# Integrated course „Energy Economics“
# - Microeconomics: basic concepts -

Chair of Energy Systems | Department of Energy Systems
Technische Universität Berlin

# Outline

- Particularities of energy sector
- Market structures
- Supply and demand
- Welfare effect of markets
- Tax effect – deadweight loss
- Price elasticity of demand
- Cost of production - terminology

# Monopoly - pricing 1

Firm is able to influence the price by changing the produced quantity

→ profit = revenues − costs $\quad \pi = p \cdot Q - C$

→ maximize profits $\Rightarrow \frac{d\pi}{dQ} \overset{!}{=} 0$

$$\frac{d(p \cdot Q)}{dQ} = \frac{dC}{dQ}$$

marginal revenue = marginal cost

# Monopoly - pricing 2

Technische Universität Berlin

$$\frac{d(p\cdot Q)}{dQ} = p \cdot \underbrace{\frac{dQ}{dQ}}_{=1} + Q \cdot \frac{dp}{dQ} = p + Q\frac{dp}{dQ}$$

$$= p\left(1 + \frac{Q}{p} \cdot \frac{dp}{dQ}\right) = p\left(1 + \frac{1}{\eta_{p,Q}}\right)$$

$$\frac{1}{\eta_{p,Q}} = \frac{dp}{dQ} \cdot \frac{Q}{p}$$

elastic demand $\eta \leq -1$

inelastic demand $-1 < \eta \leq 0$

$$\Rightarrow \frac{dC}{dQ} = p\underbrace{\left(1 + \frac{1}{\eta_{p,Q}}\right)}_{\text{smaller than } 1 \text{, since } \eta_{p,Q} < 0}$$

$$\Rightarrow \boxed{p_M > \frac{dC}{dQ}}$$ Monopoly

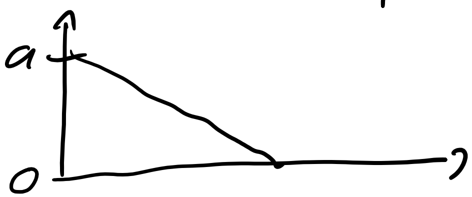
# Cournot oligopoly - pricing 1

- two identical firms, producing quantities $q_1$ and $q_2$
- Question: which quantity maximizes profits?
- linear demand. $p(q_1 + q_2) = a - q_1 - q_2 = a - q$

$a - (q_1 + q_2)$

$q = q_1 + q_2$

$a \in \mathbb{R}^+$




- linear cost functions (not cubic)

$$C_1(q_1) = c \cdot q_1$$

$$C_2(q_2) = c \cdot q_2$$

$c \in \mathbb{R}^+,\ a > c$

# Cournot oligopoly - pricing 2

- profit functions for firm 1 and 2

$$\pi_1 = p \cdot q_1 - C_1 = (a - q_1 - q_2) \cdot q_1 - c \cdot q_1$$

$$\pi_2 = p \cdot q_2 - C_2 = (a - q_1 - q_2) \cdot q_2 - c \cdot q_2$$

- maximize profits

$$\left.\begin{aligned} \frac{d\pi_1}{dq_1} &= a - 2q_1 - q_2 - c \overset{!}{=} 0 \\ \frac{d\pi_2}{dq_2} &= a - q_1 - 2q_2 - c \overset{!}{=} 0 \end{aligned}\right\} \Rightarrow \begin{aligned} q_2 &= a - 2q_1 - c \\ q_1 &= a - 2q_2 - c \end{aligned}$$

$$\Rightarrow q_2 = a - 2(a - 2q_2 - c) - c = -a + 4q_2 + c$$

## Cournot oligopoly - pricing 3

$\Rightarrow q_2 = \frac{a-c}{3} \rightsquigarrow q_1 = \frac{a-c}{3}$

$\Rightarrow$ price on the market with the above quantities?

$$p = a - q_1 - q_2 = a - \frac{2(a-c)}{3} = \frac{3a - 2a + 2c}{3}$$

$$\Rightarrow \boxed{p_O = \frac{a+2c}{3}}$$ Oligopoly $a > c$

$a, c \in \mathbb{R}^+$

$\Rightarrow$ comparison of prices between perfect competition, oligopoly, monopoly

# Comparison

perfect competition: price = marginal cost

$$p = c$$

oligopoly: $p = \frac{a+2c}{3}$ $\quad a > c$, $a, c \in \mathbb{R}^+$

monopoly: marginal revenues = marginal cost

(with demand function $p = a - q$)

$$\frac{d}{dq}(p \cdot q) = \frac{dC}{dq}$$

$$\frac{d}{dq}((a-q)\cdot q) = c \Rightarrow a - 2q = c \Rightarrow \underbrace{q = \frac{a-c}{2}}_{\text{quantity in a monopoly}}$$

# Comparison

Technische Universität Berlin

what is the price in a monopoly with the demand function?

$$p_M = a - q = a - \frac{a-c}{2} = \frac{2a-a+c}{2} = \frac{a+c}{2}$$

---

Taking the prices from slide before

perfect comp: $p = c$

oligopoly: $p_o = \dfrac{a+2c}{3}$

monopoly: $p_M = \dfrac{a+c}{2}$

$$\frac{a+c}{2} > \frac{a+2c}{3}$$

$$\Rightarrow 3a + 3c > 2a + 4c$$

$$a > c$$

$$p_{Comp} < p_{Olig} < p_{Mon}$$

# Task 3) Offer of a price taker: competitive market

A price taker has the following cost function:

cost quantities

$$\boldsymbol{C(Q) = \frac{1}{3}Q^3 - 2Q^2 + 5Q + 15}$$

quantity fixed cost

a) What are the total costs, the variable costs and the fixed costs?
b) How much will the company offer if the market price is 10?
c) What is the price for break-even?
d) What is the price for production threshold (shut-down)?

# Task 3) Offer of a price taker: competitive market

A price taker has the following cost function:

$$C(Q) = \frac{1}{3}Q^3 - 2Q^2 + 5Q + 15$$

a) What are the total costs, the variable costs and the fixed costs?

total costs $C_{tot} = \frac{1}{3} Q^3 - 2Q^2 + 5Q + 15$

variable costs $C_{var} = \frac{1}{3} Q^3 - 2Q^2 + 5Q$

fixed costs $C_{fix} = 15$

# Task 3) Offer of a price taker: competitive market

A price taker has the following cost function:

$$\boldsymbol{C(Q) = \frac{1}{3}Q^3 - 2Q^2 + 5Q + 15}$$

b) How much will the company offer if the market price is 10?

$P = 10$ no market power $\Rightarrow$ price taker

$$P = \frac{dC}{dQ} = MC$$

$$MC = Q^2 - 4Q + 5 \overset{!}{=} P = 10$$

$$Q^2 - 4Q - 5 = 0$$

$$Q_{1,2} = -\frac{-4}{2} \pm \sqrt{\left(\frac{-4}{2}\right)^2 + 5}$$

$$Q_{\text{Profits, max}} = 5 \text{ units}$$

# Task 3) Offer of a price taker: competitive market

Technische Universität Berlin

A price taker has the following cost function:

$$C(Q) = \frac{1}{3}Q^3 - 2Q^2 + 5Q + 15$$

c) What is the price for break-even?

break even: the point at which marginal cost equal average total cost

⇒ firm will break even: not earning profits, but it will not be loosing money either

$$MC = \frac{C_{total}(Q)}{Q}$$

$$Q^2 - 4Q + 5 = \frac{1}{3}Q^2 - 2Q + 5 + \frac{15}{Q}$$

$$\vdots$$

$$\hookrightarrow Q_{BE} = 4{,}25 \text{ units}$$

$$P_{BE} = MC(Q_{BE} = 4{,}25) = 6{,}06 \; €/\text{unit}$$

# Task 3) Offer of a price taker: competitive market

A price taker has the following cost function:

$$C(Q) = \frac{1}{3}Q^3 - 2Q^2 + 5Q + 15$$

d) What is the price for production threshold (shut-down)?

shut-down: the point at which the marginal revenue equals variable (marginal) cost / variable cost

$\Rightarrow$ firms marginal profit becomes negative

$MR = MC$

$Q^2 - 4Q + 5 = \frac{1}{3}Q^2 - 2Q + 5$

avg. var. cost

$\rightarrow$ avg. var. cost

$$\frac{C_{var}(Q)}{Q} = \frac{\frac{1}{3}Q^3 - 2Q^2 + 5Q}{Q}$$

$\vdots$

$Q_{SD} = 3$ units $\rightsquigarrow P_{SD} = MC(Q_{SD} = 3) = 2 \frac{€}{\text{unit}}$

# Task 4) Monopoly

Inverse market demand for a homogeneous good is given by $p(Q_D) = 1 - Q_D$ ($Q_D$: aggregate quantity). Suppose first a monopolist serves the market. The monopolist's costs are given by $C(Q) = \frac{Q^2}{2}$.

a) Determine the maximal monopoly outcome (monopoly price, quantity, profit).

b) Determine the welfare as the sum of consumer surplus and producer surplus.

Now suppose the market is served by J competitive firms with identical cost structure. Their aggregate cost (given that all firms produce the same quantity q) is the same as for the above monopolist.

c) What is the cost function for firm j?

d) Determine the competitive equilibrium (price, quantity) and the outcome for firm j (quantity and profit).

e) Determine the welfare.

f) Compare the welfare in b) with the welfare in e).

g) Give a Paretian interpretation of your result in f). (Hint: Look up the term pareto optimal)

# Task 4) Monopoly

Technische Universität Berlin

Inverse market demand for a homogeneous good is given by $p(Q_D) = 1 - Q_D$ ($Q_D$: aggregate quantity). Suppose first a monopolist serves the market. The monopolist's costs are given by $C(Q) = \frac{Q^2}{2}$.

a) Determine the maximal monopoly outcome (monopoly price, quantity, profit).

Monopolist profits: $\pi_M(Q) = P_D(Q) \cdot Q - C(Q)$

$$= (1-Q)\cdot Q - \frac{Q^2}{2}$$

$$= Q - \frac{3}{2} Q^2$$

Max profit $\pi_M$: $\frac{d\pi_M}{dQ} \overset{!}{=} 0$

$\Leftrightarrow 0 = 1 - 3Q \rightarrow Q_M = \frac{1}{3} \rightarrow P_M = 1 - Q_M = \frac{2}{3}$

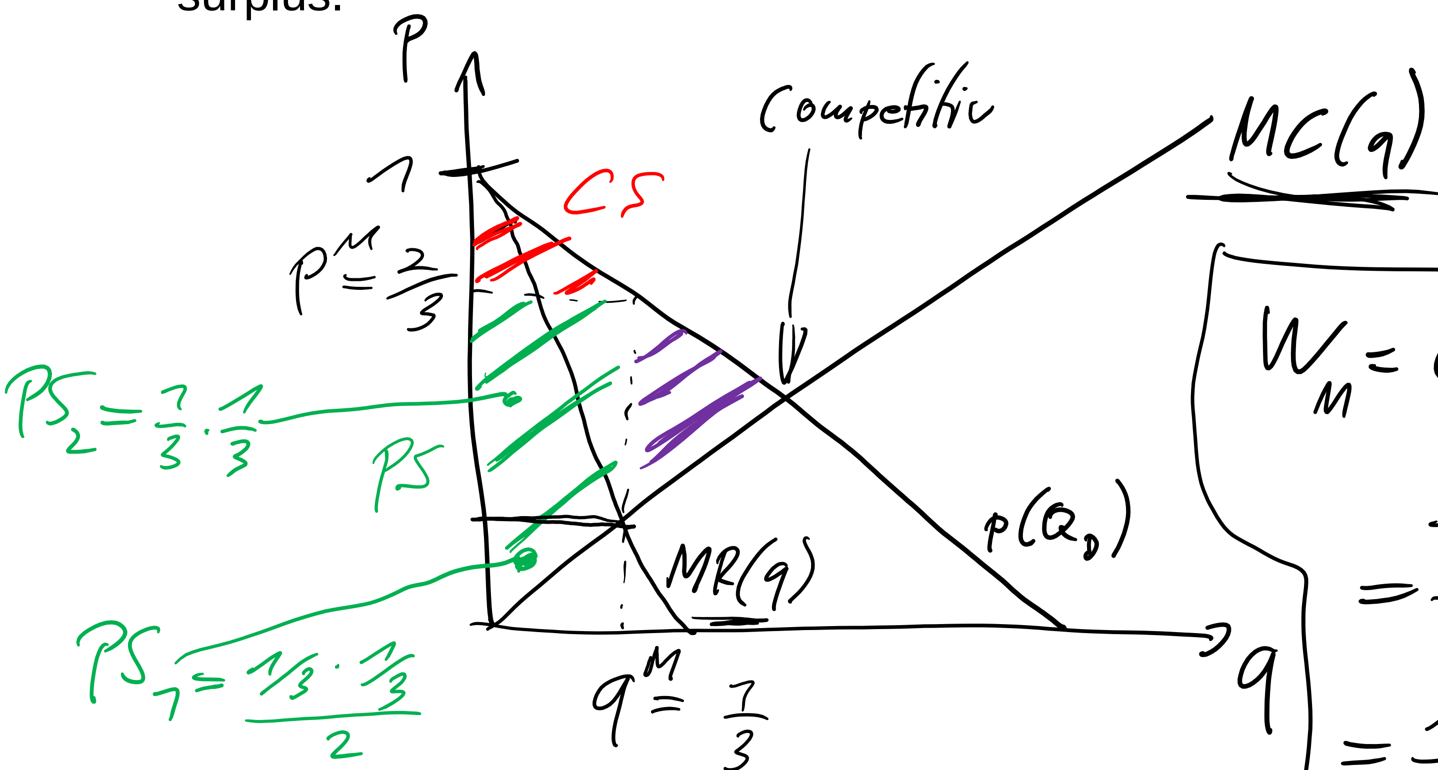
$$\pi_M(Q) = P_M \cdot Q_M - C(Q) = \frac{2}{3}\cdot\frac{1}{3} - \left(\frac{1}{3}\right)^2$$

$$= 1/6$$

# Task 4) Monopoly

Inverse market demand for a homogeneous good is given by $p(Q_D) = 1 - Q_D$ ($Q_D$: aggregate quantity). Suppose first a monopolist serves the market. The monopolist's costs are given by $C(Q) = \frac{Q^2}{2}$.

b) Determine the welfare as the sum of consumer surplus and producer surplus.




$$W_M = CS_M + PS_M$$

$$= \frac{\frac{1}{3} \cdot \frac{1}{3}}{2} + PS_1 + PS_2$$

$$= \frac{1}{18} + \frac{3}{18} = \frac{2}{9}$$

# Task 4) Monopoly

Inverse market demand for a homogeneous good is given by $p(Q_D) = 1 - Q_D$ ($Q_D$: aggregate quantity). Suppose first a monopolist serves the market. The monopolist's costs are given by $C(Q) = \frac{Q^2}{2}$.

Now suppose the market is served by J competitive firms with identical cost structure. Their aggregate cost (given that all firms produce the same quantity q) is the same as for the above monopolist.

c) What is the cost function for firm j?

$$c_j(q_j) \Rightarrow C(Q) = \sum c_j(q_j) = j \cdot c_j(q_j) = \frac{Q^2}{2}$$

$$Q = q_j \cdot j \implies q_j = \frac{Q}{j}$$

$$c_j(q_j) = \frac{(q_j \cdot j)^2}{2 \cdot j} = \frac{q_j^2 \cdot j}{2}$$

# Task 4) Monopoly

Inverse market demand for a homogeneous good is given by $p(Q_D) = 1 - Q_D$ ($Q_D$: aggregate quantity). Suppose first a monopolist serves the market. The monopolist's costs are given by $C(Q) = \frac{Q^2}{2}$.

Now suppose the market is served by J competitive firms with identical cost structure. Their aggregate cost (given that all firms produce the same quantity q) is the same as for the above monopolist.

d) Determine the competitive equilibrium (price, quantity) and the outcome for firm j (quantity and profit).

$P_D(Q) = p(Q) = MC(Q)$ overall market

$1 - Q_D = Q \longrightarrow Q^* = 1/2$

$P^* = 1 - Q^* = 1/2$

$*$ ... market equilibrium

# Task 4) Monopoly

$$MC_j(q_j) = \frac{d\,c_j(q_j)}{d\,q_j} = q_j \cdot j = p^* = \frac{1}{2}$$

$$\pi_j^* = p^* \cdot q_j^* - c_j(q_j^*) = \frac{1}{2} \cdot \frac{1}{2 \cdot j} - \frac{q_j^2 \cdot j}{2} =$$

$$= \frac{1}{4j} - \left(\frac{1}{2 \cdot j}\right)^2 \cdot j \cdot \frac{1}{2} = \frac{1}{4 \cdot j} - \frac{1}{8j}$$

$$\Longrightarrow \pi_j^* = \frac{1}{8 \cdot j}$$

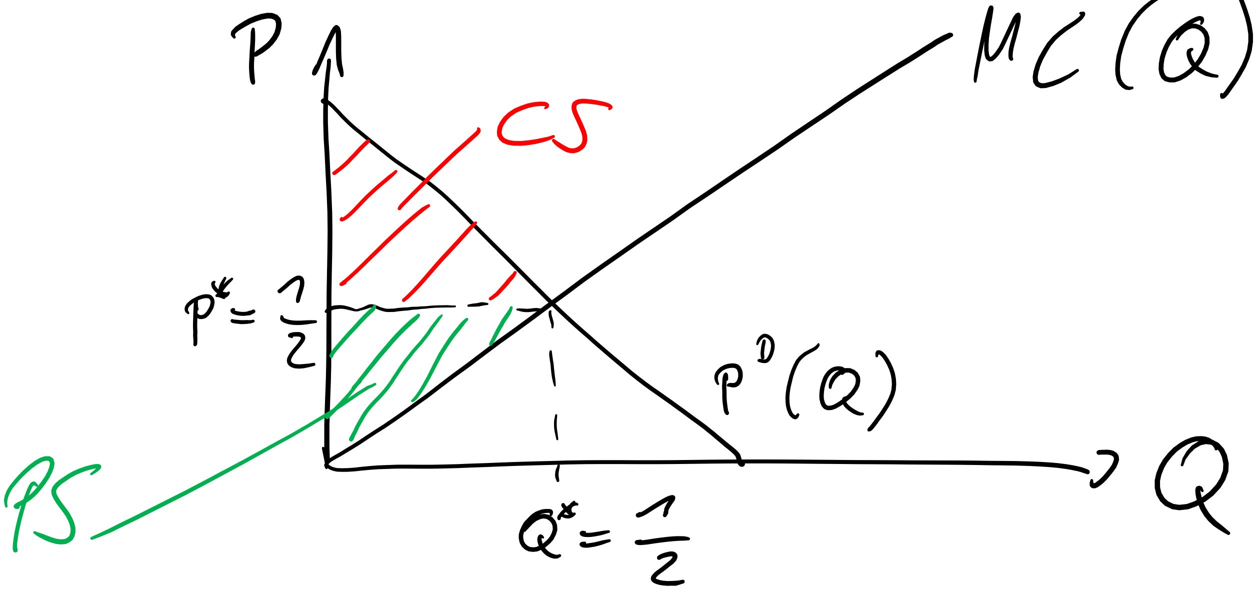
quantity and profits of every firm j depends on the number of competitors

# Task 4) Monopoly

Inverse market demand for a homogeneous good is given by $p(Q_D) = 1 - Q_D$ ($Q_D$: aggregate quantity). Suppose first a monopolist serves the market. The monopolist's costs are given by $C(Q) = \frac{Q^2}{2}$.

Now suppose the market is served by J competitive firms with identical cost structure. Their aggregate cost (given that all firms produce the same quantity q) is the same as for the above monopolist.

e) Determine the welfare.




$$CS^* = \frac{\frac{1}{2} \cdot \frac{1}{2}}{2} = \frac{1}{8}$$

$$PS^* = \frac{\frac{1}{2} \cdot \frac{1}{2}}{2} = \frac{1}{8}$$

$$W^* = CS^* + PS^*$$

$$W^* = \frac{1}{4}$$

# Task 4) Monopoly

Technische Universität Berlin

Inverse market demand for a homogeneous good is given by $p(Q_D) = 1 - Q_D$ ($Q_D$: aggregate quantity). Suppose first a monopolist serves the market. The monopolist's costs are given by $C(Q) = \frac{Q^2}{2}$.

Now suppose the market is served by J competitive firms with identical cost structure. Their aggregate cost (given that all firms produce the same quantity q) is the same as for the above monopolist.

f) Compare the welfare in b) with the welfare in e).

↳ welfare is higher under competition

$$W^* = \frac{1}{4} > W_M = \frac{2}{9}$$

# Task 4) Monopoly

Inverse market demand for a homogeneous good is given by $p(Q_D) = 1 - Q_D$ ($Q_D$: aggregate quantity). Suppose first a monopolist serves the market. The monopolist's costs are given by $C(Q) = \frac{Q^2}{2}$.

Now suppose the market is served by J competitive firms with identical cost structure. Their aggregate cost (given that all firms produce the same quantity q) is the same as for the above monopolist.

g) Give a Paretian interpretation of your result in f). (Hint: Look up the term pareto optimal)

Pareto optimal situation: state of allocation of resources in which it is not possible to make one individual better off without making one individual worse off

- consumers / firms are participants
- Welfare is maxed under perfect competition => everybody wins