Inflation Dynamics in Japan: The Calvo Model and Wage Rigidity

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February 14, 2005
ROUGH DRAFT

Abstract

This paper provides further evidence on the fit of the new Keynesian Phillips curve for Japan over the years 1972-2003. It is motivated by the sense that Japan's degree of price rigidity found in Sanchez (2005) is implausibly severe and may be unduly affected by assumption that real marginal cost is constant. This paper shows that relaxing this assumption implies real marginal cost explains 20 to 30 percent of the variation in Japan's inflation under a more generalized production function for the firm. In addition, the degree of rigidity is much less under this assumption and implies Japan firms adjust prices every 2 to 3 quarters refuting claims that the new Keynesian Phillips curve overestimates price rigidity. Tests for parameter and thus, model stability give evidence of structural breaks in the estimated coefficients. The break point dates under different specifications coincide with either Japan's land and asset price bubble or deflationary period. A simple decomposition of labor market rigidities implies a substantial degree of wage rigidity influences the dynamic behavior of real marginal cost and when incorporated into the new Keynesian framework may further improve the model's empirical performance. Robustness tests that nest forward and backward looking behavior imply that forward looking behavior dominates, a key aspect of the new Keynesian framework.

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1 Introduction

This paper provides further evidence of the fit of the new Keynesian Phillips curve for Japan over the period 1972-2003. It is motivated by the sense that Japan's degree of price rigidity found in Sanchez (2005) is implausibly severe and may be unduly affected by assumption that real marginal cost is constant. It also tests whether the estimated parameters are time invariant, using structural break techniques developed in Rossi (2004) and Andrews (1993). Second, this paper considers the impact of labor market frictions on the dynamic evolution of real marginal cost, which includes estimating the cost to the household of supplying additional labor. This parameter relates the marginal rate of substitution between consumption and labor to real wages and is analogous to the price markup over marginal cost used by the monopolistically competitive firm. Galí, Gertler and López Salido (2001) and Fuhrer and Moore (1995) point out that labor market frictions provide a additional source of inflation inertia not captured by the general new Keynesian Phillips curve, which has borne out in their studies. Excluding the tests for structural breaks, which are thought unique to Sanchez (2005) and this work, my approach uses methodology found in Galí, *et al* (2001). They show that a simple alteration in the firm's production function, which determines the measure of real marginal cost, yields a more credible degree of rigidity for the U.S. and the Euro area.

This paper shows that a similar improvement occurs for Japan. Allowing for variable marginal cost in the new Keynesian Phillips curve implies that real marginal cost explains 20 to 30 percent of the variation in inflation, a substantial improvement in empirical performance. In addition, the degree of rigidity is much less under this assumption and implies Japan firms adjust prices every 2 to 3 quarters refuting claims that the new Keynesian Phillips curve overestimates price rigidity. Tests for parameter, and thus, model stability give evidence of structural breaks in the estimated coefficients. The break point dates under different specifications coincide with either Japan's land and asset price bubble or deflationary period. A simple decomposition of labor market rigidities implies a substantial degree of wage rigidity influences the dynamic behavior of real marginal cost and when incorporated into the new Keynesian framework may further improve the model's empirical performance. Robustness tests that nest forward and backward looking behavior imply that forward looking behavior dominates, a key aspect of the new Keynesian framework.

This paper consists of four sections. Section 1 is the Introduction while Section 2 briefly discusses the model's framework. Section 3 presents the estimation strategy and results and Section 5 offers a few concluding remarks.

2 Theory Framework and Estimation Strategy

This section describes aspects of the new Keynesian Phillips curve that are most relevant to the empirical task at hand. Original derivations of the new Neoclassical Synthesis/new Keynesian framework include Yun (1996), Goodfriend and King (1997), Rotemberg and Woodford (1998) and Clarida, Galí and Gertler (1999), with Walsh (2004) and Woodford (2004) each providing a comprehensive and current treatment.

The new Keynesian Phillips curve is a model of price adjustment which relates the path of inflation, π_t to expectations of future inflation and real marginal cost, $\widehat{\psi}_t$. It stems from dynamic optimal decision making by households and firms. As shown by Walsh (2004), a log linear approximation around zero average inflation and steady state equilibrium yields:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa \widehat{\psi}_t \tag{1}$$

where κ is the persistence in inflation attributable to a real marginal cost such that:

$$\kappa = \frac{(1-\alpha)(1-\alpha\beta)}{\alpha} \tag{2}$$

The parameter α is the degree of nominal rigidity and is the probability that a firm does not change its price. It stems from Calvo's (1983) sticky prices. The parameter β is the subjective discount rate and $\hat{}$ denotes the deviation of real marginal cost from its steady state equilibrium.

The new Keynesian Phillips curve is similar in spirit to the Phillips curve often used to model aggregate supply in small macro monetary models:

$$\pi_t = \sum_{k=1}^{4} \gamma_k \pi_{t-k} + \delta \hat{y}_t \tag{3}$$

where $\hat{y}_t$ is a real output gap. The Phillips curve in equation (3) is sometimes called "expectations augmented" and includes lags and other explanatory variables to incorporate information affecting expectations. It is assumed that $\sum_{k=1}^{4} \gamma_k = 1$ to ensure that the impact of past inflation is nominal. Rudebusch and Svensson (1999) find that equation (3) fits U.S. data fairly well during the post war period, 1960-1999. That is, $\delta^{US} = 0.14$ and is statistically significant while $\sum_{k=1}^{4} \gamma_k$ is not statistically different from one.

Using detrended real GDP for the output gap, $\hat{y}$, the corresponding Phillips curves for Japan, over the period 1972:Q3-2003:Q3 is:

$$\pi_t = 0.60\pi_{t-1} + 0.25\pi_{t-2} + 0.07\pi_{t-3} - 0.04\pi_{t-4} + 0.02\hat{y}_t \quad R^2 = 0.72 \tag{4}$$

In terms of capturing inflation inertia through δ, the results for Japan are not as promising as that for the U.S. The magnitude on δ changes by less than 0.001 when Japan's deflationary episode is excluded.

Higo and Nakada (1999) provide evidence that the output gap leads inflation with a correlation coefficient of 0.6 and 0.8 for the periods 1978-86 and 1987-97, respectively.[1] They

[1] The output gap measure used in Higo and Nakada (1999) is the difference between GDP and potential GDP. Potential output is computed following Watanabe (1997) and is based on estimated production functions.

estimate equation (3) and find $\delta^{Jp} = 0.07$ for the years 1978-86 and $\delta^{Jp} = 0.24$ for the years 1987-96. These results provide two useful insights. First, the strong evidence that detrended output leads inflation suggests why output gap measures of real marginal cost are inappropriate for estimates of the new Keynesian Phillips curve, which predicts the opposite—inflation leads real marginal cost. Second, they suggest a magnitude for κ that would be consistent with the degree of inflation inertia observed in the data. Nonetheless, there are deeper issues with the Phillips curve specification. First, there is no consensus on the interpretation of the coefficients on lagged inflation, γ_{t-k} (Rudd and Whelan [2001]). The conventional view is that firms form their expectations of current inflation in a backward looking manner, which causes them to incorporate past inflation rates into current wage and price contracts. In this sense, lagged inflation is a proxy for $E_{t-1}\pi_t$. An alternate interpretation comes from rational expectations, which implies that current inflation is forward looking where lagged inflation is used to proxy for expectations of next period's inflation rate. Regardless of the interpretation however, equation (3) is most often criticized for failing to satisfy the Lucas critique. That is, equation (3) is likely to vary across policy regimes and the parameters on lagged inflation may contain information that overlaps across the regressors. Another criticism of the inflation model specified in equation (3) is that in periods of low or falling inflation, it over-predicts inflation because of its dependence on observations of lagged inflation.

One the other hand, the new Keynesian Phillips curve in Equation (1) arises from the dynamic decision making problems of households and firms, incorporates nominal rigidity and rational expectations and thus, satisfies the Lucas critique. The degree of nominal rigidity, α, is determined using Calvo's (1983) price mechanism scheme which represents the probability that a firm is unable to adjust its price due to costs associated with information gathering, decision making, negotiation and communication, for example. Eichenbaum and Fisher (2004) argue that these costs are different from menu costs which affect all prices. In addition, by being forward looking and employing rational expectations, the new Keynesian Phillips curve overcomes the critique that Phillips curves over-predict inflation in prolonged disinflationary or deflationary periods.

Galí and Gertler (1999) and Sbordone (2002) are early works that provide estimates of the new Keynesian Phillips curve for the U.S. They show that real marginal cost may be approximated by the unit labor cost and when technology is specified with constant returns to scale, it implies that real marginal cost is constant. Sanchez (2005) provides estimates for Japan over the period 1972:Q3 to 2003:Q3 that are consistent with the U.S. but only when the measure is year on year growth in inflation rather than quarterly growth, the theory implied measure. For U.S. studies, critics of the new Keynesian model argue that κ, the parameter on real marginal cost is too small when the measure is the unit labor cost. Motivated by the pursuit of more plausible estimates of price rigidity, Galí *et al* (2001) allow marginal cost to vary across firms and estimate the resulting new Keynesian Phillips curves for the U.S. and the Euro area.

2.1 The new Keynesian Phillips Curve with variable marginal cost

Galí *et al* (2001) generate variable marginal cost in the new Keynesian Phillips curve by assuming the average firm has decreasing returns to scale. This means doubling inputs will less than double output and is an assumption sometimes used to describe production in large scale firms where the ratio of management to workers is small or capital use is very large, e.g., manufacturing sectors. These conditions are thought to introduce inefficiencies due to coordination problems or inefficient management of capital that can cause output increases to lag input ones.

Under decreasing returns to scale, the production function becomes $Y_{jt} = A_t N_{jt}^{1-a}$. Firm j's output in time t is Y_{jt}, N_{jt} is the firm's demand for labor and A_t is technology where it is assumed that $E(A_t) = 1$. The parameter $a \in (0, 1)$ affects labor's input share of output, $(1-a)$, and the curvature of the production function. In addition, we assume each firm faces the same isoelastic demand curve with elasticity parameter, e. Price rigidity enters the framework using Calvo's (1983) mechanism. To each firm, he assigns the exogenous probability, α, the probability that a firm is unable to change its price in period t. As α increases so does the amount of time prices remain unchanged. Although the pricing history of each firm is different, if a firm is able to set its price in t, it will choose the same price as other firms doing the same. It can be shown that in time t, the optimal price, p_t^* is:

$$p_t^* = \mu + (1 - \alpha\beta) \sum_{k=0}^{\infty} E_t(\psi_{t,t+k}^n) \tag{5}$$

where $\mu \equiv \ln \frac{e}{e-1}$ is the firm's desired gross markup. Equation (5) implies that the firm sets its price as a markup over its discounted stream of expected future nominal marginal cost, adjusted by the degree of rigidity, α. In real terms, a measure of real marginal cost arises from firm j's decision to minimize the cost of its demand for labor:

$$L = \min_{N_{jt}} \left(\frac{W_{jt}}{P_t} \right) N_{jt} + \psi_t (Y_{jt} - A_t N_{jt}^{1-a}) \tag{6}$$

where $\frac{W_{jt}}{P_{jt}}$ is firm j's optimal the real wage expressed in terms of nominal wages, W, and the price level, P. For each firm, j, the first order conditions imply real marginal cost, ψ_{jt} is the unit labor cost:

$$\psi_{jt} = \frac{W_{jt} N_{jt}}{(1-a) P_{jt} Y_{jt}} \tag{7}$$

shown in equation (7), which varies with the value of a. Since no firm level data is available, I use aggregate data to form real marginal cost: $\psi_t = \frac{W_t N_t}{(1-a) P_t Y_t}$, based on wages, W, employment N, and GDP, PY.

The impact of variable marginal cost can be shown by expressing real marginal cost for a firm in period $t + k$ that was last able to set its price in t, which Galí *et al* (2001)derive:

$$\widehat{\psi}_{t,t+k} = \widehat{\psi}_{t+k} - \frac{ea}{1-a}(p^* - p_{t+k}) \tag{8}$$

Equation (8) shows that when p_t^*, the optimal price in t is high relative to p_{t+k}, the optimal price in $t+k$, the firm will have a lower marginal cost than other firms. This follows directly from the assumption that firms face decreasing marginal cost. Otherwise, under constant returns to scale, i.e., $a = 0$, firms face the same marginal cost regardless whether it is able to reset prices.

For the new Keynesian Phillips curve, allowing for variable marginal cost in this manner alters equation (1) by introducing a new term, ζ:

$$\pi_t = \beta E_t(\pi_{t+1}) + \kappa\zeta\widehat{\psi}_t \tag{9}$$

where $\kappa = \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}$ and $\zeta = \frac{(1-a)}{[1+a(e-1)]}$. In this case, the slope parameter depends on both the structural parameters, α and β as well as a and e. The decomposition of the slope parameters is somewhat arbitrary and is done to show directly the impact of allowing for variable marginal cost. It also separate the estimated structural parameters, α and β from the calibrated ones, a and e, which is part of the empirical strategy used in the estimation exercise.

2.2 A Hybrid New Keynesian Phillips Curve

Galí and Gertler (1999) test the hypothesis that firms are forward looking by nesting a backward looking inflation model in the new Keynesian Phillips curve which is done in spirit of Hall's (1978) test of the permanent income hypothesis. Simply, the hybrid new Keynesian Phillips curve adds a new regressor on the right hand side, lagged inflation, π_{t-1}. As a test of the new Keynesian Phillips curve, we hypothesize that if inflation is truly forward looking then η_b, the parameter on lagged inflation should be statistically insignificant or very small relative to that on next period's inflation, η_f. In their extension of this model, Galí *et al* (2001) incorporate variable marginal cost to the hybrid new Keynesian Phillips curve derived in Galí and Gertler (1999). For the hybrid model, it as assumed that some share, ω, of the firms able to change prices in time t choose a price based on a backwards looking rule of thumb. That is, they choose last period's price adjusted for average inflation, $\overline{\pi}p_{t-1}$. Under these conditions, Galí *et al* (2001) show the hybrid new Keynesian Phillips curve with variable marginal cost:

$$\pi_t = \tilde{\kappa}\zeta\widehat{\psi}_t + \eta_f\pi_{t+1} + \eta_b\pi_{t-1} \qquad (10)$$

where $\tilde{\kappa} = \frac{(1-\omega)(1-\alpha)(1-\alpha\beta)}{\phi}$, $\eta_f \equiv \alpha\beta\phi^{-1}$, $\eta_b \equiv \omega\phi^{-1}$ and $\phi = \alpha + \omega[1 - \alpha(1-\beta)]$.

3 Results

This section presents estimates for Japan's inflation over the period 1972:Q2-2003:Q3 using the new Keynesian Phillips curve. Hansen (1982) and Hansen and Singleton (1982) prove that the Generalized Method of Moments is the most consistent estimator for dynamic marcro models with rational expectations arising from Euler equations. These are the conditions underlying the structural and hybrid models shown in equations (9) and (10). The empirical strategy is to estimate the model using instruments to account for measurement error known to exist in aggregated data. The instruments also act as restrictions on the model that can then be tested using a J-statistic. In addition, to focus attention on the structural parameters, α and β, these are estimated using calibrated values for the marginal product and price elasticity parameters, a and e. The use of calibrated values is the same technique followed in Galí *et al* (2001).

The data used to generate the results reported in this paper are found in various issues of the Monthly Statistical Bulletin of Japan and at the Bank of Japan website. The model is evaluated using two measures of inflation, the GDP deflator and CPI, both computed as the quarterly log difference.[2] Next period's expected inflation, $E_t(\pi_{t+1})$, is measured, consistent with rational expectations, using the observed value.

Average real marginal cost, $\widehat{\psi}_t$, is measured by the log deviation in unit labor cost from

[2]A later draft will utilize the CPI excluding food, but data availability limits sample estimation to 1981-2003.

its steady state value, the sample average. The unit labor cost for Japan stems from equation (**??**) in which wages, W are average monthly cash earnings, and employment, N, per hour, h, expressed as a share of Japan's GDP P_tY_t: $ulc = \frac{W_tN_t}{(1-a)P_tY_th_t}$. This is the measure used in Gordon's (1982) influential work on wages in Japan, the U.S. and the U.K. and adjusts unit labor costs for changes in hours. This adjustment is particularly helpful for Japan, which implemented a shortened work week during the sample period.

Galí *et al* (2001) obtain measures for a and e from the average mark up, $\bar{\mu}$, and average labor income share, $\overline{S} \equiv \frac{W_tN_t}{P_tY_t}$. It can be shown that the average mark up is the inverse of real marginal cost, $\overline{\mu} = (\overline{\psi})^{-1}$. Under decreasing returns to scale then,

$$a \equiv 1 - \frac{\bar{S}}{\bar{\mu}} \tag{11}$$

Using an annual frequency, Hayashi and Prescott (2003) compute Japan's wage share over the period 1970-2000, which includes costs in excess of wages that are borne by the firm in hiring. Based on their estimates, then the average wage is, $\bar{S} = 0.648$. In addition, Martins, Scarpetta, Pilat (1996) estimate the mark up in the manufacturing sectors of OECD nations over the period, 1970-1992. This is used to compute $\bar{\mu}$, the average markup as the sample average across manufacturing sectors for the period: $\bar{\mu} = 1.2$, which implies $a = 0.46$ for Japan.[3] Similarly, κ, depends on the elasticity of demand, e, which is related to the markup: $e = \frac{\bar{\mu}}{\bar{\mu}-1}$. Together these imply $e = 6$ and $\zeta = 0.15$.

The vector of instruments, $\mathbf{z}_t$ consists of 4 lags each of inflation, real marginal cost, wage growth, the real GDP output gap, CPI inflation, and the spread between a short term and long term nominal interest rate. This is the same set used by Galí and Gertler (1999) and Galí *et al* (2001).

[3] Galí *et al* (2001) use $\bar{S}^{Euro} = 0.6667$ and $\bar{S}^{US} = 0.75$ for the Euro region and United States and $\bar{\mu} = 1.1$ for both areas.

3.1 Baseline Estimates: The Reduced Form

Equation (1) may be estimated as a linear equation in κ. Galí and Gertler (1999) call this the reduced model to distinguish it from the specification which depends on the structural parameters, α and β. Theory suggests that these specifications are analytically identical and should yield equivalent estimates. Thus, comparing the results for the reduced form to the others provides an informal test of the GMM estimator, which is known to be sensitive in small samples. For Japan, 1972:Q3-2003:Q3, the new Keynesian Phillips curve in reduced form in quarterly growth in the GDP deflator:

$$\begin{array}{rcccc} \pi_t = & 0.98\pi_{t+1} & + & 0.05\widehat{\psi}_t & J = 12.22 \\ & (0.019) & & (0.018) & [0.97] \end{array} \tag{12}$$

and when inflation is quarterly growth in the CPI:

$$\begin{array}{rcccc} \pi_t = & 0.98\pi_{t+1} & + & 0.06\widehat{\psi}_t & J = 14.96 \\ & (0.020) & & (0.017) & [0.90] \end{array} \tag{13}$$

The standard errors are placed in parentheses below the coefficients. For either inflation measure, the J statistic, which tests whether that the overidentifying restrictions are valid, is not rejected based on the p-value shown in brackets. The subjective discount rate, β, is effectively one and significant and the parameter on real marginal cost, $\widehat{\psi}_t$, is positive and significant. Under variable marginal cost, κ is larger than that shown in Sanchez (2005) with constant marginal cost, where $\kappa^{CRTS} = 0.04$. However, under either inflation measures, κ^{JP}, Japan's marginal cost parameter, is substantially smaller than those for the Euro Area and U.S. estimated by Galí *et al* (2001), where $\kappa^{EA} = 0.09$ and $\kappa^{US} = 0.25$, respectively. With respect to the Phillips curve estimates shown in equations (4) using detrended output, Japan's new Keynesian Phillips curve estimates suggest a higher degree of inertia but it is less than that found in Higo and Nakada (1999), who find parameter values between 0.07 and 0.24 across subsamples between 1978 and 1996.

3.2 Structural Estimates of the new Keynesian Phillips curve

The structural parameters, α and β, the degree of rigidity and subjective discount rate, are jointly estimated using two analytically equivalent normalizations of the new Keynesian Phillips curve implied by substituting equation (2) into equation (9). The first normalization is:

$$E_t\{(\alpha\pi_t - (1-\alpha)(1-\beta\alpha)\zeta\hat{\psi}_t - \alpha\beta\pi_{t+1})\mathbf{z}_{it}\} = 0 \tag{14}$$

The second is:

$$E_t\{(\pi_t - \frac{(1-\alpha)(1-\beta\alpha)}{\alpha}\zeta\hat{\psi}_t - \beta\pi_{t+1})\mathbf{z}_{it}\} = 0 \tag{15}$$

Galí and Gertler (1999) recommend this step to address the case that the GMM is sensitive in small samples. Equation (14) multiplies the orthogonality condition across by α.

In Table 1, rows (1) and (2) present estimates of equations (14) and (15), respectively. It also includes estimates for constant marginal cost ($a = 0,\ \zeta = 1$), for comparison. While there is some variation across the normalizations, equations (14) and (15), the results suggest the new Keynesian Phillips curve with variable marginal cost is a good approximation for Japan's inflation. First, the J-test statistics, (J_T), show the overidentifying restrictions are not rejected. Under both inflation measures, the subjective discount rate, β is effectively one with either variable or constant marginal cost. The degree of rigidity, α is of similar magnitude when either the GDP deflator or CPI is used to measure inflation. However, the magnitude for α varies across the normalization of the Euler equation. In general, equation (15), the specification resulting directly from the optimization problem, yields a higher degree of rigidity in both inflation measures and across both types of marginal cost, variable or constant. For variable

Table 1: New Keynesian Phillips Curve for Japan, 1972-2003

		α	β	κ	$\frac{1}{1-\alpha}$	J_T
$\mu = 1.2, \quad a = 0.46$ (Variable Marginal Cost)						
	GDP Deflator					
(1)		0.63^{**}	0.98^{**}	0.22	3	9.8
		(0.02)	(0.02)			[0.99]
(2)		0.82^{**}	0.97^{**}	0.05	6	15.2
		(0.04)	(0.02)			[0.89]
	CPI					
(1)		0.58^{**}	0.97^{**}	0.32	2.4	9.22
		(0.02)	(0.03)			[0.995]
(2)		0.80^{**}	0.98^{**}	0.05	5	15.0
		(0.03)	(0.02)			[0.89]
$a = 0, \ \zeta = 1$ (Constant Marginal Cost)						
	GDP Deflator					
(1)		0.86^{**}	0.98^{**}	0.03	7	12.3
		(0.01)	(0.01)			[0.97]
(2)		0.89^{**}	1.03^{**}	0.01	8	5.52
		(0.02)	(0.03)			[0.90]
	CPI					
(1)		0.85^{**}	1.00^{**}	0.03	7	8.80
		(0.01)	(0.02)			[0.9967]
(2)		0.92^{**}	0.98^{**}	0.008	13	12.80
		(0.01)	(0.02)			[0.96]

Table Notes: Parameters a and μ, the parameter on labor's marginal product and the firm's mark up are calibrated. Sample Period: 1972-2003 using quarterly data. Rows (1) and (2) correspond to equations (14) and (15), respectively. κ is computed based on the degree of nominal rigidity α, and the subjective discount rate, β. The instrument set includes four lags of inflation, wage growth, CPI inflation, the real output gap and the spread between a short and long term government bond. The ratio, $\frac{1}{1-\alpha}$, is the number of quarters between price adjustments and J corresponds to the Hansen test of overidentifying restrictions with brackets below indicating the p-value. Standard errors are shown in parentheses while ** and * indicate a significant t-test at the 1% and 5% significance levels, respectively. Inflation, π, is alternately measured as the quarterly log difference in the GDP deflator and the CPI. See text.

marginal cost, the specification that multiplies α across the new Keynesian model, equation (14), suggests Japan firms wait 2-3 quarters between making price adjustments, a substantial increase in price flexibility over the case with constant marginal cost, which predicts a 7 quarter wait. However, the estimates of equation (15), imply a deeper degree of rigidity with firms waiting between 5 and 6 quarters to reset prices. Galí and Gertler (1999) and Galí *et al* (2001) find that rigidity increases under equation (15) as well, but to a much lesser extent. Typically, the increase in waiting time was about one quarter. Under this specification, the slope parameter for Japan shown in Table 1, $\kappa = 0.05$ for both GDP deflator CPI inflation, is substantially less than that for the U.S., $\kappa^{US} = 0.665$, but closer to that for the European area, $\kappa^{EA} = 0.228$. However, Japan's slope parameter, κ, is larger than the values reported in the Phillips curve estimation for the same period, equation (4), and its at least as large as the estimates by Higo and Nakada (1999) for the period, 1978-97.

3.3 Hybrid Estimates

Similar to the structural model, the hybrid model in equation (10) is estimated using two normalizations which correspond to rows (1) and (2) respectively in Table 3.3:

$$E_t\{(\phi\pi_t - (1-\omega)(1-\alpha)(1-\alpha\beta)\zeta\widehat{\psi}_t - \alpha\beta\pi_{t+1} - \omega\pi_{t-1})\mathbf{z}_{it}\} = 0 \qquad (16)$$

and

$$E_t\{\pi_t - \frac{(1-\omega)(1-\alpha)(1-\alpha\beta)}{\phi}\zeta\widehat{\psi}_t - \frac{\alpha\beta}{\phi}\pi_{t+1} - \frac{\omega}{\phi}\pi_{t-1})\mathbf{z}_{it}\} = 0 \qquad (17)$$

where $\phi = \alpha + \omega[1 - \alpha(1-\beta)]$. Overall, the model is not rejected based on the J-statistic. However, the estimates bear out Galí and Gertler's (1999) assertion that GMM is sensitive to the specification in small samples. Clearly, the normalization in equation (16), yields more plausible estimates. Galí and Gertler (1999) and Galí *et al* (2001) find the same result but the disparity for Japan estimates is more pronounced.[4] Row (1) for both GDP deflator and CPI inflation show forward looking behavior dominates backward looking behavior, i.e., $\eta_f > \eta_b$. However, for CPI inflation, ω, the share of firms setting prices using a backward looking rule of thumb is negative and significant. The degree of rigidity in the moment condition α is multiplied across the moment condition is about 0.60 for both inflation measures which suggest firms reset prices once a year, roughly every 3 quarters. When GDP deflator inflation us used with this same moment condition, α increases by 0.7 percent but is not statistically significant, which is why the wait is described as non-existent, i.e., DNE. The estimated rigidity deteriorates the most under this specification with CPI inflation, where $\alpha = 1.34$ and is statistically significant. Otherwise, variable marginal cost performs better as a measure than constant marginal cost which predicts a 7 quarter wait between price changes under the linear moment condition.

3.4 Parameter Stability Tests

Andrews (1993) designs tests of structural stability for parameters estimated using the GMM. These are similar in nature Chow tests for structural breaks in the OLS context. Specifically, Andrews (1983) provides the basis that tests whether the estimated parameters are constant over the sample against the alternative that they are not when the break point date is unknown and unspecified. The break point is determined by ranking the test statistics over a partition of the whole sample and selecting the statistic with the largest magnitude. For this exercise we focus on the later part of the sample, 1988-1996 which includes the asset and land price bubble, 1988-91, and deflationary episodes. This section discusses results for tests of pure, rather than partial, structural change where the former evaluates all parameters jointly and is based on a likelihood ratio-like test. Procedurally, the stability test occurs separately from the test for

[4] For example, under variable marginal cost, Galí *et al* (2001) find the waiting period between price setting varies by less than 1 quarter, and rigidity, α, increases by 7 to 11 percent, while retaining statistical significance.

Table 2: The Hybrid New Keynesian Phillips Curve for Japan, 1972-2003

	α	β	ω	η_f	η_b	$\tilde{\kappa}$	$\frac{1}{1-\alpha}$	J_T
$\mu = 1.2, \quad a = 0.46$								
(Variable Marginal Cost)								
GDP Deflator								
(1)	0.61^{**}	0.97^{**}	0.16^{**}	0.77	0.21	0.17	3	8.8
	(0.03)	(0.03)	(0.06)					[0.99]
(2)	0.67	1.48	0.98	0.5	0.5	0.00	DNE	7.87
	(67.82)	(155.5)	(3.63)					[0.9957]
CPI								
(1)	0.63^{**}	0.99^{**}	-0.21^{**}	1.45	-0.49	0.41	3	8.6
	(0.02)	(0.02)	(0.05)					[0.99]
(2)	1.34^{**}	1.0^{**}	1.06^{**}	0.56	0.44	0.00	-3	8.95
	(0.55)	(0.36)	(0.16)					[0.99]
$a = 0, \ \zeta = 1$								
(Constant Marginal Cost)								
GDP Deflator								
(1)	0.85^{**}	0.99^{**}	0.25^{**}	0.76	0.23	0.02	7	10.1
	(0.02)	(0.03)	(0.07)					[0.98]
(2)	0.32	3.15	0.99^{**}	0.48	0.52	0.00	DNE	7.90
	(18.6)	(181.0)	(0.38)					[0.9956]
CPI								
(1)	0.86^{**}	1.00^{**}	-0.29^{**}	1.49	-0.49	0.04	7	8.65
	(0.01)	(0.02)	(0.03)					[0.99]
(2)	1.00	0.99^{**}	0.70	0.59	0.41	0.00	DNE	9.7
	(23.5)	(0.27)	(16.2)					[0.98]

Table Notes: Parameters a and μ, the parameter on labor's marginal product and the firm's mark up are calibrated. Sample Period: 1972-2003 using quarterly data. Rows (1) and (2) correspond to equations (16) and (17) respectively. The instrument set includes four lags of inflation, wage growth, CPI inflation, the real output gap and the spread between a short and long term government bond. $\frac{1}{1-\alpha}$ is the number of quarters between price adjustments and J corresponds to the Hansen test of overidentifying restrictions with brackets below indicating the p-value. Standard errors are shown in parentheses while ** and * indicate a significant t-test at the 1% and 5% significance levels, respectively. Inflation, π, is alternately measured as the quarterly log difference in the GDP deflator and the CPI. See text.

statistical significance. Rossi (2004) develops tests that evaluate estimated parameters for a structural break statistical significance simultaneously and proves these tests have an optimal weighted average power against equally likely alternatives.

Table 3 reports results on the tests for parameter stability when inflation is quarterly growth in the GDP deflator or CPI inflation. "SupLR" and "SupLR*" denote Andrews (1993) supremum likelihood ratio and Rossi's (2004) optimal version of it. As a whole, the results suggest pure structural change occurs under both inflation measures and model specifications either at the bubble period or during the deflationary episode. Under Andrews (1993), the analytically equivalent model for GDP deflator inflation, based on equation (14) suggests structural breaks occur in 1996:Q4 when marginal cost is variable or constant. Roughly, this is the start of the deflationary episode. Rossi's (2004) optimal tests for the same inflation and variable marginal cost suggest the structural break occurs in 1990:Q3, during the asset and land price bubble and near a turning point in Japan's inflation rate. For the moment condition arising most immediately from the optimization problem, the supremum likelihood ratio test (SupLR) suggests the break occurs at the start of bubble, 1988:Q2. Rossi's (2004) optimal test for the same specification suggests the deflationary period, 1994:Q4. For CPI inflation, the tests statistics indicate similar disparities around the two events.[5]

4 Dynamics and Frictions affecting Real Marginal Cost

Galí *et al* (2001) derive a simple decomposition of real marginal cost that enable a deeper analysis of the factors affecting its dynamic path. In part this responds to the observation that New Keynesian/New Neoclassical Synthesis models for price adjustment fail to generate the inflation inertia otherwise demonstrated in the data. The argument is that imperfect labor markets results in wage rigidity that is inadequately captured by the Calvo price adjustment

[5]A later draft will discuss similar tests for the hybrid model. It is thought that this will provide another robustness test for the nested model.

Table 3: Results of Parameter Stability Tests

	Statistical Test	
	SupLR	SupLR*
GDP Deflator Inflation		
Variable Marginal Cost		
Equation (14)	115.96	1072.7
	(0.00)	(0.00)
Date of Structural Break	1996:Q4	1990:Q3
Equation (15)	105.7	1224.9
	(0.00)	(0.00)
Date of Structural Break	1988:Q2	1996:Q4
Constant Marginal Cost ($a = 0$)	1133	16522
	(0.00)	(0.00)
Date of Structural Break	1996:Q4	1996:Q4
CPI Inflation		
Variable Marginal Cost		
Equation (14)	382.7	1123.1
	(0.00)	(0.00)
Date of Structural Break	1990:Q1	1995:Q2
Equation (15)	383.4	2442.6
	(0.00)	(0.00)
Date of Structural Break	1988:Q2	1996:Q4

Table Notes: (p-value) Respectively, SupLR and SupLR* test statistics for parameter instability based on Andrews (1993) supremum likelihood ratio-like test over the partition, 1988-96 and Rossi's (2004) optimal version of Andrews (1993).

mechanism.

Suppose the representative household's preferences for consumption and leisure, $\sum_{t=0}^{infty} \beta^t U(C_t, N_t)$ are separable within $U(C_t, N_t)$. By assuming firms and households optimize, Galí *et al* (2001) express the relationship between real wages and household preferences:

$$\frac{W_t}{P_t} = -\frac{U_{N,t}}{U_{C,t}} \mu_t^w \tag{18}$$

where $-\frac{U_{N,t}}{U_{C,t}}$ is the marginal rate of substitution between consumption and labor. They describe the relationship as the marginal cost the household faces for supplying additional labor (measured in consumption units). They argue then that μ_t^w is interpretable as the gross wage mark up demanded by households when they have "market power." They describe μ_t^w as analogous to the gross price markup over marginal cost held by firms with monopoly power. They also assume that the household cannot be forced to supply labor to the point where the marginal benefit exceeds the marginal cost so that the wage markup, $\mu_t^w \geq 1$. A perfectly competitive labor market is said to exist when $\mu_t^w = 1$ because this means the real wage equals the household's marginal cost of supplying labor. When $\mu_t^w > 1$, labor market frictions exist and could be caused by households having some form of monopoly power in the labor market, nominal wage rigidities, or distortionary taxes, for example. Recalling that optimizing firms set the real wage to the marginal product of labor, equation (18) allows for the household's real marginal cost of supplying labor to be substituted for the real wage in the measure for real marginal cost:

$$\psi_t = \frac{(W_t/P_t)}{(1-\alpha)(Y_t/N_t)} = -\frac{U_{N,t}/C_{N,t}}{(1-\alpha)Y_t/N_t} \mu_t^w \tag{19}$$

Equation (19) expresses real marginal cost, ψ_t to the household's real marginal cost of supplying labor. The right side of equation (19) can be interpreted as equating the unit labor cost for the firm to the household's wage markup, μ_t^w, and the ratio of the household's marginal cost to the marginal product of labor where the latter is a measure of the efficient level of output.

That is, $(1-a)(Y_t/N_t)$ corresponds to a frictionless competitive equilibrium. For this reason, Galí *et al* (2001) describe the ratio as an "inefficiency wedge." When $\frac{U_{N,t}/C_{N,t}}{(1-\alpha)Y_t/N_t} = 1$, output is at its potential and the household's marginal cost is identical to the firm's marginal product of labor. When it is less than 1, i.e., $(1-\alpha)Y_t/N_t > -U_{N,t}/U_{C_t}$, output is below potential. Intuitively, this means that the output gain from one extra unit of labor for the firm exceeds the household's benefit from giving up one more unit of consumption to gain one more unit of labor.

Separability in the preferences implies, $U(C_t, N_t) = lnC_t - \frac{1}{1+\varphi)} N_t^{1+\varphi}$. This implies $U_{C,t} = \frac{1}{C_t}$ and $U_{N,t} = -N_t^{\varphi}$, where φ is the inverse of the elasticity of labor supply, which is set at unity, for analytical ease. Log linearizing equation (19) yields the following expression for real marginal cost:

$$\psi_t = \log \mu_t^w + [(c_t + \varphi n_t) - (y_t - n_t)] \quad (20)$$

where the log of the wage markup is given by, $\log \mu_t^w = (w_t - p_t) - (c_t + \varphi n_t)$. Lower case variables denote natural logarithms. The other expression in brackets on the right hand side of equation (20) is the inefficiency wedge.

Consumption is measured as the log of seasonally adjusted private consumption (rather than household consumption, which is limited to observations from 1994)collected by the Japan's Economic and Social Research Institute (ESRI). The employment variable is employment per household which is measured as the log difference between employment and the labor force per hour, which are published in the Japan Monthly Statistical Bulletin. The parameters are log linearized around the steady state, which is defined to be the sample mean. Figure 1 presents the decomposition for Japan over 1972-2003 compared to real marginal cost used in the previous sections, the unit labor cost based on production with decreasing returns to scale, $\widehat{\psi}_t$.

Looking first to the wage mark up, presented in the lower region of Figure 1, it is clear that

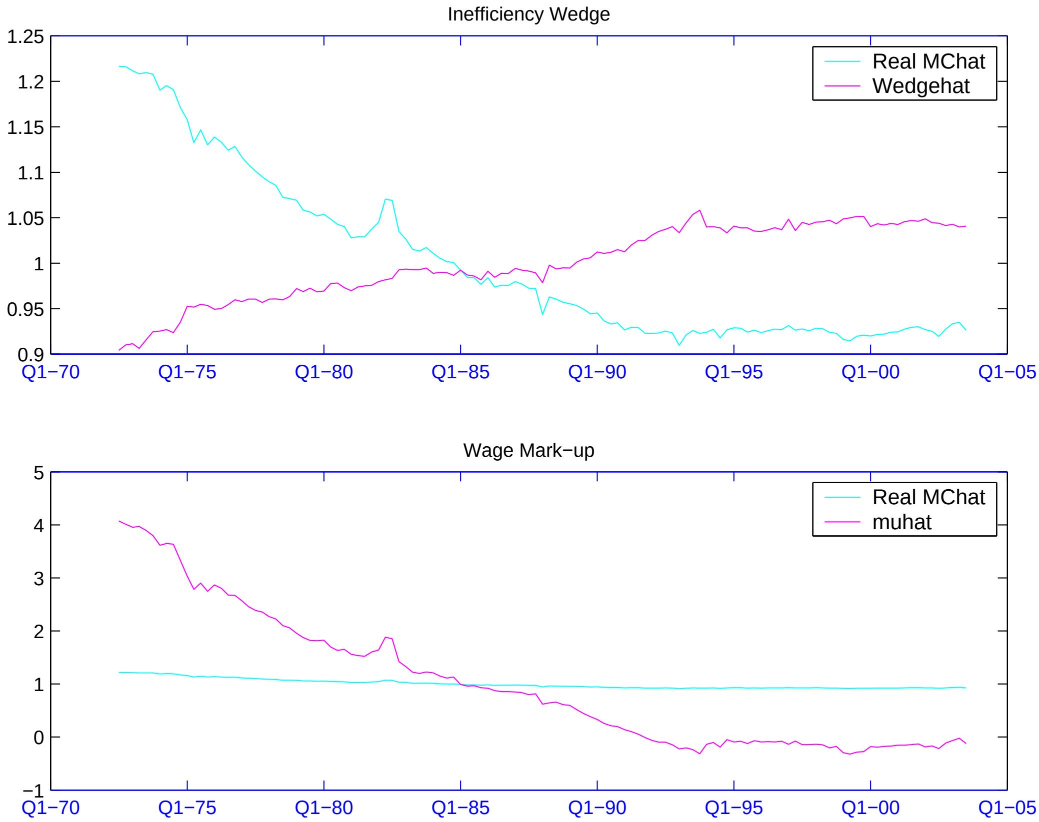

Figure 1: Inefficiency Wedge and Wage Markup for Japan, 1972-2003

the wage markup fell steeply over the first half of the sample suggesting that the household's ability to command wages mark ups fell, perhaps due in part to a weakening in labor union power and the popularity of the Japan's Liberal Democratic Party (LDP). This result starkly contrasts the Euro area experience documented by Galí *et al* (2001), which shows μ_t^w rising over the same period but falling though the late 80s, rising in the early 90s and tapering off in the second half of that decade. Japan shows a steady decline with μ_t^w (shown in logs) being close to unity (from below) during the deflationary episode. Deflationary pressures may have been exacerbated by the wage markup which fell below zero in the early 1990s. This suggests that for much of the sample, labor market distortions are evident implying wage rigidity may be an additional source of inflation inertia that the baseline new Keynesian Phillips curve does not capture. For Japan, however, the wage rigidity and labor market friction, though declining, may have contributed to the length of the deflationary period, slowing recovery. Japan's inefficiency wedge increased over most of the sample, mirroring the wage markup. This is consistent with the interpretation that Japan achieved high capacity utilization.

5 Conclusion

These results suggest that the new Keynesian Phillips curve under decreasing returns to scale provides a reasonable characterization of Japan's inflation, though room for improvement remains. It also suggests output gap measures are not good measure of real marginal cost. We find evidence the forward looking behavior dominates in nested model tests and that structural breaks occur around the land and asset price bubble and deflationary episodes. There is further documentation that GMM is sensitive in small samples to analytically equivalent forms of the Euler equation. This study finds a deeper disparity between estimates than those found by Galí and Gertler (1999) and Galí *et al* (2001). Decomposition of real marginal cost expressed in terms of the household's labor supply decision suggests that wage rigidity may play a role in finding improved estimates of Japan's inflation inertia in the new Keynesian/New Neoclassical Synthesis framework. Specifically, market power on the labor supply side of the economy was substantial but falling throughout the sample.

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