Chapter C – Productive und Dynamic Efficiency

Competition Policy and Strategy – German Title: Wettbewerbspolitik und -strategie

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English version of my 2020 lecture

Efficiency – Basics

- Allocative Efficiency: welfare maximized, no Pareto-improvements possible
- Productive Efficiency: production in the cost minimum
- Dynamic Efficiency: degree of innovation (new products/processes)

Possible Trade-offs:

- In perfect competition, allocative efficiency but no incentive to innovate (dynamic inefficiency)
- In monopoly productive efficiency (caveat: managerial slack!), but allocative and dynamic inefficiency

Efficiency – Productive Efficiency

- Production technology $f(x_1, x_2, \ldots, x_n)$ with factor prices w_i, $i \in \{1, 2, \ldots, n\}$.
- Production of a given quantity q in the cost minimum:

$$\min_{x_1, x_2, \ldots, x_n} \sum_{i=1}^{n} w_i x_i \quad : q = f(x_1, x_2, \ldots, x_n)$$

- FOC:

$$w_i - \lambda \frac{\partial f(x_1, x_2, \ldots, x_n)}{\partial x_i} = 0 \; \forall i \in \{1, 2, \ldots, n\}$$

- and

$$q - f(x_1, x_2, \ldots, x_n) = 0.$$

- yields **conditional factor demand** $x_i(w_1, w_2, \ldots, w_n, q)$.
- Cost function $C(w_1, w_2, \ldots, w_n, q) = \sum_{i=1}^{n} w_i x_i(w_1, w_2, \ldots, w_n, q)$.
- In IO, factor prices $(w_1, w_2, \ldots, w_n)$ are usually exogeneously given.
- Stylized cost function $C(q) = F + c(q)$ (s. Chapter A.2)

Efficiency – Productive Efficiency

- Economies of Scale in production exist where $AC(q)$ are decreasing:

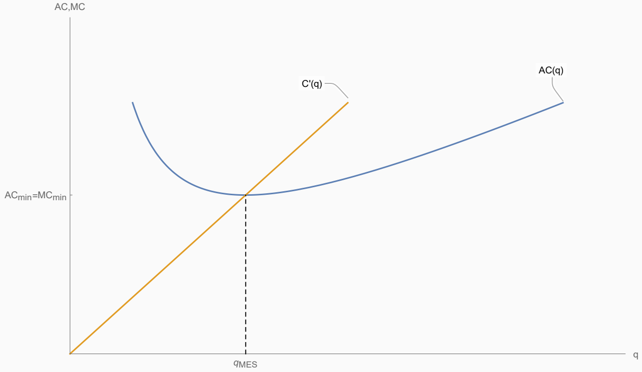
$$AC'(q) = \frac{d}{dq}\frac{C(q)}{q} = \frac{C'(q)q - C(q)}{q^2} < 0 \Leftrightarrow \underbrace{C'(q)}_{\text{marginal costs}} < \underbrace{\frac{C(q)}{q}}_{\text{average costs}}$$

- In other words, Economies of Scale where average costs above marginal costs.
- “fixed cost degression”
- *Scale Economy Index* $SI := \frac{AC(q)}{C'(q)}$
    - $SI > 1$ when $AC(q) > C'(q)$: *Economies of Scale.*
    - $SI < 1$ when $AC(q) < C'(q)$: *Dis-economies of Scale.*
    - For $SI = 1 \Leftrightarrow AC(q) = C'(q)$ Economies of Scale are completely exhausted, *Most efficient Scale, MES.*

Efficiency – Productive Efficiency

Illustration: q_{MES} with $AC(q_{MES}) = C'(q_{MES})$ such that

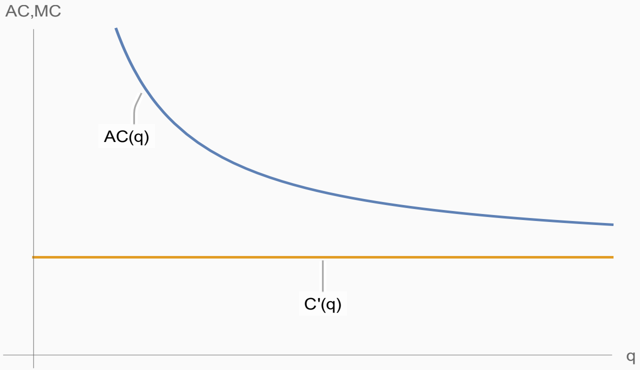
- for all $q < q_{MES}$, we have *Economies of Scale*.
- for all $q > q_{MES}$, we have *Dis-economies of Scale*.



Efficiency – Productive Efficiency

Natural Monopoly

- For $C(q) = F + cq$ (constant marginal costs), Economies of Scale for all $q > 0$.
- Productive Efficiency when one firm serves the entire market! (industries with high average costs, e.g., infrastructure, telecommunication, water supply, ...)



Efficiency – Productive Efficiency

Economies of Scope

- Joint production of multiple products cheaper than production by separate producers/plants
  - shared inputs: transport goods and individuals
  - cost complementarities: casein as byproduct of production whey protein
- Economies of Scope in production of goods 1 and 2 arise if

$$C(q_1, q_2) < C(q_1, 0) + C(0, q_2).$$

- Economies of Scope facilitate
  - multi-product firms
  - industry concentration because cost-advantages for one product can translate lead lower total costs, thus resulting in overall cost-advantage over firms that produce only single product.

Efficiency – Dynamic Efficiency

- Dynamic efficiency through innovation
  - Process innovation: new production technology reduces costs
  - Product innovation: new products/variants
- Here: process innovation (for product innovation, see EoI/IO; also on Economics2Go!)
- Inverse U-shaped relationship between intensity of competition and innovation (Aghion et al 2005, QJE)
  - Monopoly: incentive to innovate is low because of absence of competition (caveat: contestable markets)
  - Oligopoly: incentive to innovate is high because each firm can gain competitive advantage by lowering costs
  - The higher the number of firms in the market the lower additional profits through innovation/lower costs (caveat: Bertrand with homogeneous goods)

Efficiency – Dynamic Efficiency

- Linear demand $q(p) = a - p$
- Cournot competition with n firms.
- Before innovation, all firms are symmetric with costs $C(q_i) = c_0 q_i$
- Profits in equilibrium before innovation $\pi_0 = \left(\frac{a-c_0}{n+1}\right)^2$
- Process innovation lowers marginal costs to $c_1 < c_0$.
- Patent protection (see below): if firm $i \in \{1, 2, \ldots, n\}$ innovates, no other firm can replicate the innovation.

Efficiency – Dynamic Efficiency

Scenario 1 – All firms have access to innvation (e.g., auctioning of innovation)

- Firm i innovates:

$$\max_{q_i} \pi_i(q_i, q_{-i}) = (a - q_i - q_{-i} - c_1)q_i \;\Rightarrow\; q_i(q_{-i}) = \frac{a - c_1}{2} - \frac{q_{-i}}{2}.$$

- Profit-maximization of a non-innovator $j \neq i$:

$$\max_{q_j} \pi_j(q_j, q_{-j}) = (a - q_j - q_{-j} - c_0)q_j \;\Rightarrow\; q_j(q_{-j}) = \frac{a - c_0}{2} - \frac{q_{-j}}{2}.$$

- Equilibrium output of innovator reads q_I. Non-innovator produces $q_{\neg I}$.
- Only firm i innovates, such that $q_{-i} = (n-1)q_{\neg I}$.
- Firm j does not innovate such that $q_{-j} = q_I + (n-2)q_{\neg I}$.
- Equilibrium output reads $q_I^* = \frac{a - c_1 n + c_0(n-1)}{n+1}$ and $q_{\neg I}^* = \frac{a - 2c_0 + c_1}{n+1}$. Ensuing equilibrium price: $p^* = \frac{a + c_1 + (n-1)c_0}{n+1}$.

Efficiency – Dynamic Efficiency

Scenario 1 – All firms have access to innvation (e.g., auctioning of innovation)

- Equilibrium profits:

$$\pi_I = \left(\frac{a - c_0 + n(c_0 - c_1)}{n+1}\right)^2, \; \pi_{\neg I} = \left(\frac{a - 2c_0 + c_1}{n+1}\right)^2.$$

- Incentive to innovate:

$$\Delta\pi_{Scen.1} = \pi_I - \pi_{\neg I}.$$

- For $n \to \infty$, we have $\pi_{\neg I} = 0$ and $\Delta\pi = \pi_I = (c_0 - c_1)^2$. Hence, incentive to innovative decreases in n for all $n \geq 2$.
- Monopolist's incentive to innovate reads $\Delta\pi_M = \pi_M(c_1) - \pi_M(c_0) = \frac{(a-c_1)^2-(a-c_0)^2}{4}$.

Efficiency – Dynamic Efficiency

Scenario 2 – Only firm i has access to innovation (e.g., innovation within the firm)

- Incentive to innovate

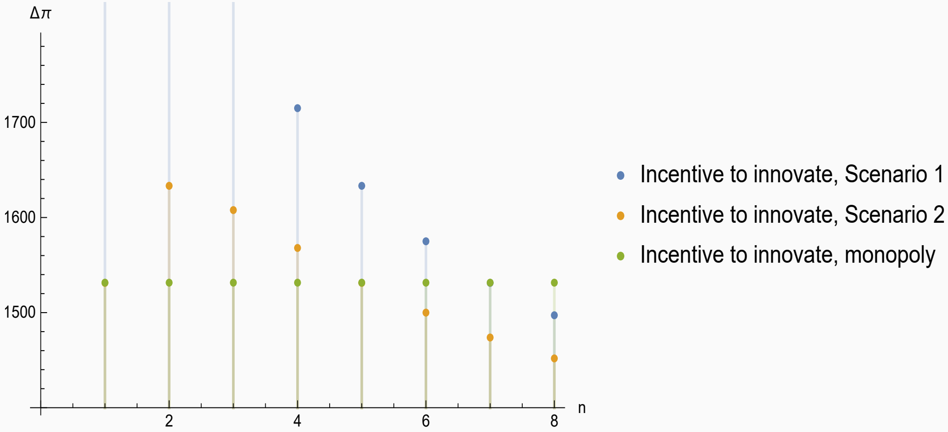
$$\Delta\pi_{Scen.2} = \pi_I - \pi_0.$$

Comparison

- *Business stealing effect* in oligopoly increases incentive to innovate: firms with lower marginal costs have higher market share in equilibrium.
- Monopolist only benefits from lower marginal costs (productive efficiency).
- Incentive to innovate in Scenario 1 always higher than in Scenario 2 as $\pi_0 > \pi_{\neg I}$. In Scenario 1, i anticipates that another firm can adopt innovation if it does not, which would lead to decrease in market shares/profits. This raises incentive to innovate.

Efficiency – Dynamic Efficiency

Innovation incentives for $(a, c_0, c_1) = (110, 40, 5)$



Efficiency – Dynamic Efficiency

- With Bertrand competition, innovating firm can undercut rivals and serve entire market (stronger business stealing than in Cournot).
- Before innvoation $\pi_0 = 0$
- Two cases
    - Non-drastic innovation occurs if monopoly price for c_1 exceeds c_0, $p_M(c_1) > c_0$.
        - Innovating firm charges price $p_I = c_0 - \epsilon \approx c_0$ with $\epsilon \to 0$.
        - Innovating firm's profit $\pi_I = (c_0 - c_1)q(c_0)$.
    - Drastic innovation occurs if $p_M(c_1) < c_0$.
        - Innovating firm undercuts rival(s) by setting $p_M(c_1)$
        - Innovating firm's profit $\pi_M = (p_M(c_1) - c_1)q(p_M(c_1))$.
- In any case, non-innovating firms realize profits of zero.

Efficiency – Dynamic Efficiency

Patents

- Firm *i*'s innovation cannot be adopted by another firm without costs
- Consider Bertrand duopoly with two symmetric firms and homogeneous products. Non-drastic innovation (wlsg).
- Payoffs (π_1, π_2), with indices referring to respective firm
- Costs of innovation F (*sunk costs*) with $\pi_I - F > 0$.
- Payoffs with patent protection:

		Firm 2	
		innovate	do not innovate
Firm 1	innovate	$(-F, -F)$	$(\pi_I - F, 0)$
	do not innovate	$(0, \pi_I - F)$	$(0, 0)$

- Two Nash-equilibria: Either firm 1 innovates and firm 2 does not or vice versa.

Effizienz – Dynamische Effizienz

Patents

- Payoffs without patent protection:

		Firm 2	
		innovate	do not innovate
Firm 1	innovate	$(-F, -F)$	$(-F, 0)$
	do not innovate	$(0, -F)$	$(0, 0)$

- Unique Nash-equilibrium, no firm innovates:
  - free-riding: non-innovator can (costlessly) copy innovation
  - In case of copying, both firms realize zero market profits, however, innovator bears costs of innovation F
  - Firms anticipate free-riding and do not innovate!

Annex – Cost Minimization Slide 2

- Solution cost-minimization

$$\min_{x_1, x_2, \ldots, x_n} \sum_{i=1}^{n} w_i x_i \quad : q = f(x_1, x_2, \ldots, x_n)$$

- Lagrangean

$$\mathcal{L}(x_1, x_2, \ldots, x_n, \lambda) = \sum_{i=1}^{n} w_i x_i + \lambda(q - f(x_1, x_2, \ldots, x_n)).$$

- For all $i \in \{1, 2, \ldots n\}$, using $\frac{\partial \mathcal{L}}{\partial x_i} = 0$, the FOC emerges:

$$w_i = \lambda \frac{\partial f(x_1, x_2, \ldots, x_n)}{\partial x_i}$$

- together with $\frac{\partial \mathcal{L}}{\partial \lambda} = 0$, we also have

$$q = f(x_1, x_2, \ldots, x_n).$$

- Equation system with $n + 1$ equations and unknowns.

Annex – Asymmetric Cournot, Slide 9

- From $\max_{q_i} \pi_i(q_i, q_{-i}) = (a - q_i - q_{-i} - c_1)q_i$, we get FOC

$$\frac{\partial \pi_i}{\partial q_i} = a - 2q_i - q_{-i} - c_1 \overset{!}{=} 0.$$

- Analogously for Firm j with c_0:

$$\frac{\partial \pi_j}{\partial q_j} = a - 2q_j - q_{-j} - c_0 \overset{!}{=} 0.$$

- Let q_I and $q_{\neg I}$ be output of innovating firm and all other firms, respectively. In equilibrium, $q_i = q_I$, $q_{-i} = (n-1)q_{\neg I}$, $q_j = q_{\neg I}$ and $q_{-j} = q_I + (n-2)q_{\neg I}$. Thus,

$$q_I = \frac{a - c_1}{2} - \frac{(n-1)q_{\neg I}}{2}, \quad q_{\neg I} = \frac{a - c_0 - q_I}{2}.$$

- Insert (e.g., $q_{\neg I}$ in q_I) and rearrange:

$$q_I^* = \frac{a - c_1 n + c_0(n-1)}{n+1}, \quad q_{\neg I}^* = \frac{a - 2c_0 + c_1}{n+1}.$$

Annex – Asymmetric Cournot, Slide 9

- Total quantity reads

$$Q^* = q_I^* + (n-1)q_{\neg I}^* = \frac{n(a-c_0) - c_1 + c_0}{n+1}.$$

- With $p = a - Q$, we have $p(Q^*) = a - Q^* = \frac{a+c_1+(n-1)c_0}{n+1}$.
- Profit of innovating firm

$$\pi_I = (p^* - c_1)q_I^* = \left(\frac{a+c_1+(n-1)c_0}{n+1} - c_1\right)\frac{a - c_1 n + c_0(n-1)}{n+1} = \left(\frac{a - c_0 + n(c_0 - c_1)}{n+1}\right)^2.$$

- Profit of non-innovating firm

$$\pi_I = (p^* - c_0)q_{\neg I}^* = \left(\frac{a+c_1+(n-1)c_0}{n+1} - c_0\right)\frac{a - 2c_0 + c_1}{n+1} = \left(\frac{a - 2c_0 + c_1}{n+1}\right)^2.$$