Advanced Macroeconomics

Imperfect Competition and Staggered Price Adjustment

- In this chapter we will extend the RBC model to account for imperfect competition.
- We assume monopolistic competition instead of fully competitive goods markets: Firms have market power and set prices as to maximize profits.
- We include nominal variables and discuss monetary policy.

9. Monopolistic Competition

Monopolistic Competition

(Dixit und Stiglitz 1977)

- Product differentiation (imperfect substitutes): each firm faces a demand curve for its product
- The more effective product differentiation is, the larger is the firm's market power and the less elastic is demand
- Firms take the price-setting behavior of other firms as given
- Optimization problem: A higher price increases average revenue but decreases demand

9. Monopolistic Competition

Model with Monopolistic Competition

- Only goods and labor market (no capital)
- Consumption bundle C consists of M different goods
- Households maximize intertemporal utility
- Firms maximize present value of profits

Consumption Bundle of the Representative Household

- Utility function

$$E_t \sum_{s=0}^{\infty} \left(\frac{1}{1+\rho} \right)^s u(C_{t+s}, N_{t+s})$$

- Consumption bundle (M different goods, elasticity of substitution $\varepsilon > 1$)

$$C_t = \left(\sum_{m=1}^{M} C_{t,m}^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{\varepsilon}{\varepsilon-1}}$$

$$\frac{\partial C_t}{\partial C_{t,m}} = \frac{\varepsilon}{\varepsilon - 1} \left(\sum_{m=1}^{M} C_{t,m}^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{1}{\varepsilon-1}} \frac{\varepsilon - 1}{\varepsilon} C_{t,m}^{-\frac{1}{\varepsilon}} = \left(\frac{C_t}{C_{t,m}} \right)^{\frac{1}{\varepsilon}}$$

- Consumption expenditure and price level

$$P_t C_t = \sum_{m=1}^{M} P_{t,m} C_{t,m}, \qquad P_t = \sum_{m=1}^{M} P_{t,m} \frac{C_{t,m}}{C_t}$$

Households' Optimization Problem

- Households receive labor income and firms' profits (competitive labor market: $W_{m,t} = W_t$)

$$P_t C_t = W_t N_t + \sum_{m=1}^{M} \Pi_{t,m}$$

- LAGRANGE function

$$\mathcal{L} = \sum_{s=0}^{\infty} \left[\left(\frac{1}{1+\rho} \right)^s u(C_{t+s}, N_{t+s}) + \lambda_{t+s} \left(W_{t+s} N_{t+s} + \sum_{m=1}^{M} \Pi_{t+s,m} - P_{t+s} C_{t+s} \right) \right]$$

- First-order condition for good m for $s = 0$

$$\frac{\partial \mathcal{L}}{\partial C_{t,m}} = U_{c,t} \frac{\partial C_t}{\partial C_{t,m}} - \lambda_t P_{t,m} = 0 \quad \Rightarrow \quad \left(\frac{C_t}{C_{t,m}} \right)^{\frac{1}{\varepsilon}} = \frac{\lambda_t P_{t,m}}{U_{c,t}} \tag{2}$$

Consumption

- First-order condition for aggregate consumption

$$\frac{\partial \mathcal{L}}{\partial C_t} = U_{c,t} - \lambda_t P_t = 0 \quad \Rightarrow \quad \lambda_t = \frac{U_{c,t}}{P_t} \tag{3}$$

- Demand for good m (insert (3) into (2))

$$C_{t,m} = \left(\frac{P_{t,m}}{P_t}\right)^{-\varepsilon} C_t \tag{4}$$

or

$$P_{t,m} = \left(\frac{C_{t,m}}{C_t}\right)^{-\frac{1}{\varepsilon}} P_t \tag{5}$$

Aggregate Consumption Euler Equation

- Add government bonds (B) and lump-sum transfers (T) to the budget constraint

$$P_{t+s}C_{t+s} + \frac{1}{1+i_{t+s}}B_{t+s} + T_{t+s} = W_{t+s}N_{t+s} + B_{t+s-1} + \sum_{m=1}^{M} \Pi_{t+s,m}$$

- First-order condition for aggregate consumption

$$\left(\frac{1}{1+\rho}\right)^{s} u_{C,t+s} - \lambda_{t+s}P_{t+s} = 0 \quad \Rightarrow \quad \lambda_{t+s} = \left(\frac{1}{1+\rho}\right)^{s} \frac{u_{C,t+s}}{P_{t+s}}$$

- First-order condition for bond holdings

$$\lambda_{t+s}\frac{1}{1+i_{t+s}} - \lambda_{t+s+1} = 0$$

- Insert consumption foc into bond holdings foc for $s = 0$

$$\frac{u_{C,t}}{P_t}\frac{1}{1+i_{t+s}} - \frac{1}{1+\rho}\frac{u_{C,t+1}}{P_{t+1}} = 0 \quad \Rightarrow \quad \frac{1}{1+i_t} = \frac{1}{1+\rho}\frac{u_{C,t+1}}{u_{C,t}}\frac{P_t}{P_{t+1}}$$

Labor Supply

- First-order condition

$$\frac{\partial \mathcal{L}}{\partial N_t} = U_{N,t} + \lambda_t W_t = 0 \tag{6}$$

- Insert consumption foc

$$-\frac{U_{N,t}}{U_{C,t}} = \frac{W_t}{P_t} \tag{7}$$

Price Elasticity of Demand

- Demand function for firm i

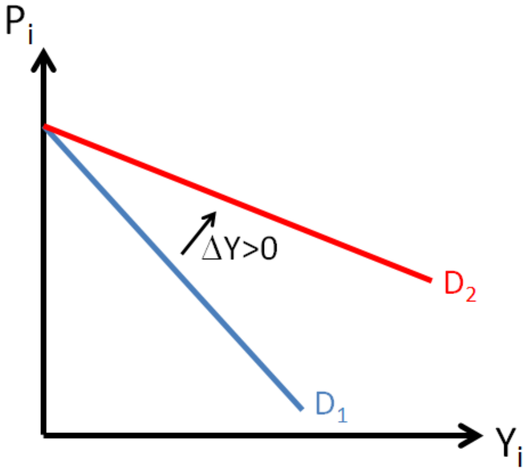
$$Y_i = D(P_i, P, Y) = D\left(\frac{P_i}{P}\right) Y$$

- Price elasticity of demand

$$\varepsilon = -\frac{\mathrm{d}Y_i/Y_i}{\mathrm{d}P_i/P_i} = -\frac{\mathrm{d}Y_i}{\mathrm{d}P_i}\frac{P_i}{Y_i}$$

- $\varepsilon = 5$: price increase by 1% reduces demand by 5%
- If aggregate demand increases, individual demand for firm i does also increase
- Inverse demand function

$$P_i = \Phi(Y_i, P, Y)$$



Profit Maximization: Graphical Analysis

- Profit = Revenue − Costs
- Revenue

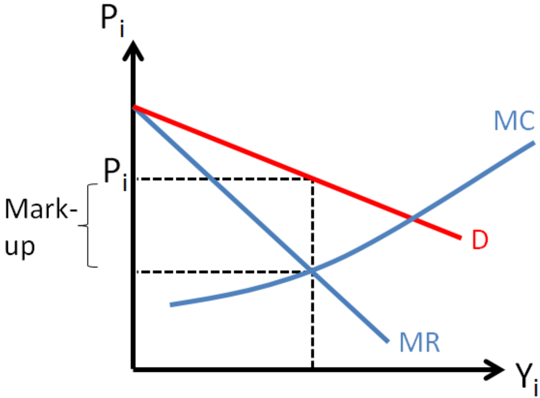
$$R_i = Y_i \cdot \Phi(Y_i, P, Y)$$

- Marginal revenue

$$MR_i = \frac{dR_i}{dY_i} = P_i + Y_i \frac{dP_i}{dY_i}$$

- First-order condition

$$MR_i = MC_i$$



Mark-up

- Rewrite marginal revenue

$$MR_i = P_i + Y_i \frac{\mathrm{d}P_i}{\mathrm{d}Y_i} = \left(1 + \frac{\mathrm{d}P_i}{\mathrm{d}Y_i}\frac{Y_i}{P_i}\right) P_i = \left(1 - \frac{1}{\varepsilon}\right) P_i$$

- Mark-up pricing

$$P_i = (1+\mu) MC_i \qquad \text{where} \qquad 1 + \mu = \frac{1}{1 - 1/\varepsilon}$$

- Example: $\varepsilon = 5$

$$1 + \mu = \frac{1}{1 - 1/5} = \frac{1}{4/5} = \frac{5}{4} = 1.25$$

- The more demand reacts to price changes, the lower the mark-up (perfect competition: $\mu = 0$)

Marginal Costs

- No capital in the model
- Producing more implies higher labor demand
- Marginal costs depend on the hourly wage (W_i) and on the number of additional hours to produce one additional unit of output ($1/MPL_i$)

$$MC_i = \frac{W_i}{MPL_i}$$

Profit Maximization

- Profit function

$$\Pi_{t,m} = P_{t,m} Y_{t,m} - W_t N_{t,m} \tag{8}$$

- LAGRANGE-Function

$$\mathcal{L} = P_{t,m} Y_{t,m} - W_t N_{t,m} + \lambda_t \left(Y_{t,m} - F(N_{t,m}) \right) \tag{9}$$

- First-order conditions

$$\frac{\partial \mathcal{L}}{\partial Y_{t,m}} = \frac{\partial P_{t,m}}{\partial Y_{t,m}} Y_{t,m} + P_{t,m} + \lambda_t = 0 \tag{10}$$

$$\frac{\partial \mathcal{L}}{\partial N_{t,m}} = -W_t - F_{N,t} \lambda_t = 0 \tag{11}$$

Optimal Production

- Insert (11) into (10) and divide by $P_{t,m}$

$$\frac{\partial P_{t,m}}{\partial Y_{t,m}} \frac{Y_{t,m}}{P_{t,m}} + 1 - \frac{W_t / P_{t,m}}{F_{N,t}} = 0 \tag{12}$$

- From (5) follows ($Y = C$)

$$\frac{\partial P_{t,m}}{\partial Y_{t,m}} \frac{Y_{t,m}}{P_{t,m}} = -\frac{1}{\varepsilon} \tag{13}$$

- Labor demand

$$F_{N,t} = \frac{\varepsilon}{\varepsilon - 1} \frac{W_t}{P_{t,m}} \tag{14}$$

- Mark-up

$$P_{t,m} = \underbrace{\frac{\varepsilon}{\varepsilon - 1}}_{1+\mu} \underbrace{\frac{W_t}{F_{N,t}}}_{MC} \tag{15}$$

Equilibrium

- Perfect competition on the labor market: $W_{t,m} = W_t$
- Labor supply (7) and labor demand (14) determine real wage ($w = W/P$) and hours worked (N)
- Hours worked and production function determine aggregate production and consumption ($Y = C$)
- Since all firms exhibit the same production function, they all set equal prices
- Nominal wage (W) and price level (P) are not determined by the model
- Real wage and output are lower than in case of perfect competition

9. Monopolistic Competition

Simulation of Monopolistic Competition Model: Functional Forms

- Utility function

$$U(C_t, N_t) = \frac{C_t^{1-\theta}}{1-\theta} - \frac{N_t^{1+\varphi}}{1+\varphi}$$

where $1/\theta$ is the intertemporal elasticity of substitution in consumption and $1/\varphi$ the Frisch elasticity of labor supply

- Household first-order conditions

$$\begin{aligned} \frac{W_t}{P_t} &= C_t^{\theta} N_t^{\varphi} \\ \frac{1}{1+i_t} &= \frac{1}{1+\rho}\left(\frac{C_{t+1}}{C_t}\right)^{-\theta}\frac{P_t}{P_{t+1}} \end{aligned}$$

- Production function

$$Y_t = A_t N_t^{1-\alpha}$$

Model Equations

- Exogenous variable: A_t
- 6 Endogenous variables: C_t, Y_t, N_t, W_t, P_t, i_t
- Only 5 equations:
  1. Aggregate expenditure (resource constraint): $Y = C$
  2. Production function
  3. Consumption Euler equation
  4. Labor supply optimality condition
  5. Labor demand

Closing the Model: Monetary Policy

(`moncomp_stoch.mod`)

- We introduce a central bank that sets the nominal interest rate i_t
- The central bank follows an interest rate rule (linear version)

$$i_t = \rho + \pi^* + \phi(\pi_t - \pi^*) + \nu_t, \qquad \nu_t = \eta_i \nu_{t-1} + \varepsilon_{i,t} \quad \varepsilon_{i,t} \sim N(0, \sigma_i)$$

- Fisher equation

$$(1 + R_t) = \frac{1 + i_t}{1 + \pi_{t+1}}$$

- We replace the nominal wage by the real wage ($w_t = W_t / P_t$) and the price level by the inflation rate ($\pi_t = P_t / P_{t-1} - 1$)
- Price level and nominal wage can be calculated once the model is solved from a given initial price level P_0

9. Monopolistic Competition

Log-linear Monopolistic Competition Model

$$
\begin{aligned}
y_t &= c_t \\
y_t &= a_t + (1-\alpha)n_t \\
c_t &= E_t c_{t+1} - \frac{1}{\theta}(i_t - E_t\pi_{t+1} - \rho) \\
w_t &= \theta c_t + \varphi n_t \\
w_t &= a_t - \alpha n_t - \mu \\
r_t &= i_t - E_t\pi_{t+1} \\
i_t &= \rho + \pi^* + \phi(\pi_t - \pi^*) + \nu_t
\end{aligned}
$$

$\mu = \ln(\epsilon/(\epsilon - 1)) - \ln(1-\alpha)$ and $w_t = \ln(W_t/P_t)$

Solving for Hours Worked

- Set labor supply equal to labor demand and insert $c_t = y_t$ and $y_t = a_t + (1-\alpha)n_t$

$$
\begin{aligned}
\theta c_t + \varphi n_t &= a_t - \alpha n_t - \mu \\
\theta(a_t + (1-\alpha)n_t) + \varphi n_t &= a_t - \alpha n_t - \mu \\
\theta a_t + \theta(1-\alpha)n_t + \varphi n_t &= a_t - \alpha n_t - \mu \\
n_t^* &= \underbrace{\frac{1-\theta}{\theta(1-\alpha)+\varphi+\alpha}}_{\phi} a_t + \underbrace{\frac{-\mu}{\theta(1-\alpha)+\varphi+\alpha}}_{\bar{n}}
\end{aligned}
$$

- The sign of the response of hours worked to a productivity shock depends on $\theta \gtreqqless 1$
- The higher the mark-up (the lower ϵ), the lower hours worked
- The real wage can be computed from $w_t = a_t - \alpha n_t - \mu$

Flexible Price Output and Natural Rate of Interest

- Plug hours worked into production function

$$y_t^* = a_t + (1-\alpha)n_t^* = a_t + (1-\alpha)(\phi a_t + \overline{n}) = \underbrace{(1+(1-\alpha)\phi)}_{\psi} a_t + \underbrace{(1-\alpha)\overline{n}}_{\overline{y}}$$

- Insert $c_t = y_t^*$ and Fisher equation into consumption Euler equation

$$\begin{aligned} y_t^* &= E_t y_{t+1}^* - \frac{1}{\theta}(r_t - \rho) \\ r_t^* &= \rho + \theta(E_t y_{t+1}^* - y_t^*) \\ &= \rho + \theta\psi E_t \Delta a_{t+1} \end{aligned}$$

9. Aggregate Fluctuations and Real Business Cycles

Summary

- Monopolistic competition adds a friction to the RBC model.
- Therefore, the market equilibrium is not efficient.
- Flexible price output depends negatively on the degree of market power.

Literature

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