Lecture Notes on Monetary Economics

first draft: **December 2002**
this draft: March 2005

The New Keynesian Phillips Curve

I. *Inflation Dynamics:*

$$\pi_t = \beta \; E_t\{\pi_{t+1}\} + \lambda \; \widehat{mc}_t$$

Assumptions:
- staggered price setting a la Calvo
- optimal price setting by monopolistically competitive firms
- constant frictionless markup μ

II. *Marginal Cost and the Output Gap:*

$$\widehat{mc}_t = (\sigma + \varphi) \; \widetilde{y}_t$$

where $\widetilde{y}_t \equiv y_t - \overline{y}_t$ is the output gap.

Assumptions:
- all output is consumed $(y_t = c_t)$; possible generalization: $y_t = c_t + g_t$, for exogenous g_t.
- perfect competition in labor markets $(w_t - p_t = \sigma c_t + \varphi n_t)$

The New Keynesian Phillips Curve (I+II):

$$\pi_t = \beta \; E_t\{\pi_{t+1}\} + \kappa \; \widetilde{y}_t$$

where $\kappa \equiv \lambda(\sigma + \varphi)$

The New Keynesian Phillips Curve: Criticisms

In the model...:

- inflation leads measures of the output gap
- no trade-off between inflation and output gap stabilization
- disinflation can be achieved costlessly (under full credibility), may even generate a boom if anticipated.
- inflation is purely forward-looking, past inflation is irrelevant (no intrinsic inertia)
- no delay in the response of inflation to monetary policy shocks

....vs. the evidence:

- the output gap appears to lead measures of inflation (Fuhrer and Moore (1995))
- inflation stabilization may require large ouput fluctuations (at least for supply shocks)
- disinflations have historically entailed significant output losses (e.g., Ball (1994))
- inflation seems to display a lot of inertia
- hump-shaped response of inflation to monetary policy shocks.

Formal empirical estimates (GMM, reduced form):

$$\pi_t = 0.988\ E_t\{\pi_{t+1}\} - \underset{(0.005)}{0.016}\ \widehat{y}_t$$

where $\widehat{y}_t$ is detrended log GDP.

$\Rightarrow$ wrong sign for output gap coefficient

$\Longrightarrow$ the traditional Phillips curve seems to fit the data better

$$\pi_t = \pi_{t-1} + \delta\ \widehat{y}_{t-1} + u_t$$

The New Keynesian Phillips Curve Revisited

Difficulties in the empirical assessment of the NKPC:

- by definition $\overline{y}_t$ is not observable (and, hence, neither is the output gap). Detrended log GDP may be a very poor proxy, may induce large biases in the estimated comovements.
- some of the auxiliary assumptions needed to derive the baseline NKPC equation are very strong and may not hold in the data.

Galí and Gertler (JME,1999), GGLS (EER, 2001-03), Sbordone (JME, 2002):

- test the NKPC model in a way consistent with the theory, and under weaker assumptions than the existing literature.
- strategy: assess the fit of the marginal cost-based inflation equation (I).

Measuring Real Marginal Cost

Technology

$$Y_t = G(X_t)\ N_t^{1-\alpha}$$

Cost minimization:

$$\begin{aligned} MC_t &= \frac{W_t}{P_t} \frac{1}{MPN_t} \\ &= \frac{W_t}{P_t} \frac{1}{(1-\alpha)(Y_t/N_t)} \\ &= \frac{S_t^n}{1-\alpha} \end{aligned}$$

where $S_t^n \equiv \frac{W_t N_t}{P_t Y_t}$

$$\widehat{mc}_t = \widehat{s}_t^n$$

New Estimates of the New Keynesian Phillips Curve

Basic Model (GG, JME 99)

$$\pi_t = \beta \; E_t\{\pi_{t+1}\} + \lambda \; \widehat{s}_t^n$$

where

$$\lambda = \frac{(1-\theta)\;(1-\beta\theta)}{\theta}$$

Empirical Estimates (GMM, reduced form):

$$E_t\{(\pi_t - \beta \; \pi_{t+1} - \lambda \; \widehat{s}_t^n) \; \mathbf{z}_t\} = 0$$

$$\pi_t = \underset{(0.045)}{0.942} \; E_t\{\pi_{t+1}\} + \underset{(0.012)}{0.023} \; \widehat{s}_t^n$$

Empirical Estimates (GMM, structural, Table 1):

specification (1):

$$E_t\left\{[\theta\pi_t - \theta\beta \; \pi_{t+1} - (1-\theta)\;(1-\beta\theta)\;\widehat{s}_t^n] \; \mathbf{z}_t\right\} = 0$$

specification (2):

$$E_t\left\{\left[\pi_t - \beta \; \pi_{t+1} - \theta^{-1}(1-\theta)\;(1-\beta\theta)\;\widehat{s}_t^n\right] \; \mathbf{z}_t\right\} = 0$$

Table 1
Estimates of the new Phillips curve

	θ	β	λ
GDP deflator			
(1)	0.829	0.926	0.047
	(0.013)	(0.024)	(0.008)
(2)	0.884	0.941	0.021
	(0.020)	(0.018)	(0.007)
Restricted β			
(1)	0.829	1.000	0.035
	(0.016)		(0.007)
(2)	0.915	1.000	0.007
	(0.035)		(0.006)
NFB deflator			
(1)	0.836	0.957	0.038
	(0.015)	(0.018)	(0.008)
(2)	0.884	0.967	0.018
	(0.023)	(0.016)	(0.008)

Notes: This table reports GMM estimates of the structural parameters of Eq. (15). Rows (1) and (2) correspond to the two specifications of the orthogonality conditions found in Eqs. (18) and (19) in the text, respectively. Estimates are based on quarterly data and cover the sample period 1960:1–1997:4. Instruments used include four lags of inflation, labor income share, long-short interest rate spread, output gap, wage inflation, and commodity price inflation. A 12-lag Newey–West estimate of the covariance matrix was used. Standard errors are shown in brackets.

Model with Decreasing Returns to Labor (GGL, EER 2001)

$$\pi_t = \beta \; E_t\{\pi_{t+1}\} + \lambda_\alpha \; \widehat{s}_t^n$$

where

$$\begin{aligned}
\lambda_\alpha &\equiv \frac{(1-\theta)(1-\beta\theta)}{\theta} \; \frac{1-\alpha}{1+\alpha(\varepsilon-1)} \\
&= \frac{(1-\theta)(1-\beta\theta)}{\theta} \; \frac{(1-\alpha)\mu}{\mu+\alpha} \\
&= \frac{(1-\theta)(1-\beta\theta)}{\theta} \; \xi < \lambda.
\end{aligned}$$

where $\mu \equiv \frac{1}{\epsilon - 1}$.

Identification of θ and β require that α and μ are calibrated. Given μ we can estimate $\alpha \equiv 1 - \frac{S^n}{1+\mu}$.

Notice that for any given estimate of λ_α, a smaller ξ implies a smaller θ. Imposing $\xi = 1$ will create an upward bias in the estimate of θ.

Table 1
Structural estimates

	Parameters θ	β	λ	D	Test J
Euro Area					
$\mu = 1.1$, $\alpha = 0.175$					
(1)	0.777 (0.021)	0.843 (0.046)	0.099 (0.025)	4.5 (0.09)	8.843 (0.452)
(2)	0.834 (0.032)	0.915 (0.040)	0.047 (0.022)	6.0 (0.19)	8.214 (0.513)
United Sates					
$\mu = 1.1$, $\alpha = 0.270$					
(1)	0.603 (0.051)	0.872 (0.041)	0.311 (0.106)	2.5 (0.13)	7.022 (0.534)
(2)	0.698 (0.058)	0.923 (0.029)	0.154 (0.070)	3.3 (0.19)	5.760 (0.674)

Note: Parameter α is calibrated so that $(1 - \alpha)$ equals the average labor income share times the chosen markup (μ). The average labor income shares are taken to be equal to $\frac{2}{3}$ for the US and $\frac{3}{4}$ for the Euro Area. Sample Period: 1970–1998. Column D reports the implied average price duration. J is the Hansen test statistic for the overidentifying restrictions (p-value in brackets). Instruments for Euro area estimation: inflation $t-1$ to $t-5$, output gap, labor income share and wage inflation: $t-1$ to $t-2$. Instruments for US estimation: the same excepts inflation from $t-1$ to $t-4$.

A Structural Model with Backward-Looking Firms

We can generalize the baseline Calvo staggered price setting model by introducing some *backward-looking* firms. Such firms are assumed to base their pricing decisions on the recent price adjustments by other firms, thus providing a source of intrinsic inflation inertia. They co-exist with conventional forward-looking firms. The resulting inflation equation nests the New Phillips Curve as a limiting case.

Aggregate Price Level:

$$p_t = \theta \; p_{t-1} + (1-\theta) \; p_t^*$$

Index of New Prices:

$$p_t^* = \omega \; p_t^b + (1-\omega) \; p_t^f$$

Forward-looking firms:

$$p_t^f = \mu + (1-\beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k \; E_t\{mc_{t+k}^n\}$$

Backward-looking firms:

$$p_t^b = p_{t-1}^* + \pi_{t-1}$$

Remarks:

- $p_t^b \in \Omega_{t-1}$
- in the steady state: $p^b - p = \left(\frac{\theta}{1-\theta}\right) \; \pi$ (limited costs of backward looking behavior in low inflation economies).

Implied Inflation Dynamics:

$$\pi_t = \gamma_b \; \pi_{t-1} + \gamma_f \; E_t\{\pi_{t+1}\} + \lambda \; mc_t$$

where:

$$\gamma_b = \frac{\omega}{\theta + \omega \; [1 - \theta(1-\beta)]}$$

$$\gamma_f = \frac{\beta\theta}{\theta + \omega \; [1 - \theta(1-\beta)]}$$

$$\lambda = \frac{(1-\omega) \; (1-\theta) \; (1-\beta\theta)}{\theta + \omega \; [1 - \theta(1-\beta)]}$$

Special cases:

- $\omega = 0 \;\rightarrow\; \gamma_b = 0$ ("New Keynesian Phillips Curve")
- $\beta = 1 \;\rightarrow\; \gamma_b + \gamma_f = 1$ ("Hybrid Phillips Curve"):

Empirical Estimates (GMM, structural, Table 1):

Table 2
Estimates of the new hybrid Phillips curve

	ω	θ	β	γ_b	γ_f	λ
GDP deflator						
(1)	0.265	0.808	0.885	0.252	0.682	0.037
	(0.031)	(0.015)	(0.030)	(0.023)	(0.020)	(0.007)
(2)	0.486	0.834	0.909	0.378	0.591	0.015
	(0.040)	(0.020)	(0.031)	(0.020)	(0.016)	(0.004)
Restricted β						
(1)	0.244	0.803	1.000	0.233	0.766	0.027
	(0.030)	(0.017)		(0.023)	(0.015)	(0.005)
(2)	0.522	0.838	1.000	0.383	0.616	0.009
	(0.043)	(0.027)		(0.020)	(0.016)	(0.003)
NFB deflator						
(1)	0.077	0.830	0.949	0.085	0.871	0.036
	(0.030)	(0.016)	(0.019)	(0.031)	(0.018)	(0.008)
(2)	0.239	0.866	0.957	0.218	0.755	0.015
	(0.043)	(0.025)	(0.021)	(0.031)	(0.016)	(0.006)

Notes: This table reports GMM estimates of parameters of Eq. (26). Rows (1) and (2) correspond to the two specifications of the orthogonality conditions found in Eqs. (27) and (28) in the text, respectively. Estimates are based on quarterly data and cover the sample period 1960:1–1997:4. Instruments used include four lags of inflation, labor income share, long-short interest rate spread, output gap, wage inflation, and commodity price inflation. A 12-lag Newey–West estimate of the covariance matrix was used. Standard errors are shown in brackets.

Table 2
Hybrid model

	Parameters							Test
	ω	θ	β	γ_b	γ_f	λ	D	J
Euro Area								
$\mu = 1.1$, $\alpha = 0.175$								
(1)	0.028 (0.099)	0.778 (0.024)	0.846 (0.053)	0.035 (0.120)	0.820 (0.046)	0.091 (0.041)	4.5 (0.11)	8.767 (0.362)
(2)	0.307 (0.128)	0.843 (0.066)	0.923 (0.071)	0.272 (0.072)	0.689 (0.047)	0.021 (0.026)	6.4 (0.42)	7.484 (0.380)
United Sates								
$\mu = 1.1$, $\alpha = 0.270$								
(1)	0.299 (0.059)	0.591 (0.065)	0.870 (0.053)	0.345 (0.045)	0.593 (0.047)	0.161 (0.077)	2.4 (0.16)	4.726 (0.693)
(2)	0.355 (0.067)	0.640 (0.073)	0.912 (0.044)	0.364 (0.042)	0.599 (0.038)	0.100 (0.057)	2.8 (0.20)	4.216 (0.755)

Note: See note to Table 1 for details.

GGL (2003)

Actual vs. Fundamental Inflation

Model's stationary solution ($\mu_1 \leq 1 \leq \mu_2$ case):

$$\pi_t = \mu_1 \pi_{t-1} + \lambda\ \mu_2^{-1} \gamma_f^{-1} \sum_{k=0}^{\infty} \mu_2^{-k}\ E_t\{\widehat{s}_{t+k}^n\}$$

Letting $I_t = \{\pi_t, \pi_{t-1,\ldots,} z_t, z_{t-1}, \ldots\}$,

$$\pi_t = \mu_1 \pi_{t-1} + \lambda\ \mu_2^{-1} \gamma_f^{-1} \sum_{k=0}^{\infty} \mu_2^{-k}\ E\{\widehat{s}_{t+k}^n \mid I_t\} \equiv \pi_t^*$$

Evidence: π_t vs. estimates of "fundamental inflation" π_t^* based on:

$$I_t = \{\pi_t,\ \pi_{t-1,\ldots,}\ \widehat{s}_t^n,\ \widehat{s}_{t-1}^n, \ldots\}.$$

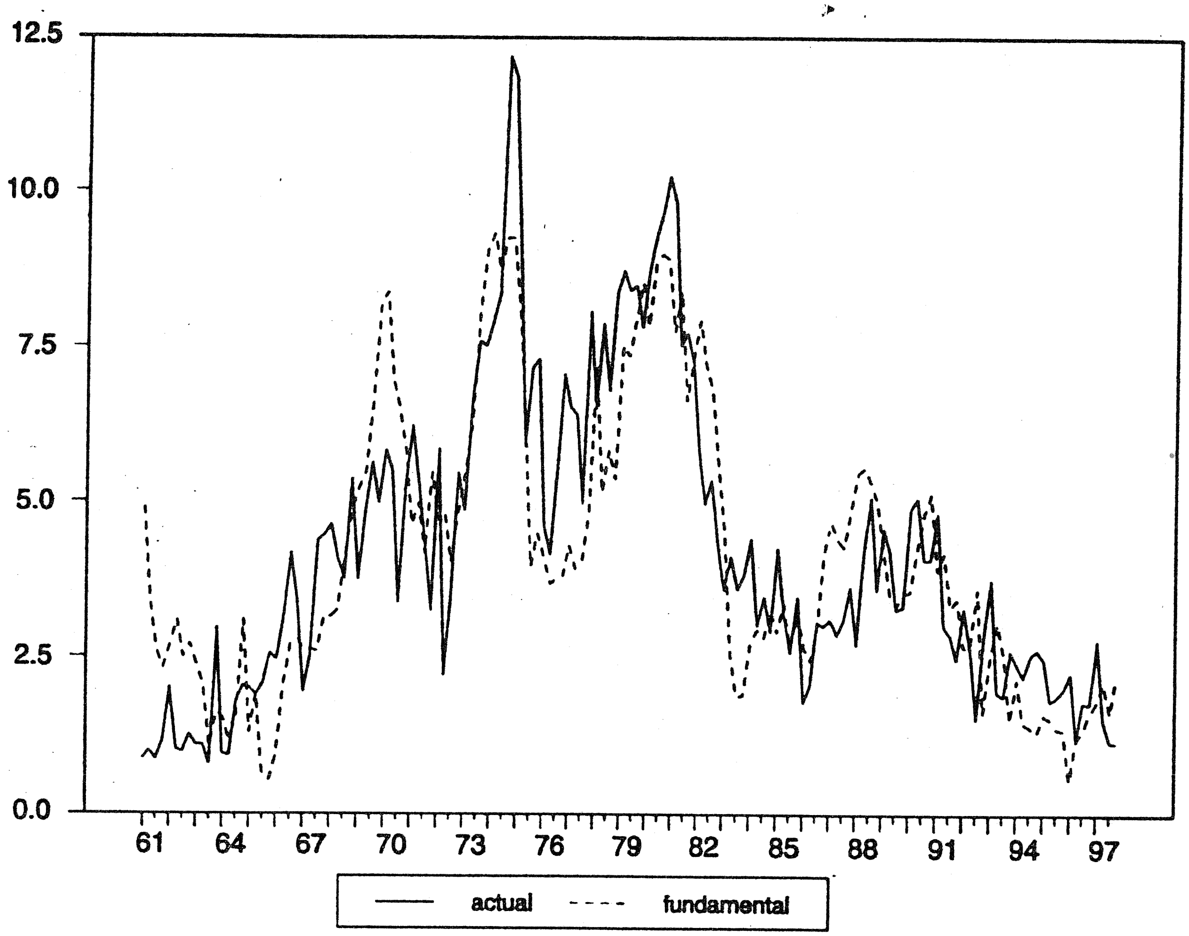

Fig. 2. Inflation: actual versus fundamental.

Conclusions

1. Real marginal costs appear to be a significant determinant of inflation, as the theory predicts.
2. The degree of *price stickiness* is considerable: prices remain fixed on average between 2 and 4 quarters (US), 4 and 6 quarters (euro area)..
3. The estimate of the fraction of *backward-looking firms* is often *quantitatively small*, but *statistically significant.*
4. *Forward looking behavior* seems very important: the estimate of the fraction of firms which set prices in a forward-looking manner is large