# MICROECONOMICS II

About the course

Topic 1 - Technology

Julie Chytilová
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# TEACHERS

Julie Chytilová

- Lectures
- Office hours: Friday 10:30-11:45 am (please email me first)
- Office 410
- Email: julie.chytilova@fsv.cuni.cz

Matěj Bajgar

- Email: matej.bajgar@fsv.cuni.cz

Seminars & Home assignments

- Dubinina Evgeniya: evgeniya.dubinina@fsv.cuni.cz
- Kantová Klára: klara.kantova@fsv.cuni.cz
- Kmeťková Diana: diana.kmetkova@fsv.cuni.cz
- Landovská Petra: petra.landovska@fsv.cuni.cz

# Classes

Lectures

- Thursday 9:30-10:50am in room 109 plus every other week on Thursday 11:00am-12:20pm in room 109

Joint seminars for all students

- Every other week on Thursday 11:00am-12:20pm in room 109

Regular seminars where the students are divided into three groups.

- Monday 8:00-9:20am in room 206
- Thursday 8:00-9:20am in room 314
- Friday 8:00-9:20am in room 206

It is recommended that the students attend all lectures (blue color in the table), all joint seminars (green) and regular seminars (light, dark or very dark yellow).

# Classes

Please see the syllabus for a visible version of this table.

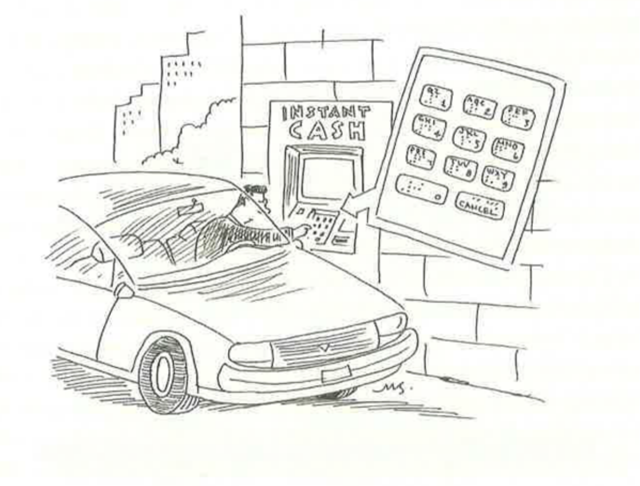
| Day | Date | Time | Room | | Instructor |
|---|---|---|---|---|---|
| Thursday | 5-Oct | 9:30-10:50am | 109 | Lecture 1 | Julie Chytilová |
| Thursday | 5-Oct | 11:00am-12:20pm | 109 | Lecture 2 | Julie Chytilová |
| Friday | 6-Oct | 8:00-9:20am | 206 | Seminar 1 | Evgeniya Dubinina |
| Monday | 9-Oct | 8:00-9:20am | 206 | Seminar 1 | Evgeniya Dubinina |
| Thursday | 12-Oct | 8:00-9:20am | 314 | Seminar 1 | Evgeniya Dubinina |
| Thursday | 12-Oct | 9:30-10:50am | 109 | Lecture 3 | Julie Chytilová |
| Thursday | 12-Oct | 11:00am-12:20pm | 109 | Seminar 2 | Klára Kantová |
| Friday | 13-Oct | 8:00-9:20am | 206 | Seminar 3 | Evgeniya Dubinina |
| Monday | 16-Oct | 8:00-9:20am | 206 | Seminar 3 | Evgeniya Dubinina |
| Thursday | 19-Oct | 8:00-9:20am | 314 | Seminar 3 | Evgeniya Dubinina |
| Thursday | 19-Oct | 9:30-10:50am | 109 | Lecture 4 | Julie Chytilová |
| Thursday | 19-Oct | 11:00am-12:20pm | 109 | Lecture 5 | Julie Chytilová |
| Friday | 20-Oct | 8:00-9:20am | 206 | Seminar 4 | Evgeniya Dubinina |
| Monday | 23-Oct | 8:00-9:20am | 206 | Seminar 4 | Evgeniya Dubinina |
| Thursday | 26-Oct | 8:00-9:20am | 314 | Seminar 4 | Evgeniya Dubinina |
| Thursday | 26-Oct | 9:30-10:50am | 109 | Lecture 6 | Julie Chytilová |
| Thursday | 26-Oct | 11:00am-12:20pm | 109 | Seminar 5 | Klára Kantová |
| Friday | 27-Oct | 8:00-9:20am | 206 | Dean's day, no seminar, please take Seminar 6 on Monday or Thursday | |
| Monday | 30-Oct | 8:00-9:20am | 206 | Seminar 6 | Diana Kmeťková |
| Thursday | 2-Nov | 8:00-9:20am | 314 | Seminar 6 | Diana Kmeťková |
| Thursday | 2-Nov | 9:30-10:50am | 109 | Lecture 7 | Julie Chytilová |
| Thursday | 2-Nov | 11:00am-12:20pm | 109 | Lecture 8 | Julie Chytilová |
| Friday | 3-Nov | 8:00-9:20am | 206 | Seminar 7 | Diana Kmeťková |
| Monday | 6-Nov | 8:00-9:20am | 206 | Seminar 7 | Diana Kmeťková |
| Thursday | 9-Nov | 8:00-9:20am | 314 | Seminar 7 | Diana Kmeťková |
| Thursday | 9-Nov | 9:30-10:50am | 109 | Lecture 9 | Julie Chytilová |
| Thursday | 9-Nov | 11:00am-12:20pm | 109 | Lecture 10 | Julie Chytilová |
| Friday | 10-Nov | 8:00-9:20am | 206 | Seminar 8 | Diana Kmeťková |
| Monday | 13-Nov | 8:00-9:20am | 206 | Seminar 8 | Diana Kmeťková |
| Thursday | 16-Nov | 8:00-9:20am | 314 | Seminar 8 | Diana Kmeťková |
| Thursday | 16-Nov | 9:30-10:50am | 109/206 | midterm | |
| Thursday | 16-Nov | 11:00am-12:20pm | 109 | seminar midterm | Evgeniya Dubinina |
| Friday | 17-Nov | 8:00-9:20am | 206 | public holiday | |
| Monday | 20-Nov | 8:00-9:20am | 206 | no seminar | The lectures and |
| Thursday | 23-Nov | 8:00-9:20am | 314 | no seminar | seminars will be replaced |
| Thursday | 23-Nov | 9:30-10:50am | 109 | no lecture | in the first two weeks of |
| Thursday | 23-Nov | 11:00am-12:20pm | 109 | no lecture/seminar | January 2024, if needed |
| Friday | 24-Nov | 8:00-9:20am | 206 | Seminar 9 | Diana Kmeťková |
| Monday | 27-Nov | 8:00-9:20am | 206 | Seminar 9 | Diana Kmeťková |
| Thursday | 30-Nov | 8:00-9:20am | 314 | Seminar 9 | Diana Kmeťková |
| Thursday | 30-Nov | 9:30-10:50am | 109 | Lecture 11 | Julie Chytilová |
| Thursday | 30-Nov | 11:00am-12:20pm | 109 | Seminar 10 | Klára Kantová |
| Friday | 1-Dec | 8:00-9:20am | 206 | Seminar 11 | Petra Landovská |
| Monday | 4-Dec | 8:00-9:20am | 206 | Seminar 11 | Petra Landovská |
| Thursday | 7-Dec | 8:00-9:20am | 314 | Seminar 11 | Petra Landovská |
| Thursday | 7-Dec | 9:30-10:50am | 109 | Lecture 12 | Matěj Bajgar |
| Thursday | 7-Dec | 11:00am-12:20pm | 109 | Lecture 13 | Matěj Bajgar |
| Friday | 8-Dec | 8:00-9:20am | 206 | Seminar 12 | Petra Landovská |
| Monday | 11-Dec | 8:00-9:20am | 206 | Seminar 12 | Petra Landovská |
| Thursday | 14-Dec | 8:00-9:20am | 314 | Seminar 12 | Petra Landovská |
| Thursday | 14-Dec | 9:30-10:50am | 109 | Lecture 14 | Matěj Bajgar |
| Thursday | 14-Dec | 11:00am-12:20pm | 109 | Seminar 13 | Klára Kantová |
| Friday | 15-Dec | 8:00-9:20am | 206 | Seminar 14 | Petra Landovská |
| Monday | 18-Dec | 8:00-9:20am | 206 | Seminar 14 | Petra Landovská |
| Thursday | 21-Dec | 8:00-9:20am | 314 | Seminar 14 | Petra Landovská |
| Thursday | 21-Dec | 9:30-10:30am | 109 | Seminar recap | Klára Kantová |
| Thursday | 21-Dec | 10:40am-12:20pm | 109 | Final exam 1 | |
| | | | | | |
| Thursday | 11-Jan | 9:30-11:10am | 109 | Final exam 2 | |
| Thursday | 18-Jan | 9:30-11:10am | 109 | Final exam 3 | |
| Thursday | 15-Feb | 9:30-11:10am | 109 | Final exam 4 | |

| | |
|---|---|
| | Lectures |
| | Super-seminars |
| | Friday seminars |
| | Monday seminars |
| | Thursday seminars |

## TOPICS

Theory of producer behavior and market structure

- Technology
- Profit maximization
- Cost minimization
- Firm supply
- Industry supply
- Monopoly, price discrimination
- Oligopoly




Why do the keypad buttons on drive-up cash machines have Braille dots?



Why is milk sold in rectangular containers and soft drinks in round ones?



Why do budget airlines charge for onboard meals (free on luxury airlines), while luxury hotels charge for Internet access (free at budget hotels)?

# LITERATURE

Hal R. Varian, Intermediate Microeconomics: A Modern Approach, W.W. Norton and Company, 8th edition, 2010.

- Many copies are available in the IES library.
- Any extensions presented at the lectures and not available in the Varian textbook can be downloaded from SIS.

Other useful textbooks:

- T. Nechyba, Microeconomics: An Intuitive Approach with Calculus, South-Western, Cengage Learning
- W. Nicholson/C. Snyder, Microeconomic Theory: Basis Principles and Extensions, South- Western
- Schotter, Microeconomics: A Modern Approach, South-Western 2009

## GRADING

- Two home assignments (5 points each, in total 10 points)
- Mid-term exam (30 points)
- Final exam (60 points)

Final grade

- A: 90.1-100
- B: 80.1-90
- C: 70.1-80
- D: 60.1-70
- E: 50.1-60
- F: 0-50

# SCHEDULE

Home assignments

- HA1: released on October 19, submission deadline on October 29.
- HA2: released on November 30, submission deadline on December 10.

Midterm exam: November 16th, 2023, 9:30-10:50am, in rooms 109 (surname starting with K-Z) and 206 (surname starting with A-J).

There will be one midterm exam only. If you cannot attend the midterm exam you will be requested to provide confirmation that your health condition prevented you from attending it.

# Schedule

Final exam

- December 21, 2023, 10:40am-12:20pm
- January 11, 2024, 9:30-11:10am
- January 18, 2024, 9:30-11:10am
- February 15, 2024, 9:30-11:10am

# Topic 1 - Technology

# Inputs and outputs

Constraints imposed by customers, competitors, **nature**.

Technology: transformation of inputs in outputs

Factors of production: Land, labor, raw materials, (physical) capital

Flow units

Assumptions

- Costless not to use all inputs
- Perfect divisibility of inputs and outputs
- Perfect information
- Non-existence of externalities
- Homogeneity of inputs and outputs
- More assumptions later on

# TECHNOLOGICAL CONSTRAINTS

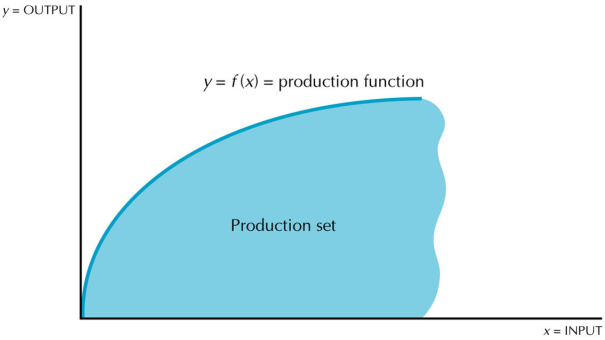



**FIGURE 18.1 A production set**

*Intermediate Microeconomics*, 8th Edition

# Technological constraints

## Production set

- All feasible combinations of inputs and outputs
- $Y = \{(y, x_1, ..., x_n) | 0 \leq y \leq f(x_1, ..., x_n); x_i \geq 0 \forall i\}$

## Production function

- Upper boundary of the production set
- Production function $f$ assigns to each bundle of inputs $(x_1, ..., x_n)$ the maximum possible output which can be produced from such a bundle: $y \leq f(x_1, ..., x_n)$

## Isoquant of production

- A set of all possible combinations of inputs that are just sufficient to produce a given amount of output
- $Q(y^0) = \{(x_1, ..., x_n) \in \mathbb{R}^n_{0,+} | f(x_1, ..., x_n) = y^0\}$

# Examples of technologies

**Fixed proportions** (Leontief technology)

- One input cannot be replaced by the other
- $y = f(x_1, x_2) = min\{ax_1, bx_2\}$
- To produce one unit of output we need $\alpha = \dfrac{1}{a}$ units of $x_1$ and $\beta = \dfrac{1}{b}$ units of $x_2$
- The slope of the line connecting the kink points is equal to $a/b$

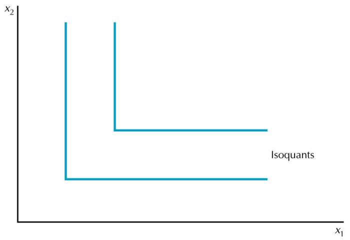
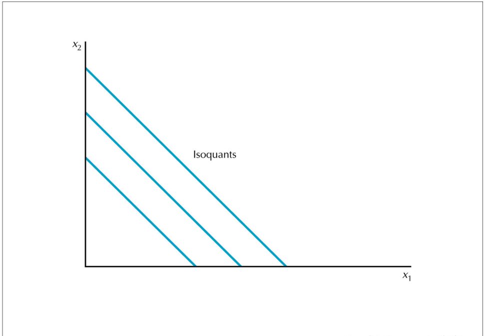



FIGURE 18.2 **Fixed proportions**

# Examples of technologies

**Perfect substitutes**

- Easy to switch between inputs.
- $y = f(x_1, x_2) = ax_1 + bx_2$
- To produce one unit of output we need $\alpha = \dfrac{1}{a}$ units of $x_1$ or $\beta = \dfrac{1}{b}$ units of $x_2$
- $a(b)$ tells us how many units of output we can produce from one unit of $x_1(x_2)$
- The slope of the isoquant is equal to $-a/b$



# EXAMPLES OF TECHNOLOGIES

**Cobb-Douglas** production function

- Less than perfect substitutes, less than perfect complements.
- $y = f(x_1, x_2) = Ax_1^a x_2^b$
- $A$ measures the scale of production.
- $a$ and $b$ measure responsiveness of output to changes in the inputs.

# Properties of technology

Assumptions about production function and isoquants

- Inputs and outputs are non-negative
- Essentiality: $f(0, ..., 0) = 0$
  - Strong essentiality: $\exists i : x_i = 0 \Rightarrow f(x_1, ..., x_n) = 0$
- Inefficient production is possible: $\forall (x_1, ..., x_n) : 0 \leq y \leq y_{max} = f(x_1, ..., x_n)$
- Perfect divisibility of all inputs and outputs
- Continuity of the production function
- Smoothness of the production function
- Monotonicity of the production function: $\forall x \in X \exists i : \dfrac{\partial f}{\partial x_i} > 0$
- Convexity (isoquants bend towards the origin): $f(\lambda x_1 + (1 - \lambda) z_1, \lambda x_2 + (1 - \lambda) z_2) \geq f(x_1, x_2) = f(z_1, z_2)$

# PROPERTIES OF TECHNOLOGY

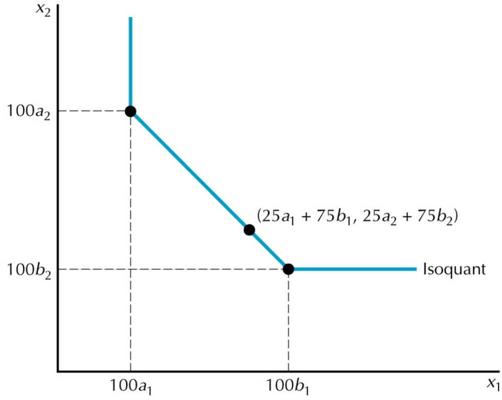



**FIGURE 18.4 Convexity**

# Marginal product

Marginal product of factor 1: Extra output from increasing the input of factor 1 a little bit and keeping factor 2 fixed.

- $MP_1(x_1, x_2) = \dfrac{\triangle y}{\triangle x_1} = \dfrac{f(x_1 + \triangle x_1, x_2) - f(x_1, x_2)}{\triangle x_1}$
- $MP_i = \dfrac{\partial f}{\partial x_i}(x)$

Assumptions

- Monotonic technology: MP non-negative
- Law of diminishing marginal product: $\dfrac{\partial MP_1(x_1, x_2)}{\partial x_1} \leq 0$

# Marginal product, application

Microcredit - promise to alleviate poverty

- Loans to poor people, who were thought to be "unbankable" (no collateral, illiteracy).
- M. Yunus, Nobel peace prize, 74 million clients in 2009.
- Repayment rate above 95%.

Important assumption: high returns to investment for the poor.

# Marginal product, application

Measuring returns to capital: deMel, McKenzie, Woodruff (2008)

- Sample: 400 microenterprises in Sri Lanka (small grocery stores, sewing clothing, making bamboo products, repairing bicycles, etc.)
- Randomized grants: \$0, \$100 or \$200.
- Follow-up data collected in the next 15 months.
- Return to capital 5% per month.

Measuring returns to other inputs (management practices): Bloom et al. (2013)

- Sample: 17 large textile firms in India.
- Randomized provision of free consulting services of Accenture.
- Follow-up data collected in the next three years.
- Adopting recommended management practices raised productivity by 17% in the first year and in three years led to opening of more new plants.

# Description of isoquants of production

- Slope
- Curvature
- Density

# Technical rate of substitution

Slope of the isoquant

- $\triangle y = MP_1(x_1, x_2) \triangle x_1 + MP_2(x_1, x_2) \triangle x_2 = 0$

$$TRS(x_1, x_2) = \frac{\triangle x_2}{\triangle x_1} = -\frac{MP_1(x_1, x_2)}{MP_2(x_1, x_2)}$$

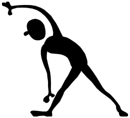
- $df(x) = \frac{\partial f}{\partial x_1}(x) \cdot dx_1 + \frac{\partial f}{\partial x_2}(x) \cdot dx_2 = 0$

$$\frac{dx_2}{dx_1} = -\frac{\frac{\partial f}{\partial x_1}(x)}{\frac{\partial f}{\partial x_2}(x)} = -\frac{MP_1}{MP_2}$$

Assumptions

- Diminishing TRS (isoquants have convex shape)

# Technical rate of substitution



**Exercise**

Production function $f(x) = \sqrt{x_1 + 1} + \sqrt{x_2 + 1} - 2$

Derive technical rate of substitution for $(x_1, x_2) = (15, 8)$

# Technological efficiency of production

Technological efficiency: Not possible to produce the output with smaller amount of at least one input while the amount of other inputs is held constant.

A cost-minimizing firm will always choose a point in the **economic region** , i.e. where the slope of the isoquant is negative

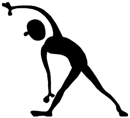
Output efficiency of production: $y = f(x)$

# Elasticity of substitution

Curvature of the isoquant can be described by the rate by which the ratio of inputs changes when we change the slope of the isoquant.

- High for substitutes
- Low for complements
- $\sigma = \dfrac{\% \triangle \dfrac{x_j}{x_i}}{\% \triangle |TRS_{ji}|} = \dfrac{\triangle \dfrac{x_j}{x_i}}{\dfrac{x_j}{x_i}} / \dfrac{\triangle |TRS_{ji}|}{|TRS_{ji}|}$
- $\sigma = \dfrac{1}{\dfrac{d|TRS_{ji}|}{d(\dfrac{x_j}{x_i})}} \cdot \dfrac{|TRS_{ji}|}{\dfrac{x_j}{x_i}}$

# Elasticity of substitution



**Exercise**

Production function $f(x) = 3\sqrt{x_1} + 4\sqrt{x_2}$

Derive the elasticity of substitution

# Elasticity of substitution

**CES function** (constant elasticity of substitution)

- $y = A(a_1 x_1^{\alpha} + a_2 x_2^{\alpha})^{\frac{1}{\alpha}}, A > 0, a_1 + a_2 = 1$
- $TRS_{21} = -\dfrac{a_1 x_1^{\alpha-1}}{a_2 x_2^{\alpha-1}}$

Special cases

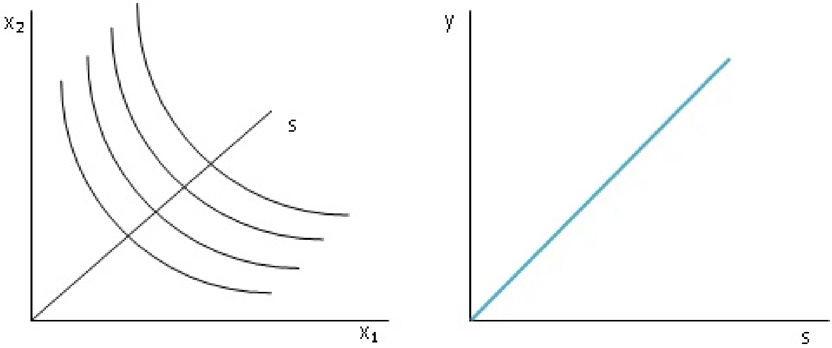
- Linear production function (perfect substitutes)
  - $\alpha = 1, \sigma \to \infty$
- Cobb-Douglas production function
  - $\alpha \to 0, \sigma = 1$
- Leontief production function (perfect complements)
  - $\alpha \to -\infty, \sigma \to 0$

# Returns to scale

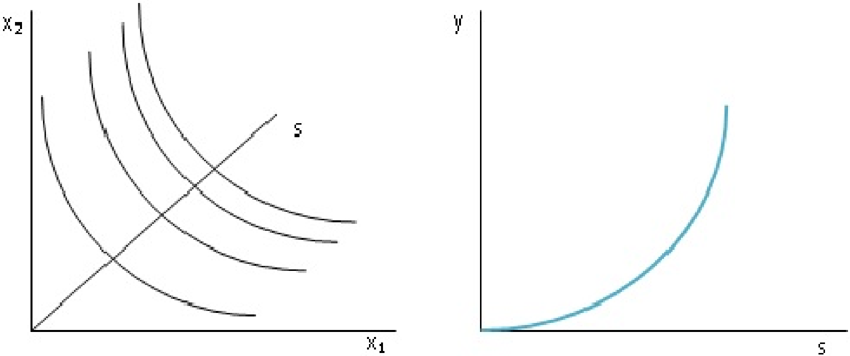
Change in output when we scale the amount of all inputs by constant factor

- Constant returns to scale
  - $f(sx_1, sx_2) = sf(x_1, x_2)$
  - $\frac{y}{s}$ is constant in $s$
  - Replicate what has been done before.
  - Consistent with diminishing *MP* to each factor.
- Increasing returns to scale
  - $f(sx_1, sx_2) > sf(x_1, x_2)$
  - $\frac{y}{s}$ is increasing in $s$
  - Not necessary to increase all inputs to increase output, synergies
- Decreasing returns to scale
  - Peculiar case
  - $f(sx_1, sx_2) < sf(x_1, x_2)$
  - $\frac{y}{s}$ is decreasing in $s$
  - Inputs not homogenous, loss of efficiency of organization

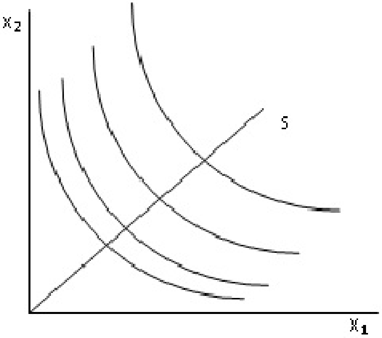
# Constant returns to scale

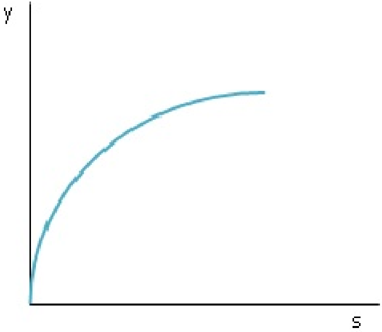


# Increasing returns to scale



# Decreasing returns to scale



# Elasticity of returns to scale

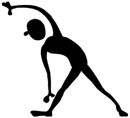
The effect of the relative change in scale of production on the relative change in production.

$$e_s^y = \frac{\frac{dy}{y}}{\frac{ds}{s}} = \frac{dy}{ds}\frac{s}{y}$$

$$e_s^y = \frac{df(sx)}{ds}\frac{s}{f(sx)}$$

- Constant returns to scale: $e_s^y = 1$
- Increasing returns to scale: $e_s^y > 1$
- Decreasing returns to scale: $e_s^y < 1$

# Elasticity of returns to scale



**Exercise**

Production function $f(x) = 3\sqrt{x_1} + 4\sqrt{x_2}$

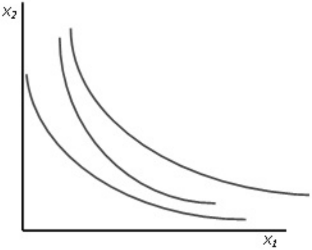
Derive the elasticity of returns to scale. Are they constant, increasing or decreasing?

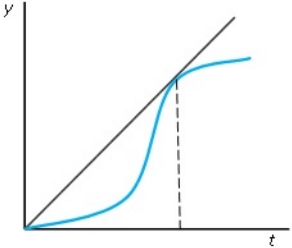
# Elasticity of returns to scale

Technology can exhibit different kind of returns to scale for different ratios of inputs.

Technology can exhibit different kind of returns to scale at different levels of production.

- Minimum efficient scale of production: highest $\frac{y}{s}$



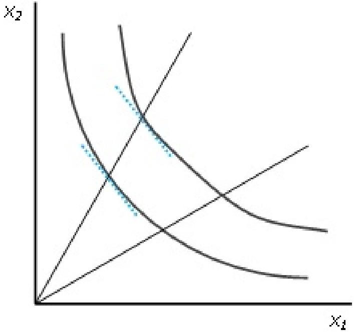
# Homogenous production function

Production function: $f(sx) = s^t f(x)$
Linearly homogenous production function: $t = 1$

Useful properties

- Elasticity of returns to scale is constant and equal to $t$.
- Function homogenous of degree $t$: MP homogenous of degree $t - 1$ .
- TRS depends on the ratio of inputs, not on the scale of production.

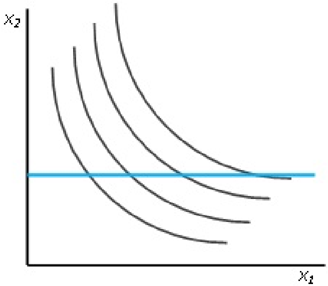
# Homogenous production function



# Short-run

Short-run: some factors of production are fixed
Long-run: all factors of production can be varied
No specific time interval

Short-run production function: $f(x_1, \bar{x_2})$



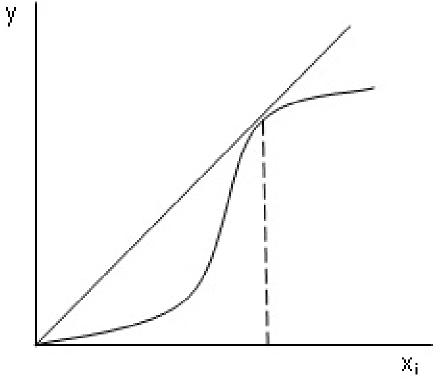
## Short-run

Average product: $AP_i(x) = \frac{y}{x_i} = \frac{f}{x_i}(x)$

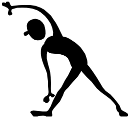
**Returns to factor**

- Elasticity of returns to factor i: $e^y_{x_i} = \frac{MP_i}{AP_i} = \frac{\frac{\partial f(x_i)}{\partial x_i}}{\frac{f(x_i)}{x_i}}$
- Increasing returns: AP increasing, $MP > AP$, $e^y_{x_i} > 1$
- Decreasing returns: AP decreasing, $MP < AP$, $e^y_{x_i} < 1$
- $MP = AP$, $e^y_{x_i} = 1$: constant returns to factor, or change from increasing to decreasing or vice versa

# SHORT-RUN



# Short-run



**Exercise**

Production function $f(x) = (\sqrt{x_1} + \sqrt{x_2})^3$ and in the short-run $x_2 = 4$

Derive the short-run production function

Calculate the elasticity of returns to factor 1 and find the amount of $x_1$ where the returns change from increasing to decreasing

# Relationship between MP and AP