Models of Incomplete Nominal Adjustment

Lecture 10

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Microeconomic Foundations of Incomplete Nominal Adjustment

Why do nominal wages and prices adjust sluggishly? (agents' level)
Romer (2006), ch.6

1. Lucas Imperfect Information Model:
   - agents have imperfect information about aggregate price level and thus about relative prices
2. New Keynesian Economic
   - introduce small costs of changing nominal prices/wages, or other frictions in nominal adjustment
3. Dynamic New Keynesian Models and Staggered Price Adjustment

1. Lucas Imperfect Information Model

- **idea:** uncertainty whether change in individual price reflects change in relative price (good specific) or in aggregate price level (inflation)
  - different implications on the optimal output decision
- **rational inference:** $\nearrow$ observed price $=>$ weighted average of relative price increase and inflation $=>$ change of output (due to change of relative price) $=>$ upward sloping AS
- **set-up:**
  - competitive markets, each agent produces differentiated good and consume basket of all goods
  - 2 types of shocks:
    - shifts in preferences $=>$ change in relative prices
    - AD shocks $=>$ change in aggregate price level

1. Lucas Imperfect Information Model

A) Perfect Information - set up

- production of typical good i: $Q_i = L_i$
- consumption: $C_i = \frac{P_i Q_i}{P} = \frac{P_i L_i}{P}$
- preferences: $U_i = C_i - \frac{1}{\gamma} L_i^{\gamma} = \frac{P_i L_i}{P} - \frac{1}{\gamma} L_i^{\gamma}; \quad \gamma > 1$
    - optimal labor supply: $\frac{P_i}{P} - L_i^{\gamma - 1} = 0 \Leftrightarrow L_i = \left(\frac{P_i}{P}\right)^{1/(\gamma-1)}$
    - in logs: $l_i = \frac{1}{\gamma - 1}(p_i - p) = y_i$
- demand specification:
    - demand for good i (logs): $q_i = y + z_i - \eta(p_i - p), \ \eta > 0$
    - $y = \bar{q}_i$, $p = \bar{p}_i$, z_i - idiosyncratic shock (good specific)
    - aggregate demand : $y = m(+v) - p$

- equilibrium : supply = demand

$$\frac{1}{\gamma - 1}(p_i - p) = y + z_i - \eta(p_i - p)$$

- solve for p_i: $p_i = \frac{\gamma-1}{1+\eta\gamma-\eta}(y + z_i) + p$
- average over i: $p = \bar{p}_i = \frac{\gamma-1}{1+\eta\gamma-\eta}y + p$
- aggregate output: $y = 0$ (but in logs, so $Y = 1$)
- aggregate price level: $p = m$ (money neutrality - no effect on y)

1. Lucas Imperfect Information Model

B) Imperfect information - setup

- change: producers only observe prices of their own goods - not aggregate price level

$$p_i = p + (p_i - p) \equiv p + r_i$$

  - production should be based on r_i only - must be inferred from p_i
  - assume **rational expectations**
- optimal labor decision (production)[1]: $l_i = \frac{1}{\gamma-1} E[r_i|p_i]$
- assumption about shocks: $m \sim N(E(m), V_m),\ z_i \sim N(0, V_z)$
- thus: $E[r_i|p_i] = \frac{V_r}{V_r+V_p}(p_i - E(p))$
- labor supply: $l_i = \frac{1}{\gamma-1} \frac{V_r}{V_r+V_p}(p_i - E(p)) \equiv b(p_i - E(p))$
- aggregate output : $y = b(p - E(p)) =$ **Lucas supply curve**

[1] **certainty - equivalence:** find expectation + behave like this estimate were certain

1. Lucas Imperfect Information Model

B) Imperfect information - solution

- equilibrium: supply = demand

$$b(p - E(p)) = m - p \Leftrightarrow \quad \begin{aligned} p &= \frac{1}{1+b} m + \frac{b}{1+b} E(p) \\ y &= \frac{b}{1+b} m - \frac{b}{1+b} E(p) \end{aligned}$$

- first equation also holds before realization of m, in expectations:

$$E(p) = \frac{1}{1+b} E(m) + \frac{b}{1+b} E(p) \quad \Leftrightarrow \quad E[p] = E[m]$$

- using the fact that $m = E[m] + (m - E[m])$ we get

$$\begin{aligned} p &= E(m) + \frac{1}{1+b}(m - E(m)) \\ y &= \frac{b}{1+b}(m - E(m)) \end{aligned}$$

- => only unexpected AD shocks (i.e. $m - E[m]$) have real effects

- model implies positive correlation of output and inflation (Phillips Curve)
- Ex: let $m_t = m_{t-1} + c + u_t$ and thus $E[m_t] = m_{t-1} + c$

$$
\begin{aligned}
p_t &= m_{t-1} + c + \frac{1}{1+b} u_t \\
y_t &= \frac{b}{1+b} u_t \\
\pi_t &= c + \frac{1}{1+b} u_{t-1} + \frac{b}{1+b} u_t
\end{aligned}
$$

- no exploitable tradeoff between output and inflation
- **Lucas Critique:** if policymakers attempt to exploit statistical relationships, then the adjustment of expectations may cause the realtionships to break down

1. Lucas Imperfect Information Model

Stabilization policy

- agents form rational expectations
- only unexpected AD shocks have real effects
- $=>$ monetary policy can stabilize output only if policymakers have info unavailable to private agents
- systematic policies (known to public) are **ineffective**

- individuals care about real prices and quantities, nominal terms of transactions do not matter much :
  - information about aggregate price level easily available
  - indexation of wages/ prices / debts
- Keynesian view: nominal imperfections explain fluctuations in aggregate activity
- Implication: small nominal frictions at **micro** level must have large effects on **macro** level
- here - "menu" cost (small fixed cost) of changing nominal price

2. New Keynesian Economics

Overview

1. Imperfect Competition and Price Setting
   - baseline model without nominal rigidities
   - macroeconomic consequences of imperfect competition
2. Are Small Frictions Enough?
   - assume small fixed cost of adjusting the prices
3. Real Rigidities

2.1 Imperfect Competition and Price Setting

Assumptions

- variation on Lucas model: no good specific shocks, competitive labor market (sell your labor, hire workers)
  individual i is producer of good i with market power => **sets its price**
- production of typical good: $Q_i = L_i$
- income (spend on PC_i): $(P_i - W)Q_i + WL_i$
- preferences: $U_i = C_i - \frac{1}{\gamma}L_i^{\gamma} = \frac{(P_i - W)Q_i + WL_i}{P} - \frac{1}{\gamma}L_i^{\gamma}, \quad \gamma > 1$
- demand for good i (in logs): $q_i = y - \eta(p_i - p),\ \eta > 1$
  - in levels: $Q_i = Y(P_i/P)^{-\eta}$
- aggregate demand: $y = m - p$

- individual chooses price of his good P_i + amount of time he works L_i

$$\max_{P_i, L_i} U_i = \frac{(P_i - W)Y(P_i/P)^{-\eta} + WL_i}{P} - \frac{1}{\gamma} L_i^{\gamma}$$

- F.O.C for price: $\frac{P_i}{P} = \frac{\eta}{\eta - 1} \frac{W}{P}$; $\frac{\eta}{\eta-1} > 1$
  - relative price set by producer with market power is higher than marg. cost (real wage)
- F.O.C for labor supply: $L_i = \left(\frac{W}{P}\right)^{\frac{1}{\gamma-1}}$
  - elasticity of supply is $\frac{1}{\gamma-1}$

- **symmetric equilibrium:** $L_i = L = Y, \; P_i = P$

$$\frac{W}{P} = Y^{\gamma-1}, \; \frac{P_i}{P} = 1 = \frac{\eta}{\eta-1} Y^{\gamma-1}, \; Y = \left(\frac{\eta-1}{\eta}\right)^{1/\gamma-1}, \; P = \frac{M}{Y}$$

- **implications**:
  - producers with market power produce less than socially optimal (that would be $L = Y = 1$)
  - recessions and booms have asymmetric effects on welfare
  - pricing decisions have externalities (AD externality)
- imperfect competition alone does not imply monetary non-neutrality

2.2 Are Small Frictions Enough?

General analysis

- new assumption: aggregate demand is **determined after** firms have set their prices; firms can readjust their prices at a small **menu cost**
- firms will readjust prices only if benefits from changing exceeds menu cost
- consider fall in AD $=>$ (picture)
- AD externality implies, that firm's incentive to change price may be small even if changes in AD have strong effects

2.2 Are Small Frictions Enough?

Quantitative example I.

- firm i's real profit (ass. $\nu \equiv 1/(\gamma - 1)$):

$$\begin{aligned} \pi_i &= \frac{Q_i P_i}{P} - L_i \frac{W}{P} = Y(P_i/P)^{-\eta} \left(\frac{P_i}{P} - Y^{1/\nu} \right) \\ &= \frac{M}{P} \left(\frac{P_i}{P} \right)^{1-\eta} - \left(\frac{M}{P} \right)^{(1+\nu)/\nu} \left(\frac{P_i}{P} \right)^{-\eta} \end{aligned}$$

- without menu costs: $1 = \frac{P_i}{P} = \frac{\eta}{\eta-1} \left(\frac{M}{P} \right)^{1/\nu} \Leftrightarrow \frac{M}{P} = \left(\frac{\eta-1}{\eta} \right)^{\nu}$
- **question:** when is not adjusting prices a Nash equilibrium?
  - $\pi_{ADJ} - \pi_{FIX} < Z$, where Z is menu cost
  - $\pi_{FIX} = \frac{M}{P} - \left(\frac{M}{P} \right)^{(1+\nu)/\nu}$
  - $\pi_{ADJ} = \frac{1}{\eta-1} \left(\frac{\eta}{\eta-1} \right)^{-\eta} \left(\frac{M}{P} \right)^{(1+\nu-\eta)/\nu}$
  - $\pi_{ADJ} \geq \pi_{FIX}$

2.2 Are Small Frictions Enough?

Quantitative example I.

- let $\nu = 0.1$ (labor supply elasticity), $\eta = 5$ (25% markup)
  - fixed-price level of output: $Y \simeq 0.978$
  - 3% drop in M implies (other prices unchanged) $\pi_{ADJ} - \pi_{FIX} \approx 0.253$
  - markup costs would have to be 25% of production to make the menu cost theory work - **unrealistic**

- source of difficulty is **labor market**
  (competitive + low elasticity of supply => drop in real wage => low costs => higher incentive to cut price)

- from general case recall: $\frac{P_i^*}{P} = \frac{\eta}{\eta-1} Y^{\gamma-1}$
- in logs: $p_i^* - p = \ln \frac{\eta}{\eta-1} + (\gamma - 1)y \equiv c + \phi y$
  - if $\phi > 0$ then p_i^* increasing in y
- fall in AD has two effects (picture)
  - firm i's profit function shifts down (if real wage effect does not counteract drop in quantity demanded)
  - since $\gamma > 1$, firm i's profit-maximizing price p_i^* decreases
- thus $\pi_{ADJ} - \pi_{FIX}$ depends on
  - (i) change in p_i^* - corresponds to **real rigidities** (e.g. higher γ implies higher ϕ - elasticity of supply)
  - (ii) curvature of profit function - costs of deviating from p_i^* - fixing the price

2.3 Real Rigidities

Sources

- properties of firm i's MC
  - flatter MC curve corresponds to greater real rigidity and less sensitivity of profits => smaller incentive to adjust
- properties of firm i's MR
  - steeper MR curve corresponds to greater real rigidity and less sensitivity of profits => smaller incentive to adjust
- characteristics of **labor market** are crucial - supply elasticity, competitiveness, ...

2.3 Real Rigidities

Quantitative example II.

- effect of labor market imperfection: firms are paying wages above market-clearing level
  (β - elasticity of wage w.r.t output - cyclical behavior):
  - real wage function: $\frac{W}{P} = AY^{\beta}$
- firm i's real profit: $\pi_i = \frac{M}{P}\left(\frac{P_i}{P}\right)^{1-\eta} - A\left(\frac{M}{P}\right)^{1+\beta}\left(\frac{P_i}{P}\right)^{-\eta}$
- without menu costs: $1 = \frac{P_i}{P} = \frac{\eta}{\eta-1}AY^{\beta} \Leftrightarrow \frac{M}{P} = \left(\frac{\eta-1}{A\eta}\right)^{1/\beta}$
  - $\pi_{FIX} = \frac{M}{P} - A\left(\frac{M}{P}\right)$
  - $\pi_{ADJ} = A^{1-\eta}\frac{1}{\eta-1}\left(\frac{\eta}{\eta-1}\right)^{-\eta}\left(\frac{M}{P}\right)^{1+\beta-\beta\eta}$

2.3 Real Rigidities

Quantitative example II.

- let $\beta = 0.1$ (cyclicality of real wage), $\eta = 5$ (25% markup), $A = 0.806$
  - then $Y \simeq 0.928$
  - 3% drop in M implies (other prices unchanged) $\pi_{ADJ} - \pi_{FIX} \approx 0.0000168$
  - relatively small menu cost sufficient for menu cost theory to work (firms do not adjust)
- combination of real rigidity and small barriers to nominal price adjustment generates substantial nominal rigidity
- problem = we assume really high degree of rigidity in labor market

3. Dynamic New Keynesian Models and Staggered Price Adjustment

Overview

- **so far:** imperfect competition in static setting (1 period only)
- **now:** dynamic decentralized setting, 3 agents:
  - households
  - firms
  - central bank

- preferences:

$$\sum_{t=0}^{\infty}[U(C_t) - V(L_t)], \quad 0 < \beta, 1$$

where $U(C_t) = \frac{C_t^{1-\theta}}{1-\theta}$, $\theta > 0$ and $V'(\cdot) > 0$, $V''(\cdot) > 0$

- F.O.C.'s:

$$\begin{aligned} V'(L_t) &= U'(C_t)\frac{W_t}{P_t} \Rightarrow \frac{W_t}{P_t} = \frac{V'(Y_t)}{U'(Y_t)} \\ C_t^{-\theta} &= (1 + r_t)C_{t+1}^{-\theta} \end{aligned}$$

- take logs and use $\ln(1 + r_t) \approx r_t$ and $Y_t = C_t = L_t$

$$\ln Y_t = \ln Y_{t+1} - \frac{1}{\theta} r_t$$

- called **New Keynesian IS curve**

- firm i:
  - technology : $Q_{it} = L_{it}$
  - demand : $Q_{it} = Y_t \left(\frac{P_{it}}{P}\right)^{-\eta}$
  - profits:
    $R_{it} = \left(\frac{P_{it}}{P}\right) Q_{it} - \frac{W_t}{P_t} Q_{it} = Y_t \left[\left(\frac{P_{it}}{P}\right)^{1-\eta} - \left(\frac{W_t}{P_t}\right)\left(\frac{P_{it}}{P}\right)^{-\eta}\right]$
- **assume:** firm sets price in the period 0; let π_t be the probability that this price is still in effect in period t
- firms are owned by households => firms value their profits according to the utility they provide to the households
  - marg. utility of HH cons in period t relative to period 0 is $\lambda_t = \frac{\beta^t U'(C_t)}{U'(C_0)}$

$$\max \nu = \sum_{t=0}^{\infty} \pi_t \lambda_t R_t = \sum_{t=0}^{\infty} \pi_t \lambda_t Y_t \left[\left(\frac{P_{it}}{P}\right)^{1-\eta} - \left(\frac{W_t}{P_t}\right)\left(\frac{P_{it}}{P}\right)^{-\eta}\right]$$

3.1 Building Blocks
Firms I

- if we assume low inflation and β close to 1, Romer (2006), p.313 shows that firms' problem can be approximated by

$$\min_{p_i} \sum_{t=0}^{\infty} \pi_t (p_i - p_t^*)^2$$

- F.O.C: $p_i = \sum_{t=0}^{\infty} \omega_t p_t^*$, where $\omega_t \equiv \frac{\pi_t}{\sum_{\tau=0}^{\infty} \pi_\tau}$
- by certainty equivalence: $p_i = \sum_{t=0}^{\infty} \omega_t E_0[p_t^*]$
- assumptions on evolution of profit max price: $p_i^* = p_t + c + \phi y_t, \ \phi > 0$
- with $y_t = m_t - p_t$ (m_t stands for nominal GDP) and c=0

$$p_i = \sum_{t=0}^{\infty} \omega_t E_0[\phi m + (1 - \phi) p_t]$$

3.1 Building Blocks

Closing the model: Central bank + Extensions

- AD - New Keynesian IS curve

$$y_t = y_{t+1} - \frac{1}{\theta} r_t \;\Leftrightarrow\; (m_t - p_t) = (m_{t+1} - p_{t+1}) - \frac{1}{\theta} r_t$$

- AS - firm's price setting behavior:

$$p_i = \sum_{t=0}^{\infty} \omega_t E_0[\phi m + (1-\phi) p_t]$$

- pin down (determine) real interest rate r_t via **monetary policy**
  - interest rate rule (as a function of other variables)
  - our approach: exogenous process for m_t (assume as a result of optimal monetary policy - can abstract from money market + IS curve)
- **extensions:** objective function of CM, introduction of money, investments, government purchases

- **timing:** every other period, firm sets prices $\{p^1_{t+1}, p^2_{t+2}\}$ for the next two periods; then AD shocks realize
  - always 1/2 of firms in economy sets in given period, i.e. average price in period t is $p_t = \frac{1}{2}(p^1_r + p^2_t)$
- since $\phi m + (1-\phi)p_t$:

$$
\begin{aligned}
p^1_t &= E_{t-1}[\phi m_t + (1-\phi)p_t] = \phi E_{t-1} m_t + (1-\phi)\frac{1}{2}(p^1_t + p^2_t) \\
p^2_t &= E_{t-2}[\phi m_t + (1-\phi)p_t] = \phi E_{t-2} m_t + (1-\phi)\frac{1}{2}(E_{t-2} p^1_r + p^2_t)
\end{aligned}
$$

- solve first for p^1_t: $p^1_t = \frac{2\phi}{1+\phi} E_{t-1} m_t + \frac{1-\phi}{1+\phi} p^2_t$
- expectation in $t-2$: $E_{t-2} p^1_r = \frac{2\phi}{1+\phi} E_{t-2} m_t + \frac{1-\phi}{1+\phi} p^2_t$
- plug into equation for p^2_t: $p^2_t = E_{t-2} m_t$
- combine: $p^1_t = E_{t-2} m_t + \frac{2\phi}{1+\phi}(E_{t-1} m_t - E_{t-2} m_t)$

- use results for p_t^1, p_t^2, $p_t = \frac{1}{2}(p_t^1 + p_t^2)$ and $y_t = m_t - p_t$ to get

$$
\begin{aligned}
p_t &= E_{t-2}m_t + \frac{\phi}{1+\phi}(E_{t-1}m_t - E_{t-2}m_t) \\
y_t &= \frac{1}{1+\phi}(E_{t-1}m_t - E_{t-2}m_t) + (m_t - E_{t-1}m_t)
\end{aligned}
$$

- Implications:
  - unanticipated AD shocks affect output, interim information affects prices and output
  - real rigidity ϕ matters (inelasticity of labor supply)
  - (monetary) policy can be used to stabilize the economy
  - $E_{t-2}m_t$ does not matter - any info that everybody has chance to respond to does not matter for output

3.3 Alternative setups

- staggered price setting makes the model dynamic
- here, the prices adjustment is **time-dependent**, i.e. length of time that a firm's price is predetermined is fixed
- alternative: **state dependent** pricing, i.e. price changes triggered by developments within the economy
- problem: no simple mapping from nominal rigidity at micro level to nominal rigidity at the macro level
- basic models have problems with matching empirical data