# Previous lecture

- Price rigidities – theory and practice
- New Keynesian model

# Equilibrium

$$\pi_t = \beta E_t\left\{\pi_{t+1}\right\} + \lambda\left(mc_t - mc\right)$$

Real marginal cost

$$p_t^* = \mu_t + \log(\psi_{t+k|t})$$

$$mc_t \equiv \log(\psi_{t+k|t}) - p_t$$

$$mc_t = -\mu_t$$

$$\lambda \equiv \frac{(1-\theta)(1-\beta\theta)}{\theta}\frac{(1-\alpha)}{(1-\alpha+\alpha\varepsilon)}$$

$$\lambda = \frac{(1-0.67)(1-0.99\cdot 0.67)}{0.67}\frac{(1-0.33)}{(1-0.33+0.33\cdot 3)} = 0.165$$

$$\pi_t = \beta E_t\left\{\pi_{t+1}\right\} + \lambda\left[\left(\log\psi_t - \log\psi\right) - \left(p_t - p\right)\right]$$

# Interpretation

$$\pi_t = \beta E_t\left\{\pi_{t+1}\right\} - \lambda\left(\mu_t - \mu\right)$$

- If markups are low (relative to steady state) then inflation is high
- Counterintuitive but depends on forward-looking behavior, firms that reset price choose a higher price

# Interpretation

$$\pi_t = \lambda \sum_{t=0}^{\infty} \beta^k E_t\left\{mc_{t+k} - mc\right\}$$

Expected real marginal cost high relative to steady state

Markups expected to be below steady state => inflation will be high => firms that reset price choose a price above the average price level

# Output gap

$$mc_t - mc = \left(\alpha + \frac{\varphi + \alpha}{1-\alpha}\right)(y_t - y_t^n)$$

$$\pi_t = \beta E_t\left\{\pi_{t+1}\right\} + \kappa\left(y_t - y_t^n\right)$$

$$\kappa = \lambda\left(\sigma + \frac{\varphi + \alpha}{1-\alpha}\right)$$

$$\kappa = 0.165\left(1 + \frac{1+0.33}{1-0.33}\right) = 0.49$$

# Dynamic IS equation

$$Y_t(i) = C_t(i)$$
$$Y_t = C_t$$

$$c_t = E_t\left\{c_{t+1}\right\} - \frac{1}{\sigma}\left(i_t - E_t\left\{\pi_{t+1}\right\} - \rho\right)$$

remember interpretation

Rewrite the consumer's Euler equation in terms of the output gap

$$y_t = E_t\{y_{t+1}\} - \frac{1}{\sigma}\left(i_t - E_t\{\pi_{t+1}\} - \rho\right)$$

$$y_t - y_t^n = E_t\{y_{t+1} - y_{t+1}^n\} - \frac{1}{\sigma}\left(i_t - E_t\{\pi_{t+1}\} - \rho\right) + E_t\{y_{t+1}^n - y_t^n\}$$

$$\tilde{y}_t = E_t\{\tilde{y}_{t+1}\} - \frac{1}{\sigma}\left(i_t - E_t\{\pi_{t+1}\} - r_t^n\right)$$

$$r_t^n = \rho + \sigma E_t\{\Delta y_{t+1}^n\}$$

Real rate of interest at flexible prices, supports output at natural level

# Equilibrium

$$c_t = E_t\{c_{t+1}\} - \frac{1}{\sigma}\left(i_t - E_t\{\pi_{t+1}\} - \rho\right)$$

$$i_t - E_t\{\pi_{t+1}\} = \rho + \sigma E_t\{\Delta y_{t+1}\}$$

rewrite

$$r_t^n = \rho + \sigma E_t\{\Delta y_{t+1}^n\}$$

$$= \rho + \sigma \psi_{ya}^n E_t\{\Delta a_{t+1}\}$$

$$y_t - y_t^n = -\frac{1}{\sigma}\sum_{k=0}^{\infty}\left(r_{t+k} - r_{t+k}^n\right)$$

that the output gap is proportional to the real interest rate gap, i.e. the difference between the real interest rate and the natural interest rate.

# Monetary policy

$$i_t = \rho + \phi_\pi \pi_t + \phi_y \left( y_t - y_t^n \right) + v_t$$

compare with 3-equation model of Svensson (1997)

Assume $\phi_\pi = 1.5 \text{ and } \phi_y = 0.125$

$v_t = \rho_v v_{t-1} + \varepsilon_t^v \qquad \rho_v = 0.5$

# and

$\beta < 1 \ \simeq 0.99$

$\rho \equiv -\log \beta \simeq 0.01$

$\sigma \simeq 1$

$\varphi \simeq 1$

$\alpha \simeq 0.33$

$\varepsilon = 6$

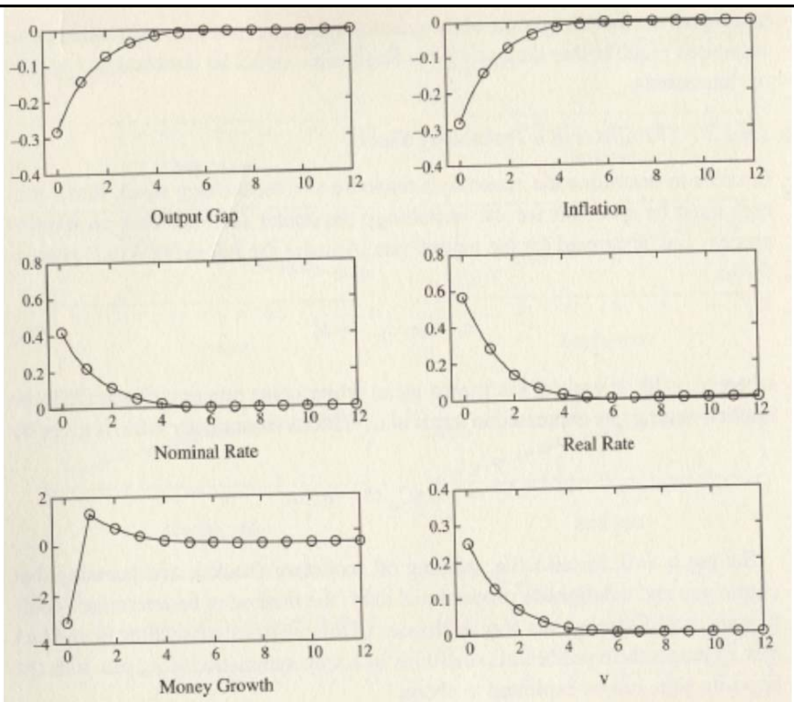
$\psi_{na} = 0$

$\upsilon_n = -0.2$

$\psi_{ya} = 1$

$\upsilon_y = -0.13$

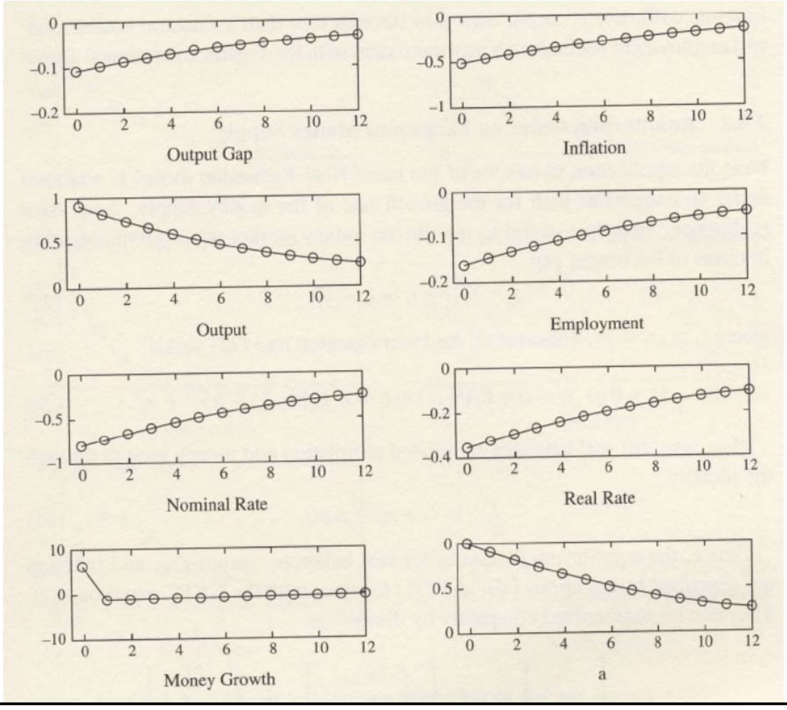
monetary policy shock



# and technology shock

$$a_t = \rho_a a_{t-1} + \varepsilon_t^a$$

$$\rho_a = 0.9$$



## More on policy

- Optimal policy
  - Uniqeness
  - Realistic rules
    - Information requirements
      - Unobservables like flexible price output or interest rate
- Simple policy rules
  - Taylor rules
- More on this later

## More on Phillips curves

- Expectations
- Price setting

# Inattentive agents, Mankiw and Reis
## Sticky information

- firms gather information and recompute optimal prices slowly over time
- a fraction of the firms obtains new information about the state of the economy and computes a new path of optimal prices
- other firms continue to set prices based on old plans and outdated information
- each firm has the same probability of being one of the firms updating their pricing plans, regardless of how long it has been since its last update

# Sticky information model

$p_t^* = p_t + \lambda\left(y_t - y_t^n\right)$ optimal price

$x_t^j = E_{t-j}\left\{p_t^*\right\}$ price based on old plans

$p_t = \gamma\sum_{j=0}^{\infty}(1-\gamma)^j x_t^j$ aggregated

$$p_t = \gamma\sum_{j=0}^{\infty}(1-\gamma)^j E_{t-j}\left\{p_t + \lambda(y_t - y_t^n\right\}$$

$$\pi_t = \left[\frac{\gamma\lambda}{1-\gamma}\right]\left(y_t - y_t^n\right) + \gamma\sum_{j=0}^{\infty}(1-\gamma)^j E_{t-1-j}\left\{\pi_t + \lambda\Delta\left(y_t - y_t^n\right)\right\}$$

## Interpretation

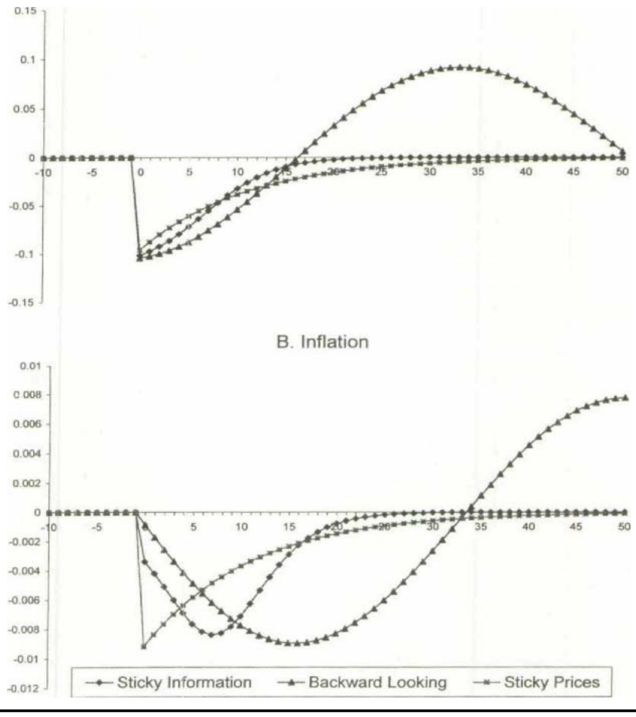
- Inflation depends on output, expectations of inflation, and expectations of output growth
- past expectations of current economic conditions
- large differences in the dynamic pattern of prices and output in response to monetary policy

## Theoretical properties

- a policy of permanently falling inflation will keep output permanently high in NKPC
- the sticky-information model satisfies the strict version of the natural rate hypothesis

# Dynamic responses

- More realistic dynamic responses in sticky information models compared to NKPC
- Hybrid Phillips curve
- Other properties of model



# Hybrid curve, Gali and Gertler 1999

$$\pi_t = \delta x_t + (1 - \phi) E_t\{\pi_{t+1}\} + \phi \pi_{t-1}$$

- The addition of the lag term is designed to capture the inflation persistence that is unexplained in the baseline model
- adaptive expectations on the part of a subset of price setters
- In this instance the estimated model is consistent with the old Phillips curve: expected future inflation does not enter significantly in the inflation equation; lagged inflation enters with a coefficient near unity, as in the traditional framework

# Hybrid curve

- from the fraction  firms that are able to reset their price only a fraction  will do so
- a fraction  instead use a rule-of-thumb that makes them set the price equal to the average of recently (last period) adjusted prices plus an adjustment for expected inflation, based on lagged inflation

$$\pi_t = \lambda\left(mc_t - mc\right) + \gamma_f E_t\left\{\pi_{t+1}\right\} + \gamma_b \pi_{t-1} + \varepsilon_t$$

$$\lambda = (1-\varpi)(1-\theta)(1-\beta\theta)\phi^{-1}$$

$$\gamma_f = \beta\theta\phi^{-1}$$

$$\gamma_b = \varpi\phi^{-1}$$

$$\phi = \theta + \varpi\left[1-\theta(1-\beta)\right]$$

# Estimation problems

- Unobservables
  - marginal cost gap
  - output gap
  - expected inflation
- Parameters to be expected (structural)
  - identification
  - model uncertainty
  - simultaneity

# Estimating the gap

- Real marginal cost $\frac{\partial C(Y,w)}{\partial Y}$
- Output gap $w$ = vector of input prices
  - Potential output
  - HP filter
  - Output at flexible prices

$$Y_t = A_t K_t^{\alpha_k} N_t^{\alpha_n}$$ Cobb-Douglas production function

$$MC_t = (W_t/P_t)/(\partial Y_t/\partial N_t)$$ marginal cost

$$\frac{\partial Y_t}{\partial N_t} = \frac{\alpha_n Y_t}{N_t}$$

$$MC_t = \frac{S_t}{\alpha_n}$$

$$S_t \equiv W_t N_t / P_t Y_t$$

$$mc_t = s_t$$ deviation from steady state

# Cost function

$$\frac{\partial C(Y,w)}{\partial Y} = C'(Y,w)$$

$$\frac{\partial C(Y,w)}{\partial w_i} = x_i^{'}(Y,w)$$

- Cobb-Douglas simplistic
- Marginal cost independent of output
- Cost shares constant (in steady state)

# Translog example

$$\log c = a_0 + \sum_i a_i \log w_i + \frac{1}{2}\sum_i \sum_j a_{ij} \log w_i \log w_j + \sum_i b_i \log w_i \log y + 0.5g \log y \log y$$

$$s_i = a_i + \sum_j a_{ij} w_j + b_i \log y$$ demand for inputs as shares

$$mc = \left[\sum_i b_i \log w_i + g \log y\right]\frac{c}{y}$$ marginal cost

simultaneous estimation of input demand and Phillips curve

## Another Phillips curve

- Sticky prices in some firms
- Adjustment costs
- Threshold for price adjustment
- Many firms
- Small and large shocks

## Shocks

- Relative shocks -> relative price changes
- Small shock -> no price change
- Large shock -> price change
- Mean of relative price changes = 0

# Distribution of shocks/relative prices

Figure 1. A symmetric distribution of relative shocks

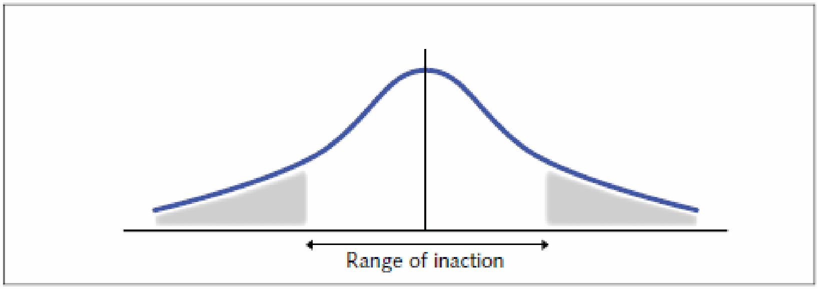



Figure 2. A positively skewed distribution of relative shocks

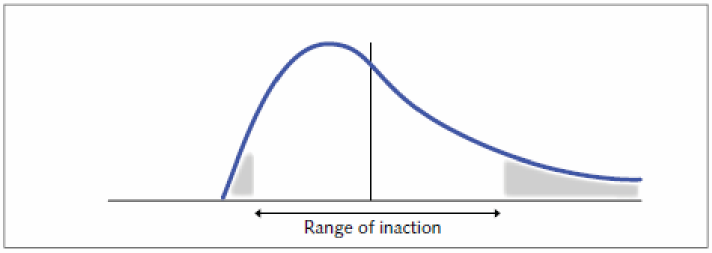



Figure 3. A negatively skewed distribution of relative shocks

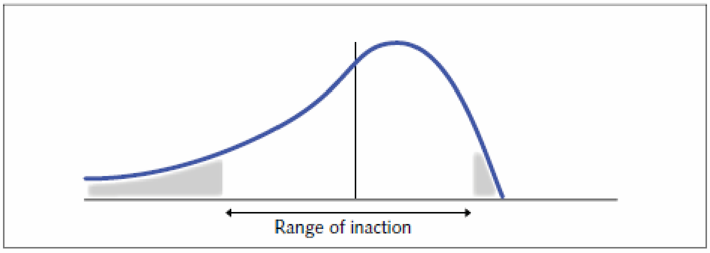
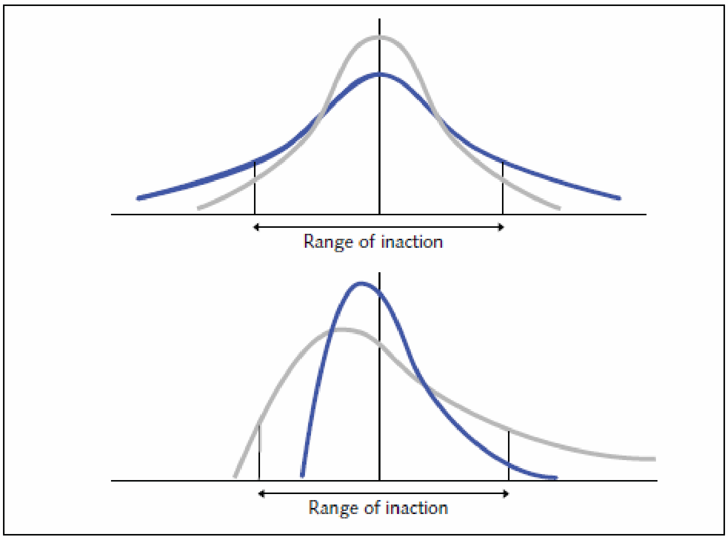


**Figure 4. Relationship between variance and skewness in the distribution of relative shocks**




$$\pi_t = \beta_0 + \beta_1 \Delta w_t + \beta_2 \Delta \rho_t + \beta_3 \pi_{t-1} + \beta_4 \left(U_t - \bar{U}_t\right) + \beta_5 \Delta p_t^{oil} +$$

$$\beta_6 \Delta p_t^{metals} + \beta_7 \Delta p_t^{food(a)} + \beta_8 \Delta p_t^{food(b)} + \beta_9 g_t$$

$$\beta_{10}\sigma_t^3 + \beta_{11}\sigma_{t-1}^3 + \beta_{12}\sigma_t^2 + \beta_{13}\sigma_t^3\sigma_t^2$$

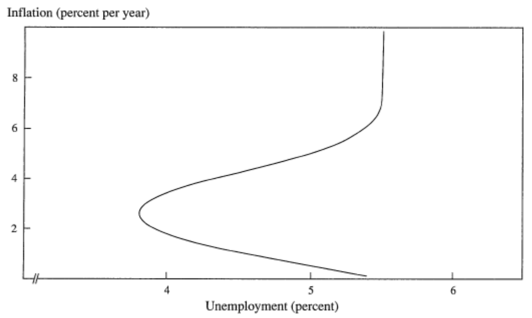
**TABLE 3. REGRESSIONS WITH MODEL RESIDUALS – $\varepsilon_t$ – AS DEPENDENT VARIABLE**

| | Model | | |
|---|---|---|---|
| | VAR | Bayesian VAR | N. I. Economic Research |
| Variable | Coefficient (p) | | |
| | Quarterly 1980–2003 | Quarterly 1981–2003 | Monthly 1998–2004 |
| Constant | −0.005012 (0.000) | −0.403792 (0.000) | 0.269104 (0.001) |
| $\varepsilon_{t-1}$ | −0.010574 (0.908) | 0.096325 (0.292) | 0.130121 (0.281) |
| $\sigma_t^3$ | 2.812243 (0.000) | 197.8204 (0.000) | 70.25972 (0.062) |
| $\sigma_{t-1}^3$ | −1.260631 (0.009) | −80.26362 (0.017) | −16.73187 (0.188) |
| $\sigma_t^2$ | 5.153802 (0.000) | 331.5355 (0.000) | −100.0026 (0.002) |
| $\sigma_t^3\,\sigma_t^2$ | −1205.869 (0.003) | −74240.61 (0.007) | −7991.953 (0.474) |
| $R^2$ | 0.372 | 0.357 | 0,292 |

Note: Quarterly changes have been used for the VAR models, 12-month changes for the forecasts from the National Institute.

# Yet another curve – Akerlof, Dickens and Perry

**Figure 1. A Hypothetical Long-Run Phillips Curve**



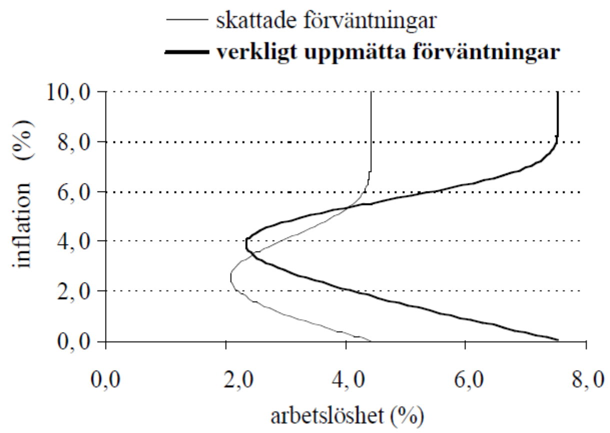

Source: Authors' calculations from calibration of the theoretical model.

# Theory

- Near-rational expectations (psychological)
- Firms set efficiency wages and prices
- Some firms near-rational, others rational
- => real wages lower at low inflation
- => long run relationship between inflation and unemployment

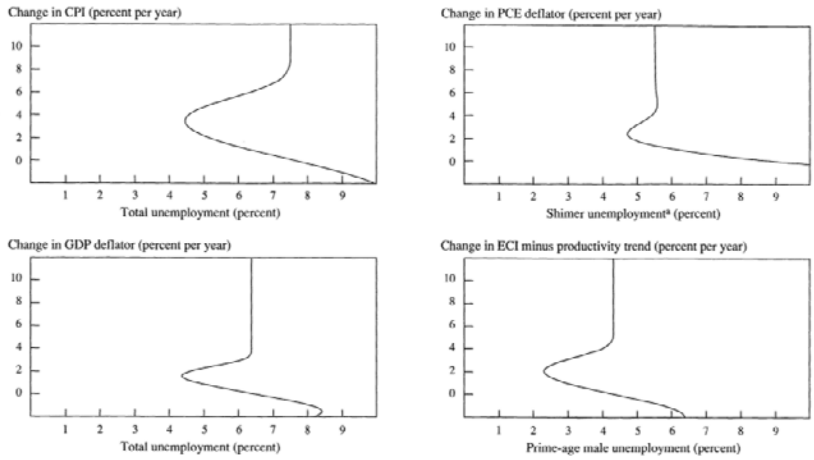
# Sweden estimates

*Figur 2* **Phillipskurvan: Svenska data 19632000.**



# US

**Figure 7. Long-Run Inflation-Unemployment Relation Estimated with Various Price Indexes**




Source: Authors' calculations from the estimated parameters reported in table 2.
a. Shimer's (1998) demographically adjusted unemployment rate.