \hat{Y}_t^n$ represents the output gap, $\hat{Y}_t \equiv log\left(\frac{Y_t}{\bar{Y}}\right)$, $\hat{Y}_t^n \equiv log\left(\frac{Y_t^n}{\bar{Y}}\right)$, $\bar{Y}$ denotes the equilibrium output in the steady state, and Y_t^n is the natural rate of output. This specification is the so-called hybrid New Keynesian Phillips Curve[2] or the New Keynesian Phillips Curve with dynamic inflation indexation. It postulates that inflation is determined by past inflation, current expectations of future inflation, and current economic activities.

2.6 NKPC with Indexation of Staggered Price and Wage Setting

Woodford (2003) contrived a model with the consideration of staggered price and wage setting. First, Woodford (2003) follows the discussions of Erceg, Henderson, and Levin (2000) and Calvo (1983). The maximization problem is described by

$$E_t\{\sum_{T=t}^{\infty}(\omega_w\beta)^{T-t}[\Lambda_T w_t(j)h_T(w_t(j)) - \upsilon(h_T(w_t(j));\xi_T)]\} \tag{28}$$

where Λ_T denotes the representative household's marginal utility of nominal income in period T, υ is the disutility of supplying labor, h_T refers to the labor demand, and ξ_T is the vector of exogenous disturbances. Wage $w_t(j)$ that is adjusted in period *t* should be chosen to maximize this objective function. With some manipulations, Woodford (2003) makes "Proposition 3.9" that insists as follows: If wages and prices are both staggered, as in Erceg, Henderson, and Levin (2000), then the joint evolution of the wage index, the price index, and aggregate real output must satisfy the relations in each period:

$$\Delta logW_t = \kappa_w(\hat{Y}_t - \hat{Y}_t^n) + \xi_w(logw_t^n + logP_t - logW_t) + \beta E_t(\Delta logW_{t+1}) \tag{29}$$

$$\Delta logP_t = \kappa_p(\hat{Y}_t - \hat{Y}_t^n) + \xi_p(logW_t - logP_t - logw_t^n) + \beta E_t(\Delta logP_{t+1}) \tag{30}$$

where $logw_t^n$ is the natural real wage, namely, the equilibrium real wage when both wages and prices are fully flexible, $\kappa_w > 0$, and $\kappa_p > 0$. Further, Woodford (2003) argues that even in the case of infrequent re-optimization of wage demand, wages might be indexed to an aggregate price index in the interim. In addition, if the wage demanded for type *j* labor is not re-optimized in period *t*, it is adjusted according to the indexation rule with the condition $0 \leq \gamma_w \leq 1$

$$logw_t(j) = logw_{t-1}(j) + \gamma_w\pi_{t-1}. \tag{31}$$

This indexation rule modifies the discussion of optimal price-setting and the system constructed by (29) and (30)

[2] This specification is regarded as a "hybrid-type" in the sense that both forward- and backward-looking components are incorporated.

$$\pi_t^w - \gamma_w \pi_{t-1}^w = \kappa_w(\hat{Y}_t - \hat{Y}_t^n) + \xi_w(logw_t^n - logw_t \ ) + \beta E_t[\pi_{t+1}^w - \gamma_w \pi_t^w] \tag{32}$$

$$\pi_t \ - \gamma_p \pi_{t-1} \ = \kappa_p(\hat{Y}_t - \hat{Y}_t^n) + \xi_p \ (logw_t \ - logw_t^n) + \beta E_t[\pi_{t+1} - \gamma_p \pi_t \ ] \tag{33}$$

where $\pi_t^w \equiv \Delta \log W_t$ is the rate of wage inflation, $w_t = \frac{W_t}{P_t}$ is the aggregate real wage, γ_p $(0 \leq \gamma_p \leq 1)$ is the rate of indexation of price commitments. This specification shows that inflation is determined by past inflation, current expectations of future inflation, current output gap, and by the current wage gap with consideration of staggered price and wage setting. The term of real marginal cost is constructed by a linear combination of the terms of output gap and wage gap.

3. EMPIRICAL RESULTS

Our empirical analysis is implemented based on the modified Woodford (2003)-type New Keynesian Phillips Curve (NKPC) which incorporates staggered price and wage setting. Estimations are conducted utilizing quarterly data spanning the period 1980:1 to 2010:4, and our data set is constructed by the following variables.[3]

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

Yr: real GDP (quarterly, chain-linked estimates, first preliminary estimates, reference year: 2000, seasonally adjusted, billion yen)

Wr: real wage index (total cash earnings, size of establishments: establishments with 30 employees or more, industries covered, 2005 average = 100, seasonally adjusted)

Yc: trend component of Yr obtained by utilizing the Hodrick-Prescott filter setting penalty parameter = 1600

Wc: trend component of Wr obtained by utilizing the Hodrick-Prescott filter setting penalty parameter = 1600

Proxy for $\hat{Y}_t - \hat{Y}_t^n$ (output gap) = $logYr - logYc$

Proxy for $logw_t - logw_t^n$ (wage gap) = $logWr - logWc$

"log" denotes natural logarithm. The overall GDP deflator, rather than the other candidates related to the price level, is applied as the factor for inflation since our interest lies in the

[3] GDP deflator and real GDP are obtained from the Economic and Social Research Institute, Cabinet Office's website (in English) (http://www.esri.cao.go.jp/en/sna/). The real wage index is surveyed by Ministry of Health, Labor and welfare, and its data is distributed by "Portal Site" of Official Statistics of Japan (in Japanese) (http://www.e-stat.go.jp/SG1/estat/eStatTopPortal.do).

investigation whether this research captures the inflation dynamics in a standard broad measure. As to the inflation rate, a four-quarter backward moving average ($\pi_t^{(4)} = \frac{1}{4}(\pi_t + \pi_{t-1} + \pi_{t-2} + \pi_{t-3})$, where $\pi_t = logDf_t - logDf_{t-1}$) is adopted.

To consider Woodford (2003)-type NKPC, it is difficult to have the output gap $\hat{Y}_t - \hat{Y}_t^n$ in equation (32) and (33) since $\hat{Y}_t^n$ is unobservable as a matter of fact. One of the plausible proxies for the output gap is obtained by applying Hodrick-Prescott filter. To be specific, it is the difference between the log real GDP and the log trend component of real GDP derived by Hodrick-Prescott filter[4] as indicated above. The wage gap $\log w_t - \log w_t^n$ is estimated in the same manner. Concerning this treatment, the modified specifications on a realistic basis are contrived:

$$\pi_t^w = \gamma_w \pi_{t-1}^w + \beta E_t[\pi_{t+1}^w - \gamma_w \pi_t^w] + \kappa_w(logYr - logYc) - \xi_w(logWr - logWc), \tag{34}$$

$$\pi_t = \gamma_p \pi_{t-1} + \beta E_t\left[\pi_{t+1} - \gamma_p \pi_t \right] + \kappa_p(logYr - logYc) + \xi_p (logWr - logWc). \tag{35}$$

One inevitable issue that we confront is the problem of correlation due to the causal relationship of the variables. Expected inflation $E_t\left[\pi_{t+1}\right]$ needs to be replaced by observed (actual) π_{t+1} under the assumption of rational expectation since it is unobservable. Thus, we set $E_t\left[\pi_{t+1}\right] = \pi_{t+1} + u_{t+1}$ (u: expectational error). However, this operation may cause correlation between the error term and the explanatory variable. To cope with this problem, GMM (Generalized Method of Moments) is applied to our estimation.

The reduced-form specifications for our research are:

$$\pi_t^w = \delta_1 \pi_{t-1}^w + \delta_2 \pi_{t+1}^w + \delta_3(logYr - logYc) - \delta_4(logWr - logWc), \tag{36}$$

$$\pi_t = \delta_5 \pi_{t-1} + \delta_6 \pi_{t+1} + \delta_7(logYr - logYc) + \delta_8(logWr - logWc), \tag{37}$$

where $\delta_1 = \frac{\gamma_w}{1+\beta\gamma_w}, \delta_2 = \frac{\beta}{1+\beta\gamma_w}, \delta_3 = \frac{\kappa_w}{1+\beta\gamma_w}, \delta_4 = \frac{\xi_w}{1+\beta\gamma_w}$

$\delta_5 = \frac{\gamma_p}{1+\beta\gamma_p}, \delta_6 = \frac{\beta}{1+\beta\gamma_p}, \delta_7 = \frac{\kappa_p}{1+\beta\gamma_p}, \delta_8 = \frac{\xi_p}{1+\beta\gamma_p}$.

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

The corresponding orthogonality conditions are constructed as:

$$E_t\{(\pi_t^w - [\delta_1\pi_{t-1}^w + \delta_2\pi_{t+1}^w + \delta_3(logYr - logYc) - \delta_4(logWr - logWc)])Z_t\} = 0, \quad (38)$$

$$E_t\{(\pi_t - [\delta_5\pi_{t-1} + \delta_6\pi_{t+1} + \delta_7(logYr - logYc) + \delta_8(logWr - logWc)])Z_t\} = 0 \quad (39)$$

where Z_t denotes the vector of instrumental variables. As equation (36) and (37) indicate, the reduced-form coefficients δ's are the functions of the structural parameters, γ_w (the rate of indexation of wage commitments), γ_p (the rate of indexation of price commitments), β (the subjective discount factor), κ's (the degree of impact on output gap movement), and ξ's (the degree of impact on wage gap movement). The discount factor is exogenously set as $\beta = 0.99$ following Erceg, Henderson, and Levin (2000), Giannoni and Woodford (2003), Steinsson (2003), Walsh (2003), and Christiano, Eichenbaum, and Evans (2005).[5]

Instrumental variables dated *t–1* and earlier are selected to construct Z_t for the following two reasons: (i) The public may not utilize all the current information when they form their expectations. (ii) A certain level of measurement errors of the variables may exist, but the errors may not be correlated with lagged instruments (as the past information). Moreover, a small number of lags for instrumental variables other than inflation rate is chosen to minimize the potential estimation bias following Galí, Gertler, and López-Salido (2001).[6] Specifically, Z_t includes five lags of inflation rate, four lags of output gap, and four lags of wage gap.

The estimation periods are constructed by two categories – the ones before and after the collapse of Japan's bubble economy. It is not easy to precisely define the end of the bubble economy in 1990s. However, the peak of the 11th business cycle determined by the Working Group of Indexes of Business Conditions at the Economic and Social Research Institute, Cabinet Office (Government of Japan) is February 1991. Taking into account this definition, the first quarter of 1991 is regarded as the end of the bubble economy, and the second quarter of 1991 is set as the start date of the period "after the bubble" for the sake of convenience in this study.

As mentioned in the introduction section, the topic of flattening of the NKPC is often focused on recently. One of the reasons of this focus is that the flattening of the NKPC implies

[5] For instance, Christiano, Eichenbaum, and Evans (2005) explains this as $\beta = 1.03^{-0.25}$. This can be interpreted as $\beta = 1.03^{-0.25} \approx 0.99$.

[6] Galí, Gertler, and López-Salido (2001) insisted that this bias arises in a small number of samples when there are too many overidentifying restrictions.

that inflation is less responsive to some aggregate economic activities such as output gap, and it should be related to the implication of monetary policy. Considering this trend of research, our study investigates the flattening of NKPC by taking notice of the estimated slope parameter.

The estimation results for New Keynesian Phillips Curve based on the modified Woodford's specification, incorporating staggered wages and prices setting, are summarized in Tables 1 to 4. Table 1 and 2 are for wage inflation dynamics, while Table 3 and 4 are for (general) price inflation. The null hypotheses of over-identification for reduced and structural forms specifications for all our estimations cannot be rejected by Hansen's tests. (See test statistics in notes under each table.)

The result of estimation of the wage inflation dynamics before the collapse of the bubble economy is indicated in Table 1. As to the reduced form parameters, δ_1 (backward-looking, or past inflation component) is significant. Also, δ_2 (forward-looking, or future inflation component) is significant. The fact that the estimated value of the former coefficient is larger than that of the latter one implies that the backward-looking factor plays a relatively dominant role in explaining wage inflation dynamics in the period we consider. The coefficients on δ_3 (output gap, or the slope parameter) and δ_4 (wage gap) are significant, but their signs do not satisfy the theoretical requirement. This means the marginal cost term formed by the linear combination of output gap and wage gap is not the leading indicator of wage inflation so far as this estimation is concerned.

On the structural parameters, γ_w (the rate of indexation of wage commitments) is significant. Nevertheless, the coefficient estimated on this term slightly exceeds the theoretical upper limit since it is assumed $0 \leq \gamma_w \leq 1$, as described in the previous section. By way of experiment, conducting the test of partial regression coefficient whether or not we can regard $\gamma_w = 1$ (full indexation) postulating the null hypothesis ($H_0 \colon \gamma_w = 1$) with the level of significance ($\alpha = 0.05$), we have $t_{n-k} = \frac{\hat{\gamma}_w - \gamma_w}{S_{\hat{\beta}}} = \frac{1.005750-1}{0.202885} = 0.283411 < 2.2021 = t_{n-k,\frac{\alpha}{2}}$. Thus, the null hypothesis cannot be rejected, and γ_w can be regarded that it does not far exceed 1. The stickiness of wages, or downward nominal wage rigidity in the labor market in Japan might be implied by this result. The estimated κ_w (the degree of impact on output gap movement) and ξ_w (the degree of impact on wage gap movement) do not have the anticipated signs. These unfavorable results are consistent with the ones derived by the two reduced form parameters, namely, δ_3 and δ_4. Therefore, no special information can be given by the estimated κ_w and ξ_w.

Table 2 indicates the estimated parameters with respect to wage inflation for the period after the collapse of the bubble economy. Concerning the reduced form parameters δ_1 and δ_2, the estimated value of the former is larger than that of the latter, while the significance of the latter

Table 1: GMM Estimation of Wage Inflation before the Collapse of the Bubble Economy

reduced form parameter				
Variable	Coefficient	S. E.	t-statistic	p-value
δ_1	0.533914	0.053284	10.02017	0.0000
δ_2	0.419062	0.088368	4.742215	0.0000
δ_3	-0.035838	0.011832	-3.029029	0.0048
$(-)\delta_4$	0.132281	0.047275	2.798093	0.0086
structural parameter				
Variable	Coefficient	S. E.	t-statistic	p-value
γ_w	1.005750	0.202885	4.957242	0.0000
κ_w	-0.062541	0.015658	-3.994267	0.0003
$(-)\xi_w$	0.450707	0.087636	5.142928	0.0000

Notes (reduced form parameter): J-statistic = 7.368824, p-value = 0.598778, Included observations = 36 (after adjustments). Convergence achieved after 499 weight matrices, 500 total coefficient iterations. S.E. refers to Newey-West heteroscedasticity and autocorrelation consistent standard error (Kernel: Bartlett, Bandwidth: Fixed (3)).
Notes (structural parameter): J-statistic = 7.229256, p-value = 0.613264, Included observations = 36 (after adjustments). Convergence achieved after 41 weight matrices, 42 total coefficient iterations. S.E. refers to Newey-West heteroscedasticity and autocorrelation consistent standard error (Kernel: Bartlett, Bandwidth: Fixed (3)).

Table 2: GMM Estimation of Wage Inflation after the Collapse of the Bubble Economy

reduced form parameter				
Variable	Coefficient	S. E.	t-statistic	p-value
δ_1	0.594995	0.175550	3.389325	0.0011
δ_2	0.453735	0.105470	4.302011	0.0001
δ_3	0.154232	0.037619	4.099801	0.0001
$(-)\delta_4$	-0.244245	0.070714	-3.453979	0.0009
structural parameter				
Variable	Coefficient	S. E.	t-statistic	p-value
γ_w	1.138446	0.475711	2.393149	0.0192
κ_w	0.326508	0.085219	3.831413	0.0003
$(-)\xi_w$	-0.482153	0.145310	-3.318091	0.0014

Notes (reduced form parameter): J-statistic = 9.359984, p-value = 0.404730, Included observations = 78 (after adjustments). Convergence achieved after 36 weight matrices, 37 total coefficient iterations. S.E. refers to Newey-West heteroscedasticity and autocorrelation consistent standard error (Kernel: Bartlett, Bandwidth: Fixed (3)).
Notes (structural parameter): J-statistic = 9.451372, p-value = 0.396693, Included observations = 78 (after adjustments). Convergence achieved after 41 weight matrices, 42 total coefficient iterations. S.E. refers to Newey-West heteroscedasticity and autocorrelation consistent standard error (Kernel: Bartlett, Bandwidth: Fixed (3)).

is higher than that of the former. In this context, both forward-looking and backward-looking elements are significant driving forces for wage inflation dynamics. What is more, the coefficients on δ_3 and δ_4 are estimated significantly with right signs showing that they are important factors for wage inflation.

The structural parameters, γ_w is significant. However, the estimated coefficient is larger than 1, like the case in Table 1. The test of estimated coefficient gives $t_{n-k} = 0.2909929 < 1.980$, so the null hypothesis cannot be rejected. It could be due to the stickiness of nominal wages in Japan. The estimated κ_w and ξ_w are significant and have the anticipated signs, as the reduced form parameters δ_3 and δ_4 do.

By comparison of the results of estimations for the periods before and after the collapse of the bubble economy, it is apparent that both reduced form and structural parameters incorporated in our specification for the latter period yield theory-consistent estimates. In other words, our modified Woodford-type NKPC provides a comparatively good approximation to wage inflation dynamics for the deflationary period after the bubble. The fact that the structural parameters ξ_w is highly significant and has the expected sign might imply that the process of determination of wages in Japan is fairly inflexible in the course of prolonged stagnant economy with very low level of inflation since the early 1990s. Concerning the aspect of the flattening of the NKPC, we cannot reach a definite conclusion because of the unanticipated sign of δ_3 for the period before the collapse of the bubble. However, this result might indicate a practically zero or extremely flat slope, since its absolute value is very small. Turning to the period after the bubble, the estimated coefficient on δ_3 is 0.154232, and it indicates the slope is rather flat. One of the plausible sources of flattening is the stickiness of wages or the downward nominal wage rigidity in the labor market in the course of very low level of inflation. In the context of our model, increase in γ_w (rate of indexation of wage commitments) makes the slope parameter $\delta_3 (= \frac{\kappa_w}{1+\beta\gamma_w})$ smaller, and causes flatter NKPC. In fact, the estimated coefficient on γ_w exceeds the assumed upper bound. Akerlof, Dickens, and Perry (1996) provide a supporting discussion on this point based on the downward nominal wage rigidity. The explanation of the flattening of the Phillips curve proposed by them is as follows. During the very low inflation period, workers are reluctant to accept a decline in their nominal wages. This kind of workers' discretion interferes with real wage adjustment in response to excess supply in the labor market, and it causes downward nominal wage rigidity. If prices are set by a fixed markup on wages, prices cannot be reduced to react to a negative output gap. Then the poor relation between prices and output gap leads the Phillips curve to be flatter. The process described by Akerlof, Dickens, and

Perry (1996) could be true of the flattening of our NKPC if we assume that wage inflation is closely related to the price inflation.

The result of estimation of (general) price inflation dynamics before the collapse of the bubble economy is reported in Table 3. With regard to the reduced form estimates, δ_5 (lagged inflation) and δ_6 (future inflation) are both significant, the value of the estimated coefficient of δ_5 is larger than that of δ_6. This suggests the backward-looking element is more important in shaping the dynamics of price inflation than the forward-looking one. The δ_7 (output gap), the slope parameter, is significant, and it yields a very small value. The δ_8 (wage gap) is not significant.

Regarding the structural parameters, the coefficient estimated on γ_p exceeds the upper limit since it is assumed $0 \leq \gamma_p \leq 1$. Implementing the test of regression coefficient whether we can regard $\gamma_p = 1$ (full indexation) postulating the same null hypothesis and the same level of significance as the case of wage inflation, we get $t_{n-k} = 3.5248527 > 2.021$. Thus, the null hypothesis should be rejected, and γ_p can be regarded that it far exceeds 1. It might be a reflection of high nominal price rigidity. The estimated κ_p and ξ_p are not significant, thus, no special information can be given by them.

Table 4 displays the estimated parameters for the period after the collapse of the bubble economy, that is, for the stagnant economy since the early 1990s. Just like the case in Table 3, δ_5 and δ_6 are both significant. In addition, the value of the estimated coefficient for the former is larger than that for the latter. This implies the backward-looking component is relatively dominant for the dynamics of price inflation over the forward-looking one. The δ_7 and the δ_8 are not significant. The prolonged stagnant economy may lead to a poor relation between economic activity and the price level since the early 1990s.

As for the structural parameters, the coefficient estimated on γ_p is apparently outside the assumed interval, implying nominal price stickiness. Incidentally, the test of coefficient for $\gamma_p = 1$ gives $t_{n-k} = 2.124227 > 1.980$. Therefore, we regard γ_p is apparently over 1. The κ_p and ξ_p do not yield significant estimates, and their insignificance is consistent with that of the reduced form parameters δ_7 and δ_8.

Comparing the results for the estimations of the price inflation dynamics for the periods before and after the bubble collapse, it can be concluded that our modified NKPC does not always provide informative approximations since some parameters are estimated with very low significance or unanticipated signs. The unfavourable estimation results with regard to the reduced form parameters δ_7 and δ_8 seem to be linked to the undesirable parameters of κ_p and ξ_p. Prolonged deflation may be related to these results for the period after the bubble collapse. With

Table 3: GMM Estimation of Price Inflation before the Collapse of the Bubble Economy

reduced form parameter				
Variable	Coefficient	S. E.	t-statistic	p-value
δ_5	0.586926	0.021558	27.22588	0.0000
δ_6	0.400190	0.031293	12.78829	0.0000
δ_7	0.013645	0.006496	2.100462	0.0437
δ_8	0.020390	0.012116	1.682942	0.1021
structural parameter				
Variable	Coefficient	S. E.	t-statistic	p-value
γ_p	1.389038	0.110370	12.58525	0.0000
κ_p	0.022225	0.014336	1.550327	0.1306
ξ_p	0.031326	0.023349	1.341641	0.1889

Notes (reduced form parameter): J-statistic = 7.211191, p-value = 0.615142, Included observations = 36 (after adjustments). Convergence achieved after 41 weight matrices, 42 total coefficient iterations. S.E. refers to Newey-West heteroscedasticity and autocorrelation consistent standard error (Kernel: Bartlett, Bandwidth: Fixed (3)).

Notes (structural parameter): J-statistic = 7.439569, p-value = 0.591453, Included observations = 36 (after adjustments). Convergence achieved after 123 weight matrices, 124 total coefficient iterations. S.E. refers to Newey-West heteroscedasticity and autocorrelation consistent standard error (Kernel: Bartlett, Bandwidth: Fixed (3)).

Table 4: GMM Estimation of Price Inflation after the Collapse of the Bubble Economy

reduced form parameter				
Variable	Coefficient	S. E.	t-statistic	p-value
δ_5	0.511756	0.064711	7.908370	0.0000
δ_6	0.496604	0.082207	6.040930	0.0000
δ_7	0.000309	0.014253	0.021692	0.9828
δ_8	-0.004291	0.024804	-0.172989	0.8631
structural parameter				
Variable	Coefficient	S. E.	t-statistic	p-value
γ_p	2.269606	0.597679	3.797368	0.0003
κ_p	-0.004186	0.032431	-0.129077	0.8976
ξ_p	0.031909	0.060168	0.530332	0.5974

Notes (reduced form parameter): J-statistic = 10.81654, p-value = 0.288494, Included observations = 78 (after adjustments). Convergence achieved after 12 weight matrices, 13 total coefficient iterations. S.E. refers to Newey-West heteroscedasticity and autocorrelation consistent standard error (Kernel: Bartlett, Bandwidth: Fixed (3)).

Notes (structural parameter): J-statistic = 11.85518, p-value = 0.221593, Included observations = 78 (after adjustments). Convergence achieved after 499 weight matrices, 500 total coefficient iterations. S.E. refers to Newey-West heteroscedasticity and autocorrelation consistent standard error (Kernel: Bartlett, Bandwidth: Fixed (3)).

regard to the flattening problem, we cannot make a clear-cut examination owing to the non-significant slope parameter indicated in Table 4. Nevertheless, the price inflation version of the NKPC might come to be flatter since the estimated δ_7 after the bubble is much smaller (and insignificant) than the one before the bubble, that practically can be regarded as zero-slope. It is often pointed out that inflation has come to be less responsive to demand pressures in major industrialized countries, so the result of our estimation is consistent with this suggestion. From another aspect, it is probable that the nominal price rigidity or stickiness implied by the estimated considerably large γ_p is closely related to this problem. The reasoning suggested by Akerlof, Dickens, and Perry (1996) mentioned above could also be true of the flattening problem for the price inflation version of our modified New Keynesian Phillips Curve.

4. CONCLUDING REMARKS

In this paper, we conducted empirical research on Japanese inflation dynamics through the GMM estimations by applying the modified Woodford (2003)-type NKPC, which incorporates staggered price and wage setting. In addition, flattening of the NKPC was examined in order to consider the implications for monetary policy.

The results of the estimation of the wage inflation dynamics before the collapse of the bubble economy implied that the backward-looking component plays a relatively dominant role in explaining wage inflation dynamics. The structural parameter γ_w (the rate of indexation of wage commitments) was virtually estimated as 1 (full indexation). The stickiness of wages or the downward nominal wage rigidity in the labor market might be implied by this result. Turning to the period after the collapse of the bubble, it was shown that both forward-looking and backward-looking elements are significant driving forces for wage inflation dynamics. What is more, the output gap and wage gap were significantly estimated with correct signs. The γ_w might imply stickiness of nominal wages. By comparison of the results of estimations for the periods before and after the collapse of bubble economy, we know that our modified Woodford-type NKPC provided a comparatively good approximation to wage inflation dynamics for the deflationary period after the bubble crash. From the aspect of the flattening of the NKPC, the result of the estimation indicated that the slope of the NKPC is rather flat, and the downward nominal wage rigidity could be related to this matter.

On the other hand, the parameters estimated to investigate price inflation dynamics before the crash of the bubble suggested that the backward-looking component is relatively dominant in shaping the dynamics of inflation rather than the forward-looking one. The slope parameter yielded a very small value. The coefficient estimated on γ_p (the rate of indexation of price commitments) might be a reflection of high nominal price rigidity. With regard to the period after the bubble crash, the estimated parameters implied the backward-looking component is relatively dominant for the dynamics of price inflation rather than the forward-looking one. As to the structural parameters, the coefficient estimated on γ_p implied nominal price stickiness. The other structural parameters were not significant. Comparing the results for the estimations of the price inflation dynamics for the periods before and after the bubble collapse, it can be concluded that our modified NKPC did not always provide informative approximations since some parameters are estimated with very low significance or unanticipated signs. With regard to the flattening problem, the price inflation version of the NKPC might come to be flatter recently according to the estimation result, and it is probable that the nominal price rigidity or stickiness is related in this matter.

Overall, the result of estimation leads our empirical study to conclude that the backward-looking component is inclined to have a stronger impact on inflation dynamics compared with the forward-looking one in Japan, so far as our modified Woodford-type New Keynesian Phillips Curve is concerned. However, since the forward-looking elements are also significantly estimated, the determination process of monetary policy should embody both backward-looking and forward-looking views. From the aspect of the applicability of the estimation model, our specification for wage inflation dynamics provided a good approximation for the deflationary period after the bubble collapse, while the one for (general) price inflation did not always give favourable results. The fact that the estimated structural parameters for the rate of indexation of price commitments are larger than those of wage commitments implied that rigidity or stickiness of (general) prices is higher than that of wages. Further, the result of estimation indicated that the slope of the NKPC might come to be flatter, and the downward nominal wage rigidity could be related to this matter. It implies that inflation is becoming less responsive to aggregate economic activities, and thus the conduct of monetary policy by the central bank faces certain difficulties in present-day Japan.

REFERENCES

Akerlof, G. A., Dickens, W. T., and G. L. Perry. 1996. "The Macroeconomics of Low Inflation," in Perry, G. L., and W. C. Brainard, eds., *Brookings Papers on Economic Activity*, 1996(1): 1-76.

Calvo, G. 1983. "Staggered Prices in a Utility Maximizing Framework," *Journal of Monetary Economics*, 12(3): 383-398.

Christiano, L., Eichenbaum, M., and C. Evans. 2001. "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy," *NBER Working Paper Series*, 8403.

Christiano, L., Eichenbaum, M., and C. Evans. 2005. "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy," *Journal of Political Economy*, 113(1): 1-45.

Clarida, R., Galí, J., and M. Gertler. 1999. "The Science of Monetary Policy: A New Keynesian Perspective," *Journal of Economic Literature*, 37(4): 1661-1707.

Erceg, C., Henderson, D., and A. Levin. 2000. "Optimal Monetary Policy with Staggered Wage and Price Contracts," *Journal of Monetary Economics*, 46(2): 281-313.

Galí, J., and M. Gertler. 1999. "Inflation Dynamics: A Structural Econometric Analysis," *Journal of Monetary Economics*, 44(2): 195-222.

Galí, J. 2008. *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework*, Princeton: Princeton University Press.

Galí, J., Gertler, M., and D. López-Salido. 2001. "European Inflation Dynamics," *European Economic Review*, 45(7): 1237-1270.

Galí, J., Gertler, M., and D. López-Salido. 2005. "Robustness of the Estimates of the Hybrid New Keynesian Phillips Curve," *Journal of Monetary Economics*, 52(6): 1107-1118.

Galí, J., Gertler, M., and D. López-Salido. 2007. "Markups, Gaps and the Welfare Costs of Business Fluctuations," *Review of Economics and Statistics*, 89(1): 44-59.

Giannoni, M. P., and M. Woodford. 2003. "Optimal Inflation-Targeting Rules," *NBER Working Paper Series*, 9939.

Giannoni, M. P., and M. Woodford. 2005. "Optimal Inflation-Targeting Rules," in Bernanke, B. S., and M. Woodford, (eds.), *The Inflation-Targeting Debate*, National Bureau of Economic Research: 93-172.

Goodfriend, M., and R. G. King. 1997. "The New Neoclassical Synthesis and the Role of Monetary Policy," in Bernanke, B. S., and J. J. Rotemberg, (eds.), *NBER Macroeconomics Annual 1997*, 12, Cambridge, MA: MIT Press: 231-283.

Hodrick, R. J., and E. C. Prescott. 1997. "Postwar U.S. Business Cycles: An Empirical Investigation," *Journal of Money, Credit, and Banking*, 29(1): 1-16.

I**akova, D.** 2007. "Flattening of the Phillips Curve: Implications for Monetary Policy," *IMF Woking Paper*, 07-76.

Kuester, K., Müller, G. J., and S. Stölting. 2009. "Is the New Keynesian Phillips Curve Flat?" *Economics Letters*, 103(1): 39-41.

Lindé, J. 2005. "Estimating New-Keynesian Phillips Curves: A Full Information Maximum Likelihood Approach," *Journal of Monetary Economics*, 52(6): 1135-1149.

Mazumder, S. 2010. "The New Keynesian Phillips Curve and the Cyclicality of Marginal Cost," *Journal of Macroeconomics*, 32(3): 747-765.

Nelson, E. 1998. "Sluggish Inflation and Optimizing Models of the Business Cycle," *Journal of Monetary Economics*, 42: 303-322.

Newey, W., and K. West. 1987. "A Simple, Positive Semidefinite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix," *Econometrica*, 55(3): 703-708.

Rotemberg, J. 1982a. "Sticky Prices in the United States," *Journal of Political Economy*, 90(6): 1187-1211.

Rotemberg, J. 1982b. "Monopolistic Price Adjustment and Aggregate Output," *Review of Economic Studies*, 49(4): 517-531.

Rotemberg, J., and M. Woodford. 1997. "An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy," in Bernanke, B. S., and J. J. Rotemberg, (eds.), *NBER Macroeconomic Annual 1997*, 12: 297-346.

Rotemberg, J., and M. Woodford. 1999. "The Cyclical Behavior of Prices and Costs," in Taylor, J., and M. Woodford, (eds.), *Handbook of Macroeconomics*, North-Holland: Elsevier, 1(1), chapter 16: 1051-1135.

Rudd, J., and K. Whelan. 2005a. "Does Labor's Share Drive Inflation?" *Journal of Money, Credit, and Banking*, 37(2): 297-312.

Rudd, J., and K. Whelan. 2005b. "New Tests of the New-Keynesian Phillips Curve," *Journal of Monetary Economics*, 52(6): 1167-1181.

Rudd, J., and K. Whelan. 2006. "Can Rational Expectations Sticky-Price Models Explain Inflation Dynamics?" *American Economic Review*, 96(1): 303-320.

Rudd, J., and K. Whelan. 2007. "Modeling Inflation Dynamics: A Critical Review of Recent Research," *Journal of Money, Credit, and Banking*, 39(s1): 155-170.

Sbordone, A. 2002. "Prices and Unit Labor Costs: A New Test of Price Stickiness," *Journal of Monetary Economics*, 49(2): 265-292.

Sbordone, A. 2005. "Do Expected Future Marginal Costs Drive Inflation Dynamics?" *Journal of Monetary Economics*, 52(6): 1183-1197.

Smets, F., and R. Wouters. 2003. "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area," *Journal of the European Economics Association*, 1(5): 1123-1175.

Steinsson, J. 2003. "Optimal Monetary Policy in an Economy with Inflation Persistence," *Journal of Monetary Economics*, 50(7): 1425-1456.

Taylor, J. 1979. "Staggered Wage Setting in a Macro Model," *American Economic Review*, 69(2): 108-113.

Taylor, J. 1980. "Aggregate Dynamics and Staggered Contracts," *Journal of Political Economy*, 88(1): 1-23.

Walsh, C. E. 2010. *Monetary Theory and Policy*, 3rd ed., Cambridge: MIT Press.

Woodford, M. 2001. "The Taylor Rule and Optimal Monetary Policy," *American Economic Review*, 91(2): 232-237.

Woodford, M. 2003. *Interest and Prices*, Princeton: Princeton University Press.

Zhang, C., and J. Clovis. 2010. "The New Keynesian Phillips Curve of Rational Expectations: A Serial Correlation Extension," *Journal of Applied Economics*, 37(2): 159-179.