EE211
PRINCIPLES OF MICROECONOMICS

Topic 7

Production and Costs in the Short and Long Run

Introduction

- Firm's objective is to maximize its profit, and the profit is defined by: Profit = Total Revenue – Total Cost

- The components of profits are:
  - Price → depends on the market structure
  - Output
  - Cost
- Hence, in this lecture, we will discuss:
  - How the firm decides to use inputs to maximize the output;
  - How the firm decides to use inputs to minimize the cost.

Economic Costs vs. Accounting Costs

- **Accounting costs** (or explicit costs) – costs that actually involve a purchase of goods and services by the firm
  - e.g. wage paid to workers, rent, costs of purchasing intermediate inputs

➢ Accounting profit = Revenues – Explicit costs

- **Economic costs** – all costs incurred in the production, including both explicit and implicit costs.
  - Implicit costs are the opportunity costs of items for which there is no market transaction (e.g. costs of the owner's time)

➢ Economic profit = Revenues – (Explicit costs + Implicit costs)

Production Function

- **Production function** illustrates the relationship between inputs and outputs for given a technology level, when the inputs are used efficiently.
- In general, a production function can be written as:

$$Q = f(inputs)$$

$$Q = f(x_1, x_2, \ldots, x_n)$$

- Simplified version:

$$\boldsymbol{Q = f(L, K)}$$

where Q = output, L = labor, K = capital

Short-Run vs. Long-Run Production

- The **short run** is the length of time over which some of the firm's factors of production are fixed.
- The **long run** is the length of time over which all of the firm's factors of production can be varied, but its technology is fixed.

Example:

- Long-run production: $Q = f(L, K)$
- Suppose capital is held constant at K_0. Short-run production can be written as:

$$\boldsymbol{Q = f(L, K_0) = TP_{K_0}(L)}$$

Graph: Long-Run Production

Graph: Short-Run Production

PRODUCTION AND COSTS IN THE SHORT RUN

Topics

- Production Function in the Short Run
  - Total product, average product, and marginal product
  - Law of diminishing returns
- Cost in the Short Run
  - Total cost, average cost, and marginal cost
  - Short-run costs: TFC, TVC, TC, AFC, AVC, ATC, MC
- Relationship between production and cost in the short run

Production Function in the Short Run

- **Total product (TP):**

$$\mathrm{TP} = Q = f(L)$$

- **Average Product (AP)** is the output per unit of input.

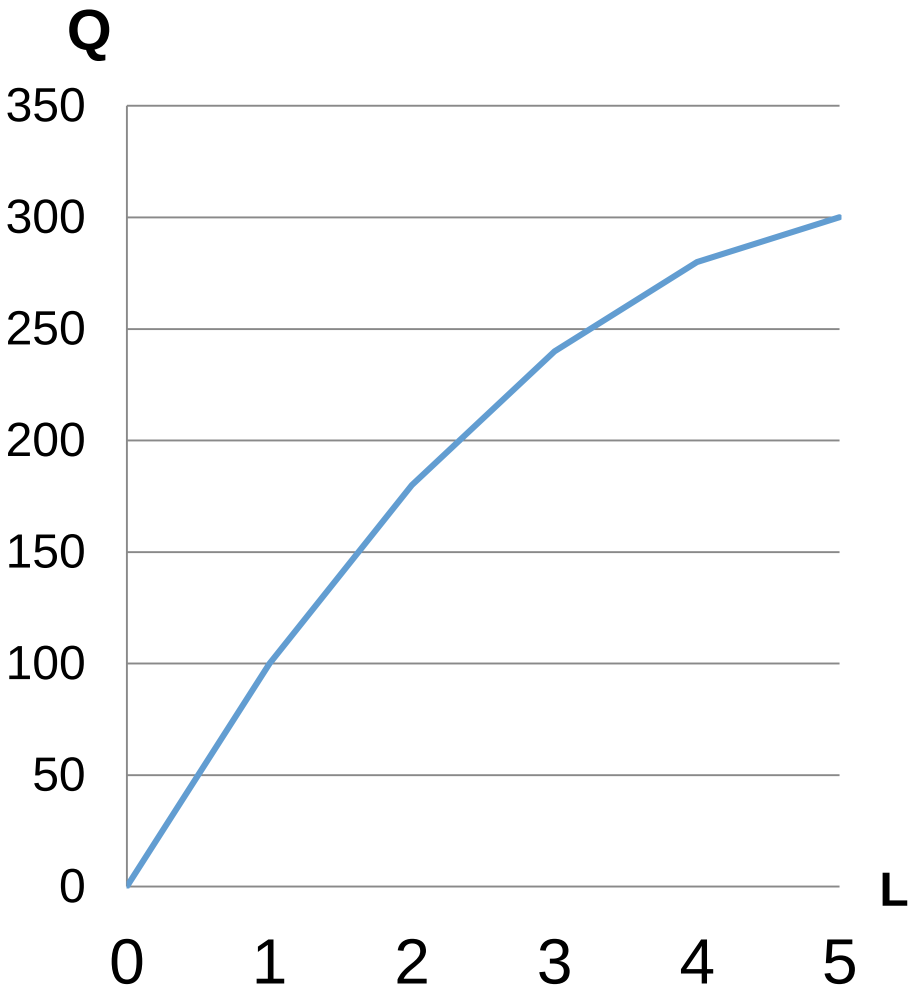
$$\mathrm{AP} = \frac{TP}{L} = \frac{Q}{L}$$

- **Marginal Product (MP)** is the increase in output arising from an additional unit of that input, holding all other inputs constant.

$$\mathrm{MP} = \frac{\Delta TP}{\Delta L} = \frac{\Delta Q}{\Delta L}$$

Example:
Production Function in the Short Run

L	Q
0	0
1	100
2	180
3	240
4	280
5	300



Example 1

L	TP	AP	MP
0	0		
1	100		
2	180		
3	240		
4	280		
5	300		

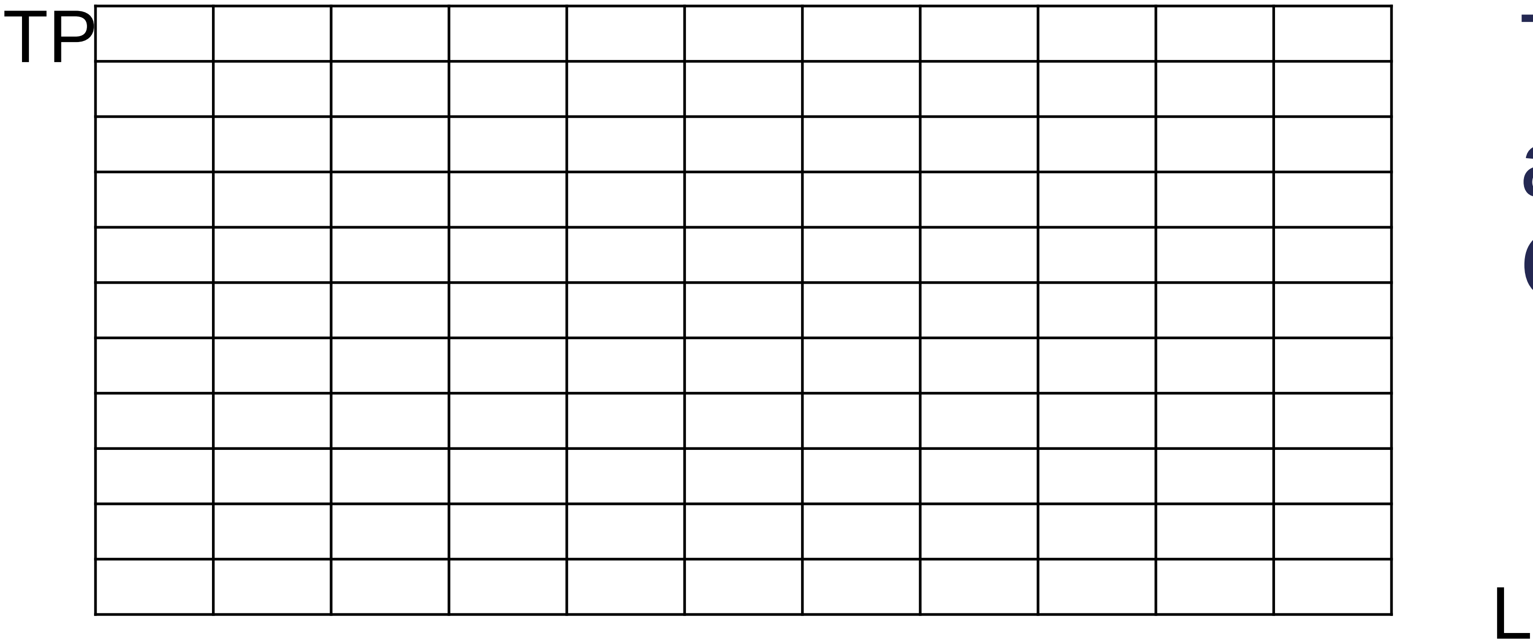
Diminishing Marginal Productivity

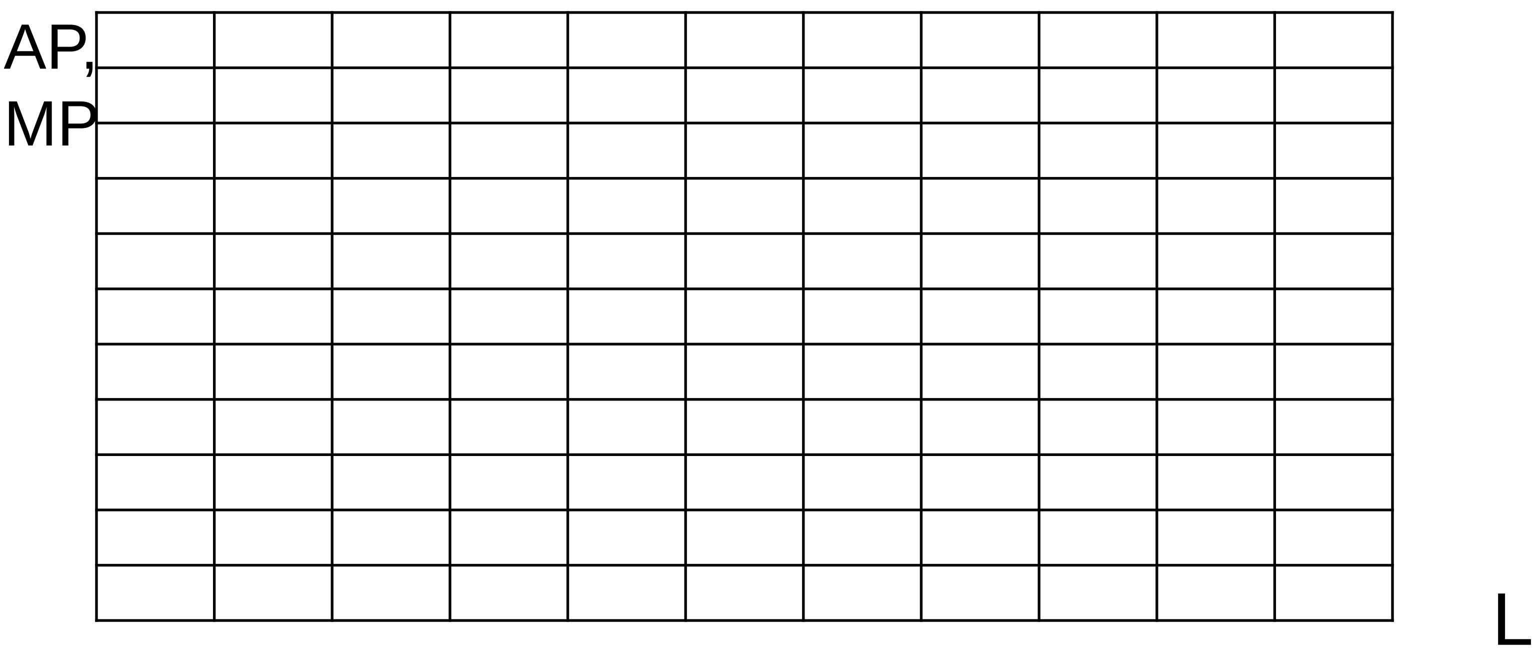
- **Law of diminishing marginal return**

If increasing quantities of a variable factor are applied to a given quantity of fixed factors, the marginal product of the variable factor will eventually decrease.

- Example: From previous slide, the output rises by a smaller and smaller amount for each additional worker. **Why?**

TP, AP, and MP Curves

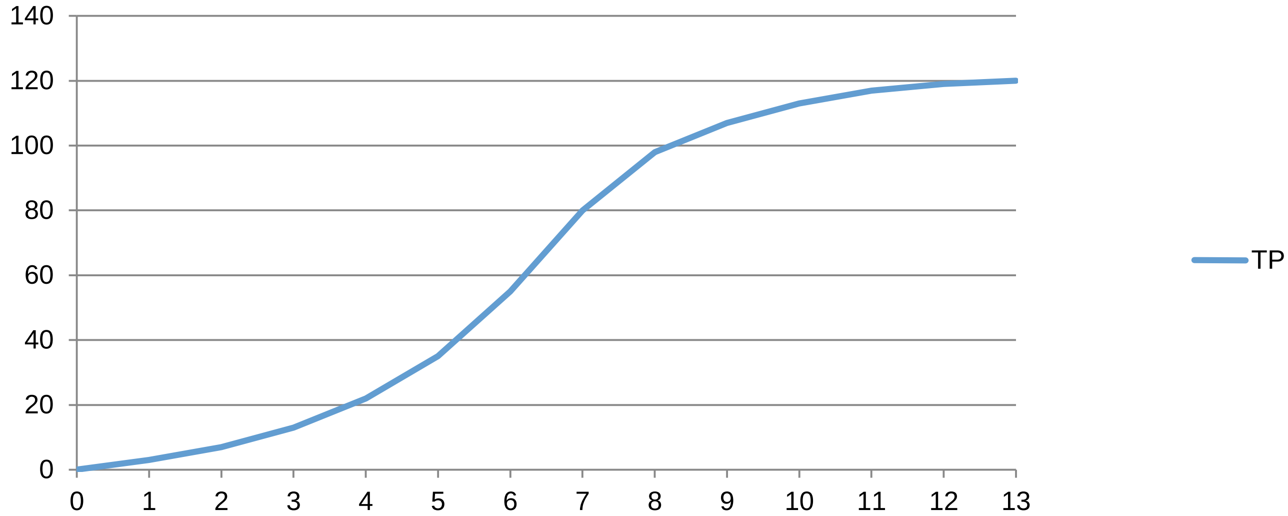


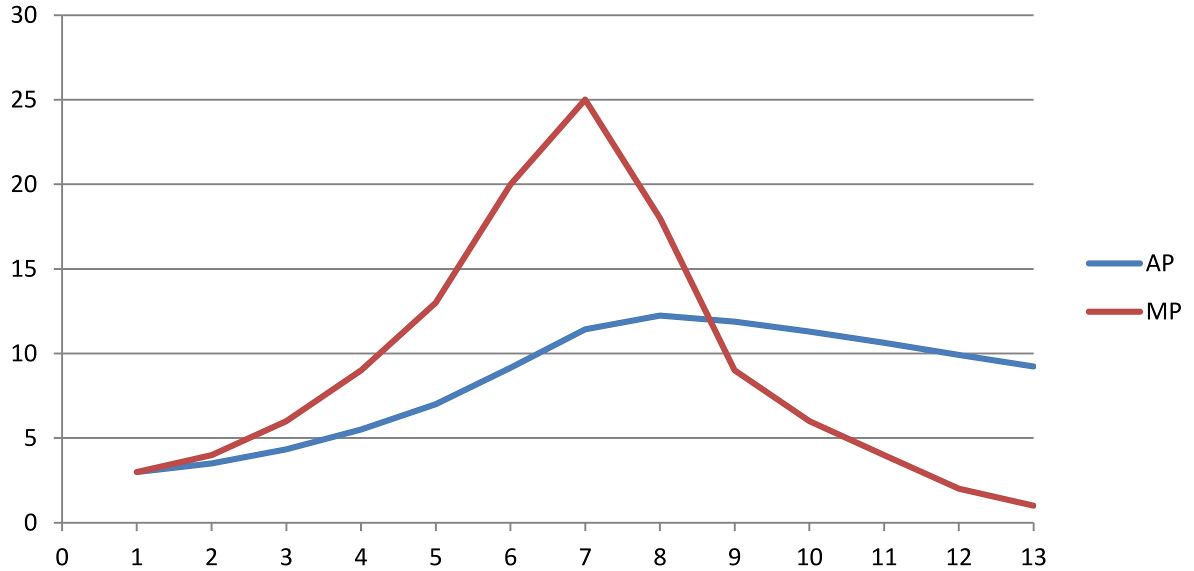


Example 2 (Exercise for Own Practice!)

L	TP	AP	MP
0	0		
1	3	3.00	3
2	7	3.50	4
3	13	4.33	6
4	22	5.50	9
5	35	7.00	13
6	55	9.17	20
7	80	11.43	25
8	98	12.25	18
9	107	11.89	9
10	113	11.30	6
11	117	10.64	4
12	119	9.92	2
13	120	9.23	1

Graph (Plot TP, AP, MP from the previous table using excel)





Costs in the Short Run: TC, TFC, and TVC

- **Total costs (TC)** - the sums of all costs that the firm incurs to produce a given level of output.

$$TC = TFC + TVC$$

- Total fixed cost (TFC) – all costs of production that do not vary with the level of output

- Total variable cost (TVC) – total costs of production that vary directly with the level of output

ATC, AFC, AVC, and MC

- Average total cost (ATC) – Total costs per unit of output

$$ATC = \frac{TC}{Q} = AFC + AVC$$

- Average fixed cost (AFC) – Total fixed costs divided by the number of units of output

$$AFC = TFC/Q$$

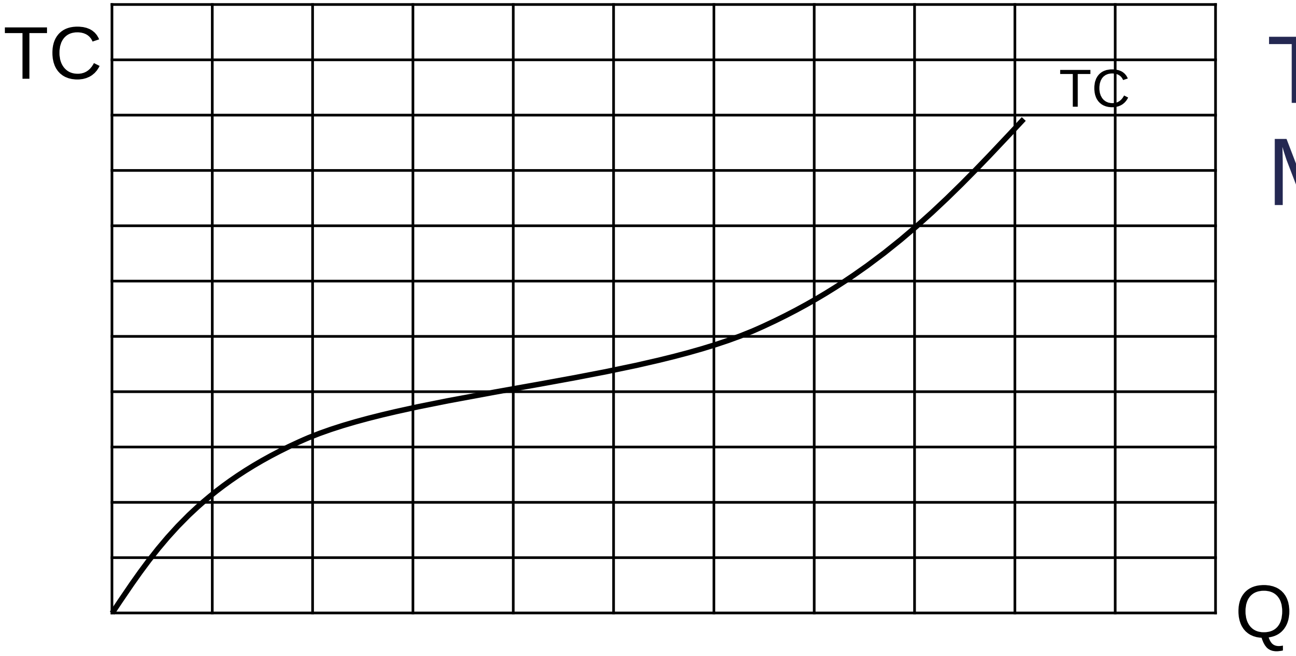
- Average variable cost (AVC) – Total variable costs divided by the number of units of output

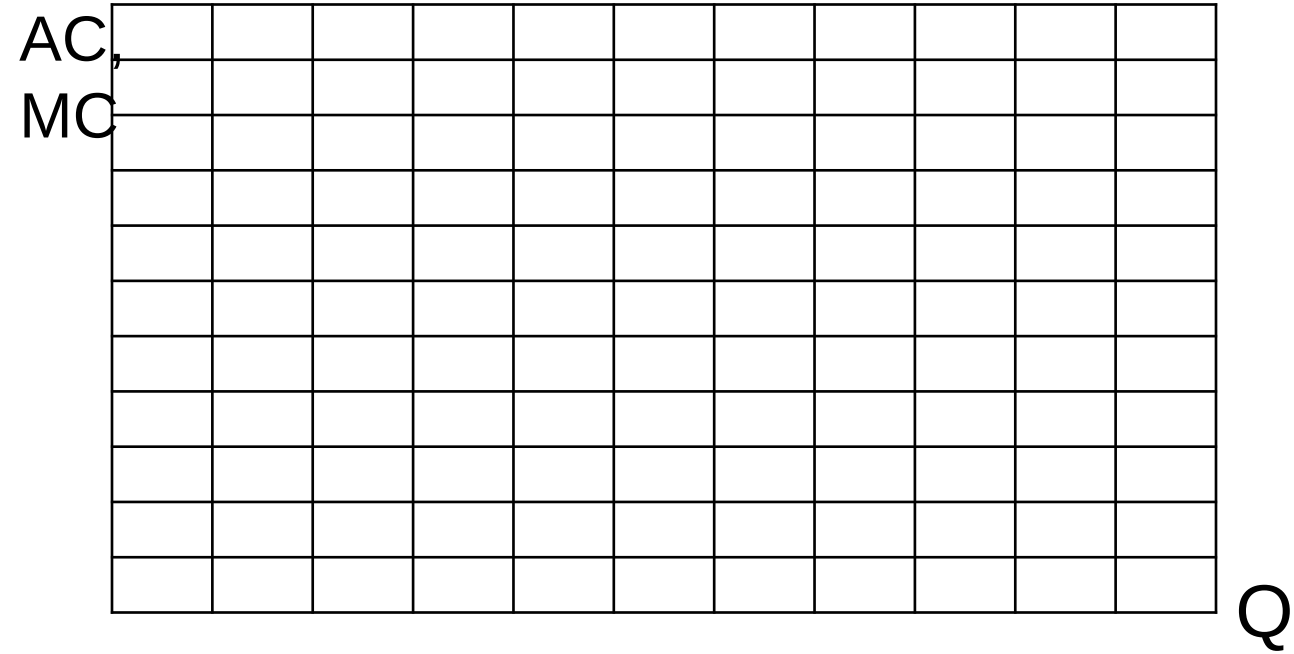
$$AVC = TVC/Q$$

- **Marginal cost (MC)** – The increase in total cost resulting from increasing output by one unit

$$MC = \frac{\Delta TC}{\Delta Q}$$

TC, ATC, and MC Curves

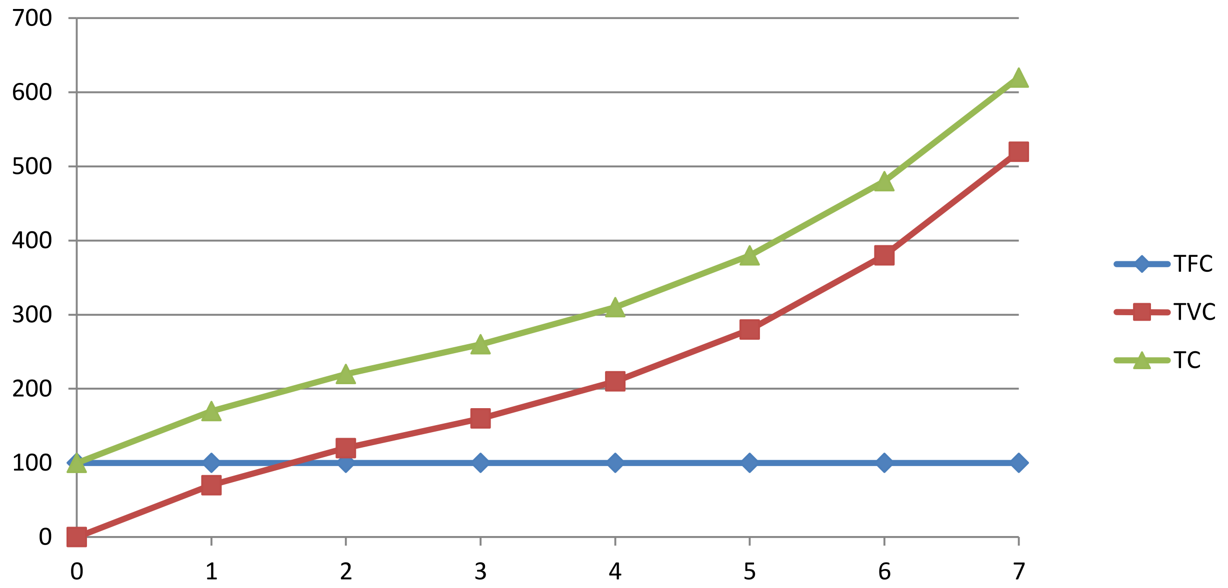


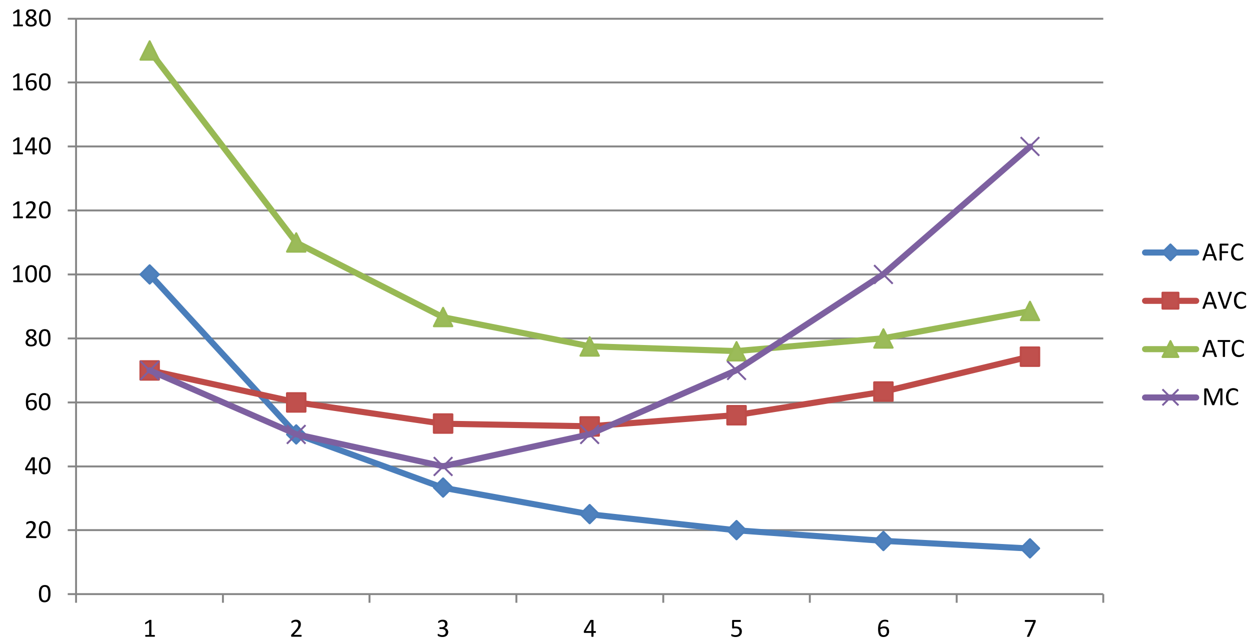


Example 3 – AFC, AVC, ATC, MC

Q	TFC	TVC	TC	AFC	AVC	ATC	MC
0	100	0	100	n/a	n/a	n/a	n/a
1	100	70	170				
2	100	120	220				
3	100	160	260				
4	100	210	310				
5	100	280	380				
6	100	380	480				
7	100	520	620				

Example 3: Graph

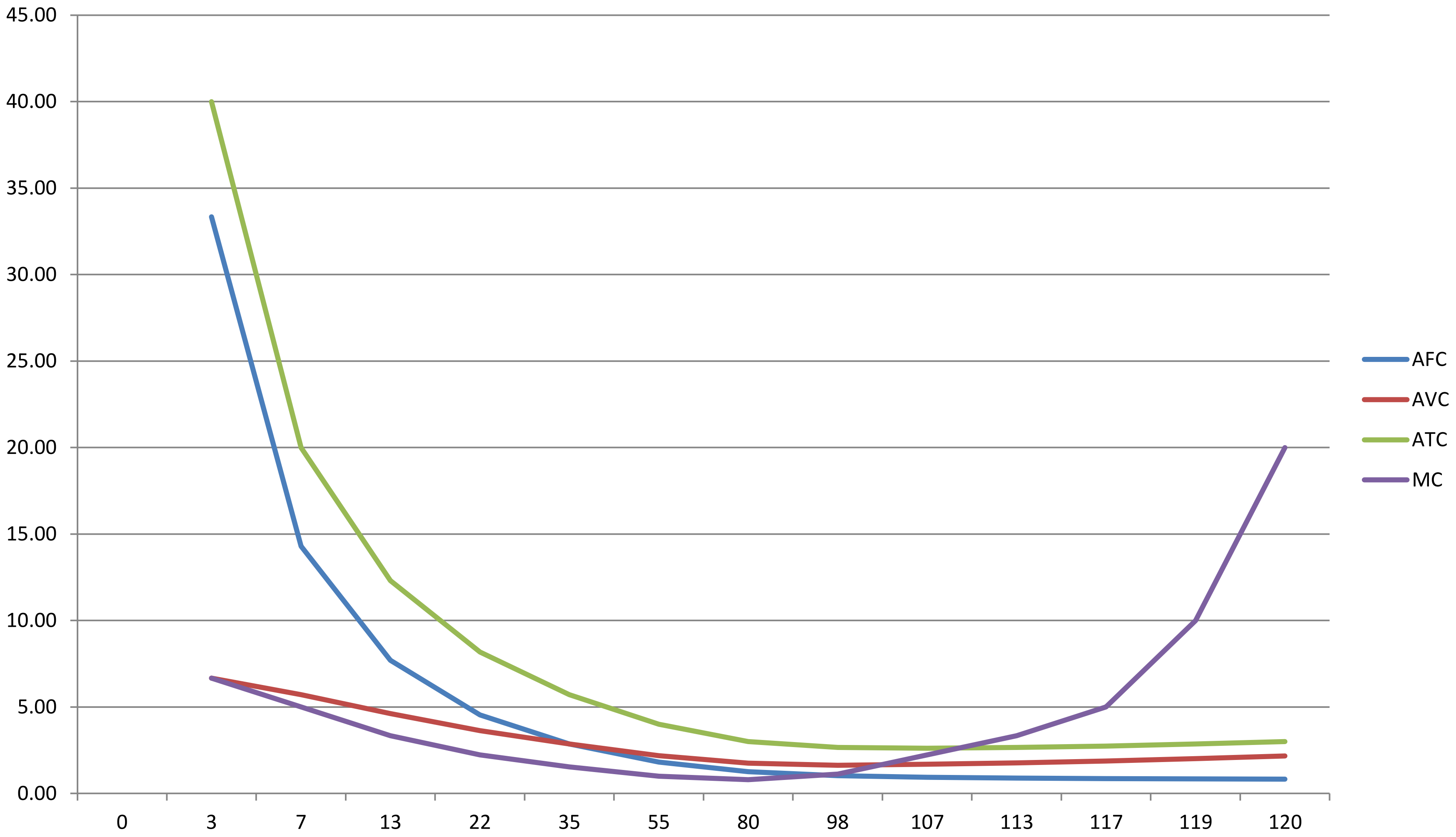




Example 4 (For Own Practice)

Q	TFC	TVC	TC	AFC	AVC	ATC	MC
0	100	0	100	n/a	n/a	n/a	n/a
3	100	20	120	33.33	6.67	40.00	6.67
7	100	40	140	14.29	5.71	20.00	5.00
13	100	60	160	7.69	4.62	12.31	3.33
22	100	80	180	4.55	3.64	8.18	2.22
35	100	100	200	2.86	2.86	5.71	1.54
55	100	120	220	1.82	2.18	4.00	1.00
80	100	140	240	1.25	1.75	3.00	0.80
98	100	160	260	1.02	1.63	2.65	1.11
107	100	180	280	0.93	1.68	2.62	2.22
113	100	200	300	0.88	1.77	2.65	3.33
117	100	220	320	0.85	1.88	2.74	5.00
119	100	240	340	0.84	2.02	2.86	10.00
120	100	260	360	0.83	2.17	3.00	20.00

Example 4: Graph



Relationship between Production and Cost in the Short Run

PRODUCTION AND COSTS IN THE LONG RUN

Topics

- Isoquant
- Isocost
- Production equilibrium and Expansion Path
- Relationship between Expansion Path and LRTC
- Long-run Costs of Production: LRTC, LRAC, LRMC
- Relationship between Long-run and Short-run Costs
- The Meaning of Returns to Scale
- Economies and Diseconomies of Scale

Production in the Long Run

- In the long run, all inputs are variable. Hence, there is no fixed cost.
- To determine the optimal amount of inputs (say, L & K) for a given price (w & r), the firm face one of the two problems:

1. Output maximization
   - To maximize the output (Q) under the constraint of a given cost (C_0).
2. Cost Minimization
   - To minimize the cost (C) under the constraint of a given output (Q_0).

Long-Run Production Function

- Suppose there are two inputs: L and K.
- Long-run production function can be written as:

$$Q = f(L, K)$$

Graph

Isoquant

- **Isoquant** illustrates all combinations of inputs that yield the same level of output (Q).

- Slope of isoquant is the Marginal Rate of Technical Substitution (MRTS):

$$\frac{\Delta K}{\Delta L} = MRTS$$

<u>Graph</u>

Properties of Isoquants

- Higher isoquants mean higher levels of output.
- Isoquants cannot cross nor be tangent to each other.
- Isoquants always have negative slope.

$$MRTS = \frac{\Delta K}{\Delta L} = -\frac{MP_L}{MP_K}$$

- MRTS is assumed to be diminishing.

Isocost

- Isocost represents all combinations of inputs that can be purchased for the same cost, given that the input prices are fixed.
- Equation: $wL + rK = C_0$
- Slope of isocost = $-\frac{w}{r}$

Graph

Changes in Isocost

- When C_0 increases.

- When r increases.

Production Equilibrium: Output Maximization

- Firm's objective:

$$\max_{L,K} Q = f(L,K) \qquad \textit{subject to} \qquad wL + rK = C_0$$

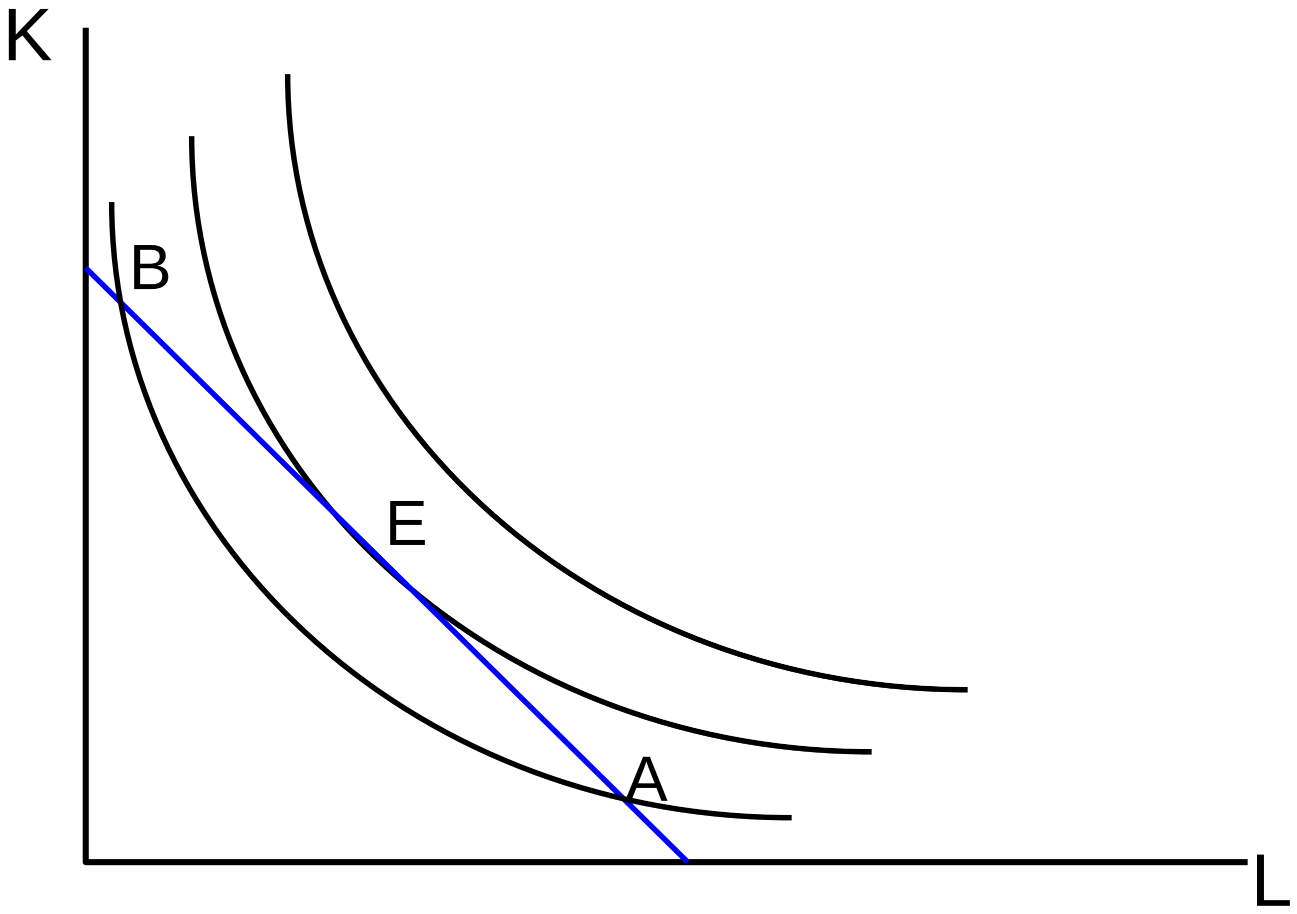
- Equilibrium condition

E = (L*,K*) is the equilibrium when:

1. $wL^* + rK^* = C_0$
2. $MRTS = -\frac{w}{r}$ (i.e. $-\frac{MP_L}{MP_K} = -\frac{w}{r}$)

➔

Graph: Output Maximization



Production Equilibrium: Cost Minimization

- Firm's objective:

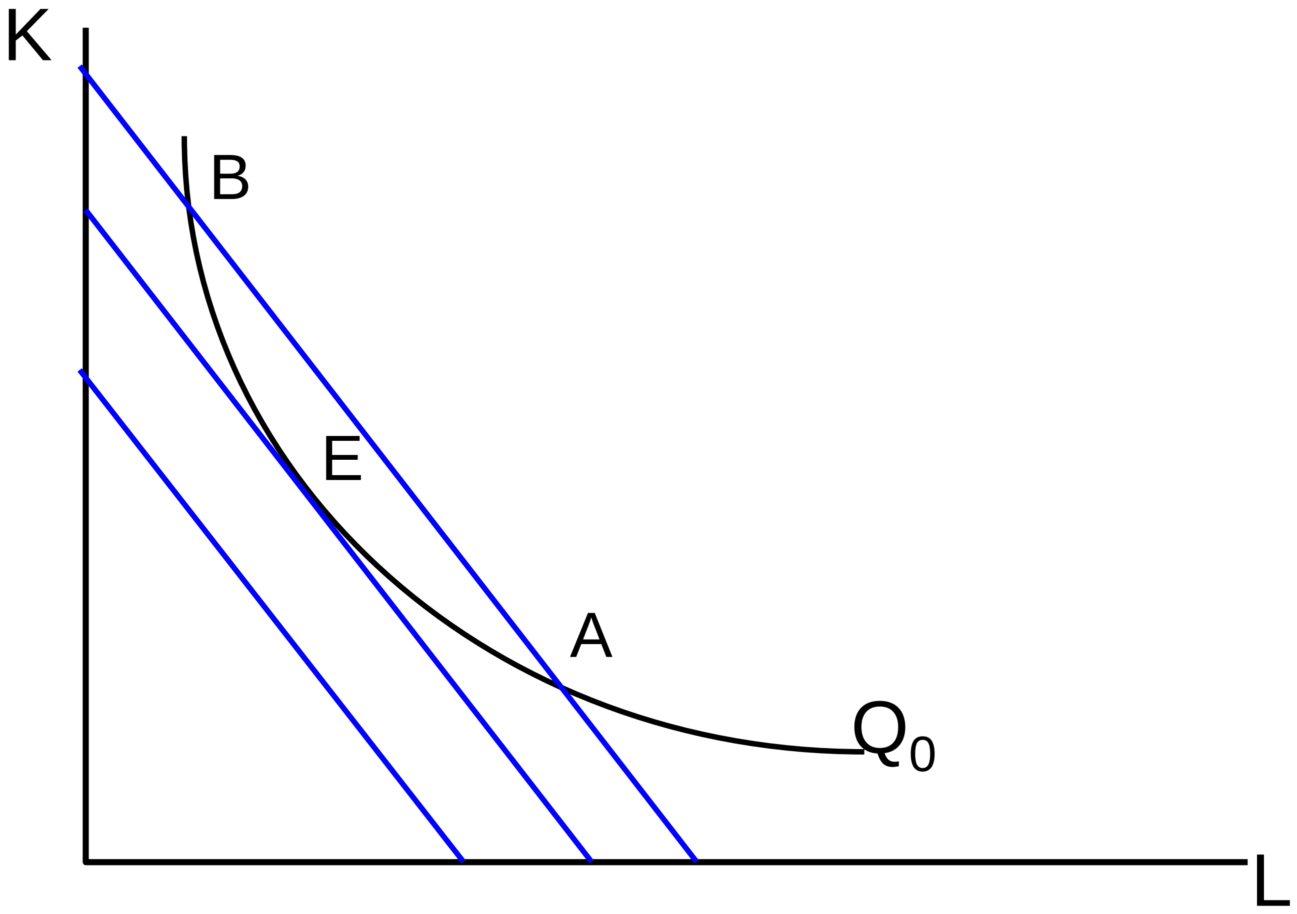
$$\min_{L,K} C = wL + rK \qquad \textit{subject to} \;\; f(L,K) = Q_0$$

- Equilibrium conditions

E = (L*,K*) is the equilibrium when:

1. $f(L^*, K^*) = Q_0$
2. $\frac{MP_L}{MP_K} = \frac{w}{r}$

Graph: Cost Minimization

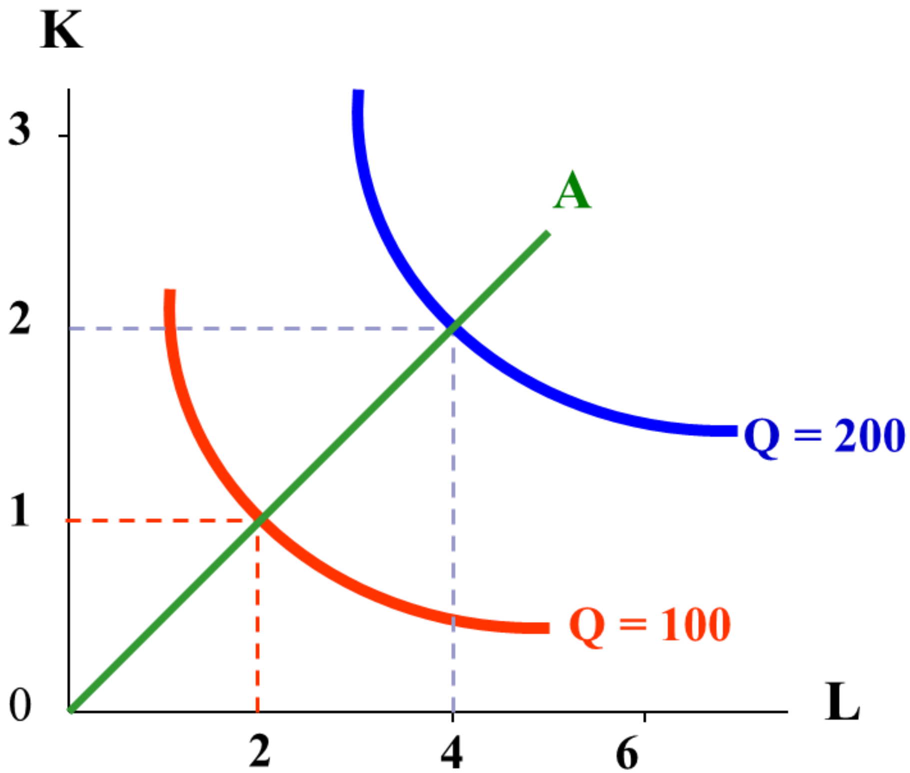


Returns to Scale

- Returns to scale is a property of production function that tells us what happens to output when all inputs are increased by exactly the same proportions.
  - Constant return to scale
    - $f(aL, aK) = af(L, K)$
  - Increasing return to scale
    - $f(aL, aK) > af(L, K)$
  - Decreasing return to scale
    - $f(aL, aK) < af(L, K)$

Graph: Returns to Scale (1)

- Constant returns to scale



Example:

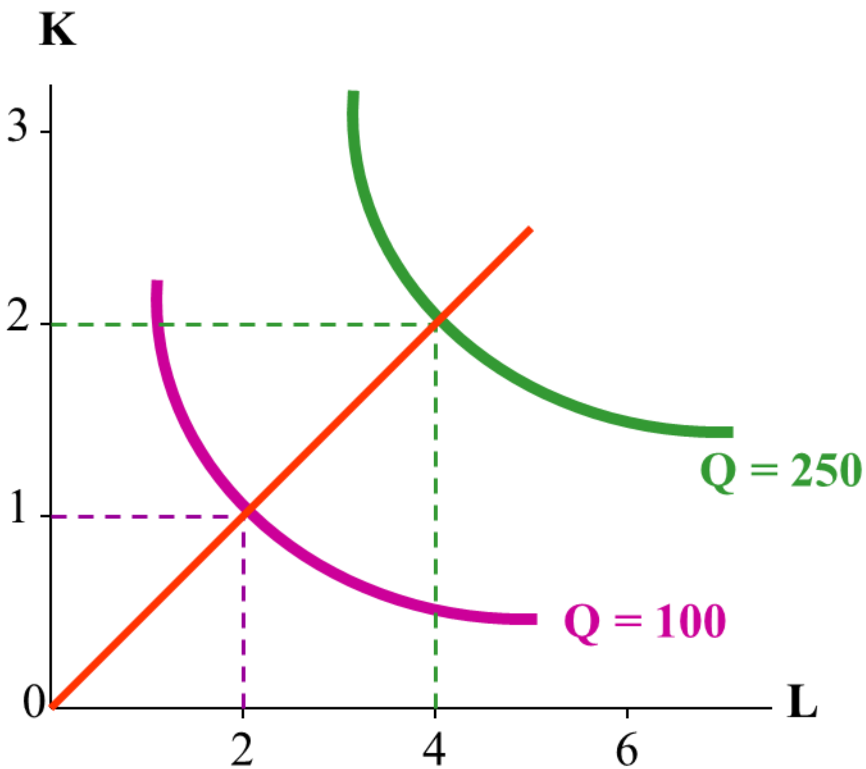
Let $Q = 5L^{1/2}K^{1/2}$.

Suppose both L and K double. What happens to Q?

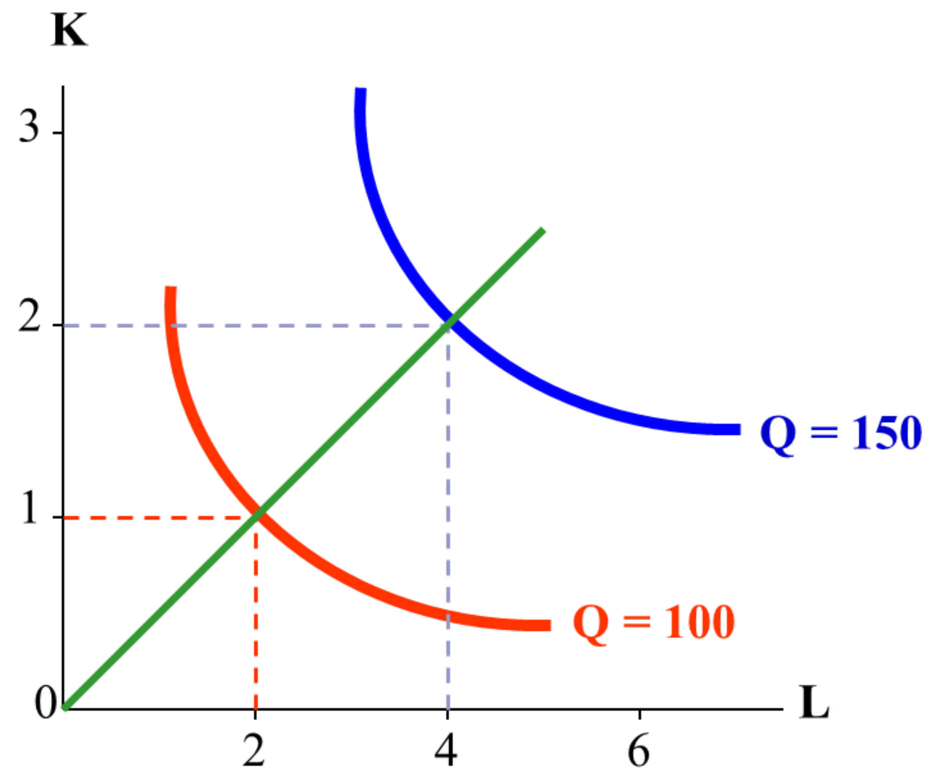
Graph credit: Ajarn Nantavut Phipatseritham

Graph: Returns to Scale (2)

- Increasing returns to scale



- Decreasing returns to scale



Graph credit: Ajarn Nantavut Phipatseritham

Least-Cost Combinations & Expansion Path

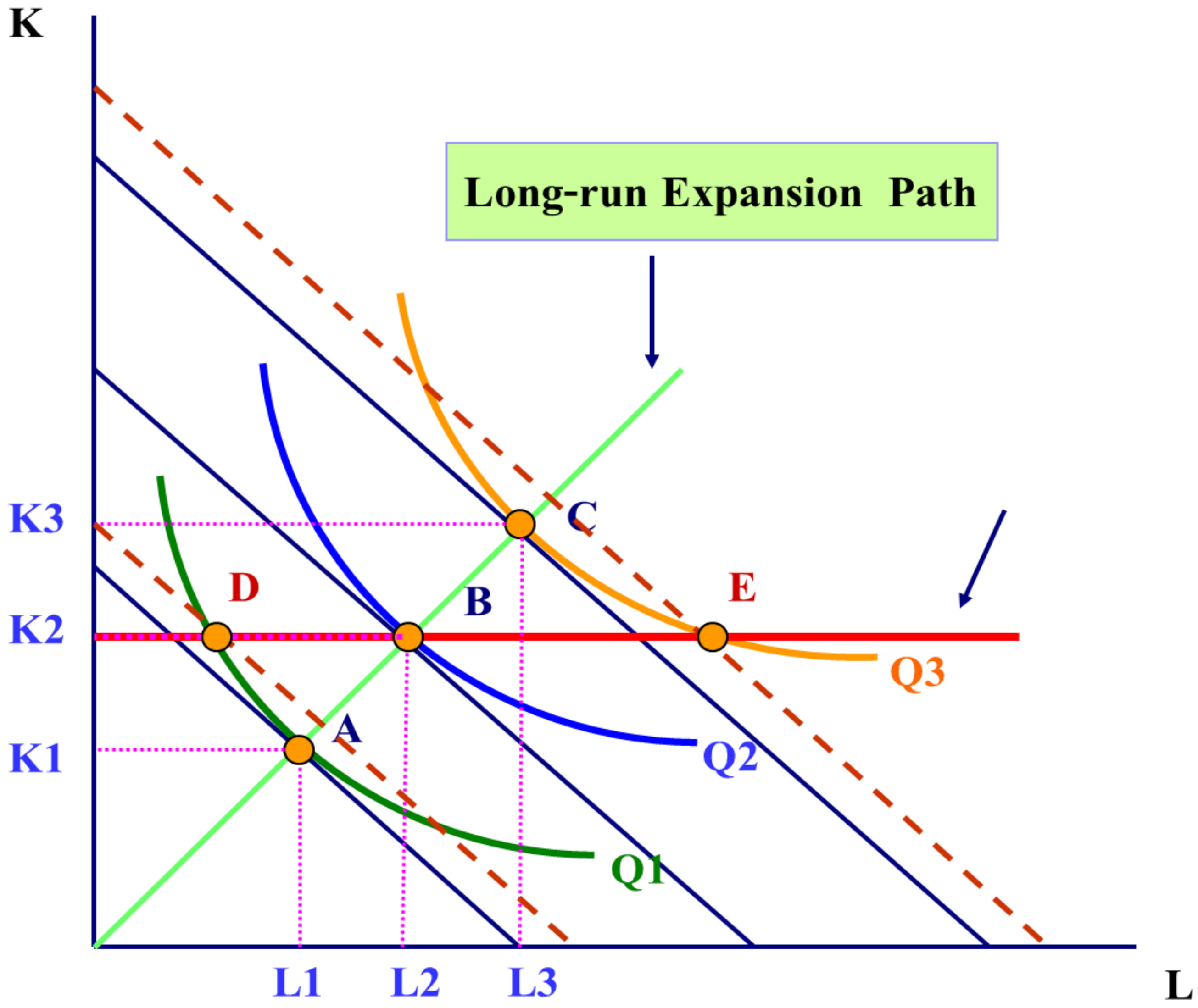
- **Expansion path** is a line that connects all the tangent points between the isocost lines and isoquants, for given w and r.

  - ➢It indicates the optimal L and K that minimizes the total cost for each given quantity level.

  (i.e. It includes all least-cost combinations of inputs).

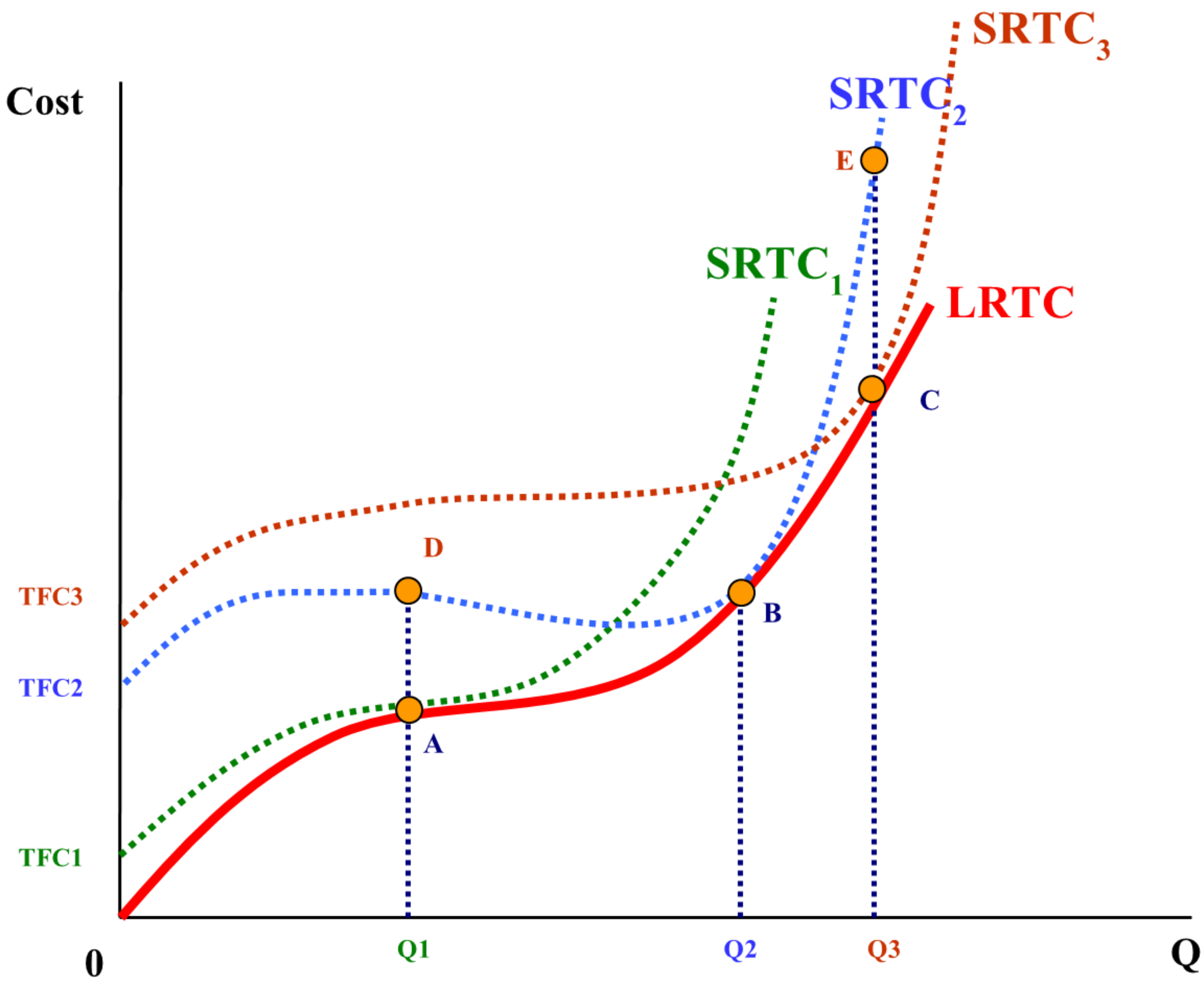
  - ➢It indicates the optimal L and K that maximizes the output Q for each given cost level.

Expansion Path & LRTC (1)



Graph credit: Ajarn Nantavut Phipatseritham

Expansion Path & LRTC (2)



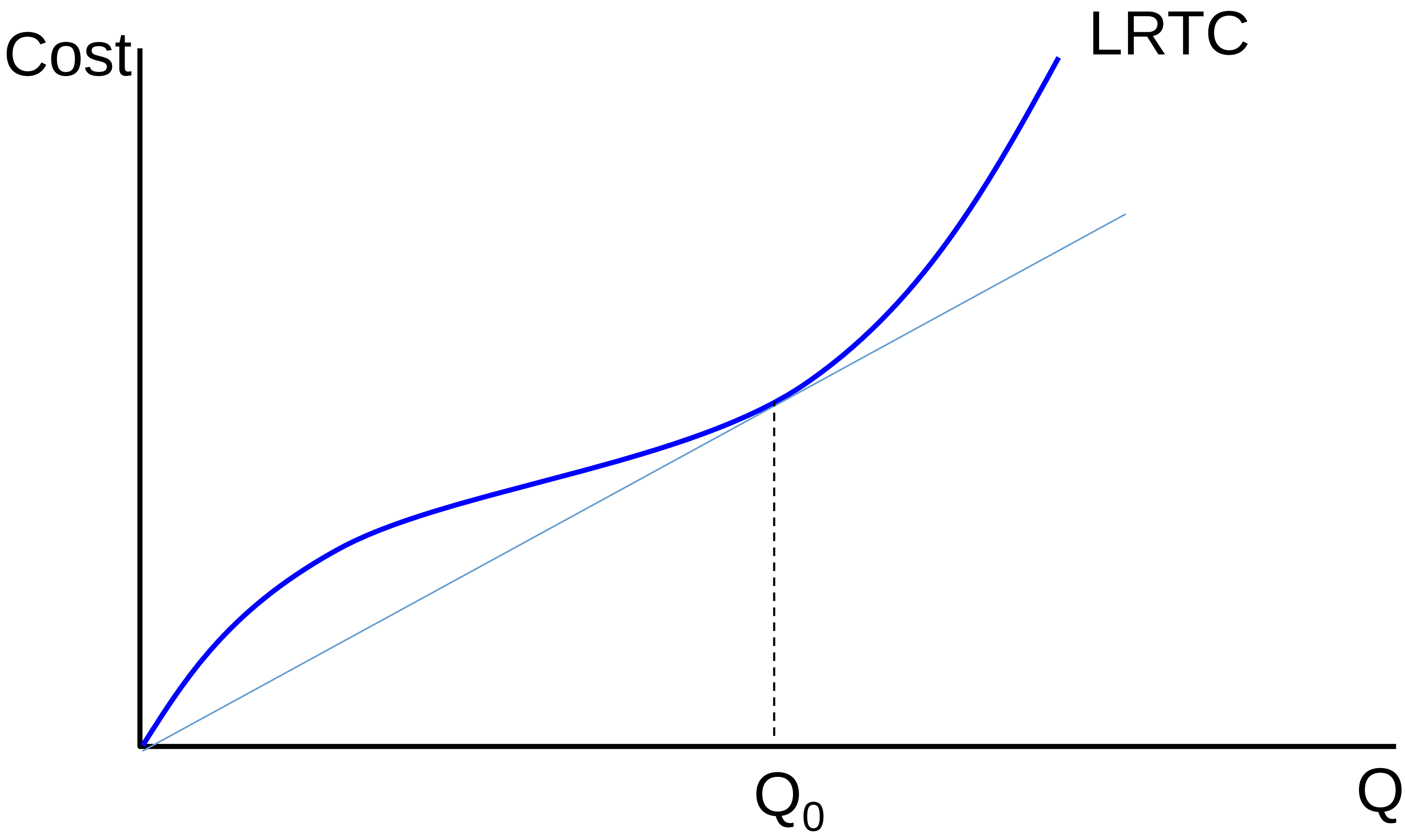
Graph credit: Ajarn Nantavut Phipatseritham

Exercise

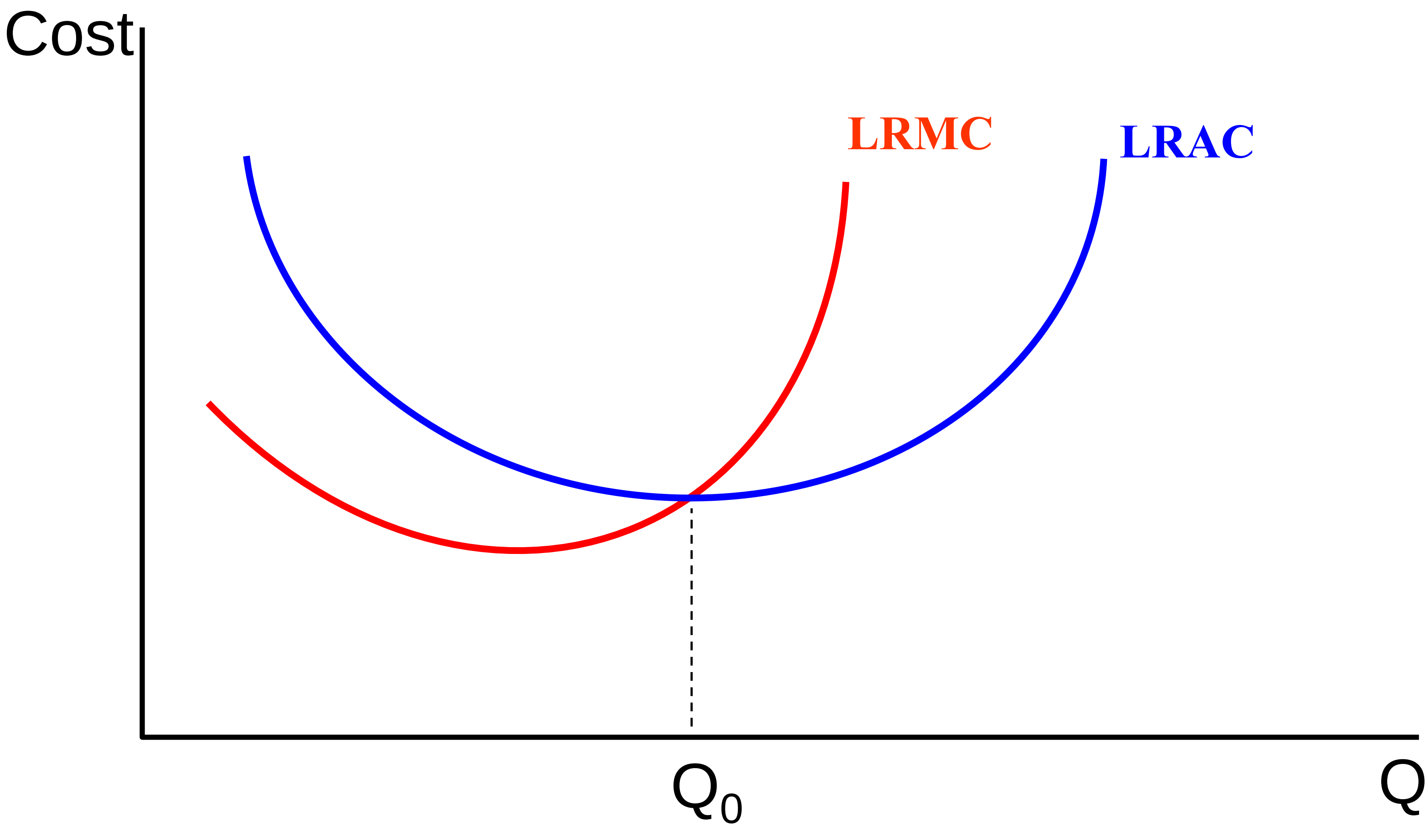
- Fill out the missing numbers in the following table, and use this information to draw the LRTC and SRTC, given w =2 and r =10. (Use the attached handout.)

Point	L	K	Q	wL	rK	LRTC	SRTC when K=4
A	10	2	50			40	n/a
B	15	3	100	30			n/a
C	20	4	200		40		n/a
D	25	5	350				n/a
E	10	4	50		40	n/a	60
F	35	4	350			n/a	

Long-Run Total Cost Curve

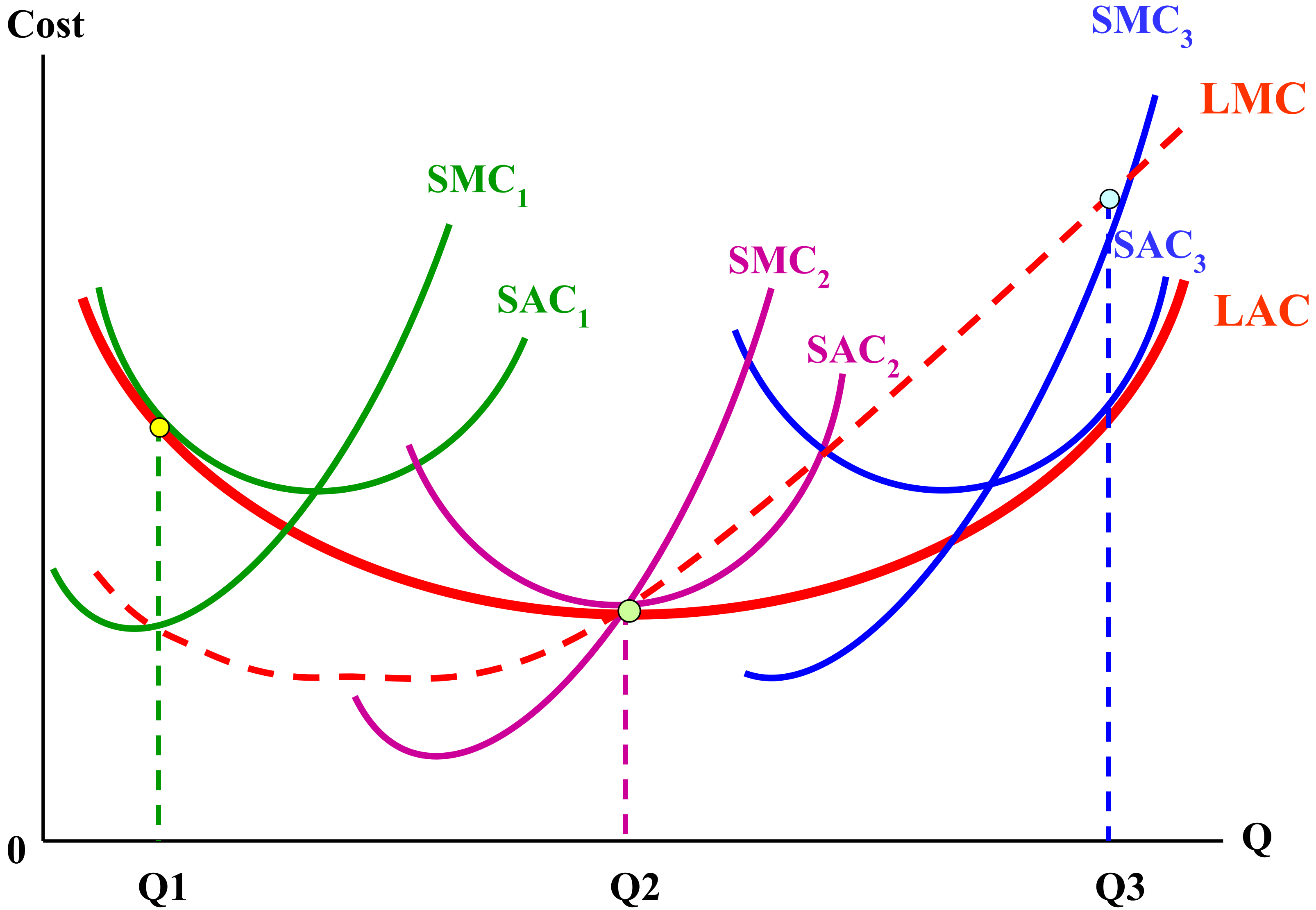


LRTC, LRAC, LRMC



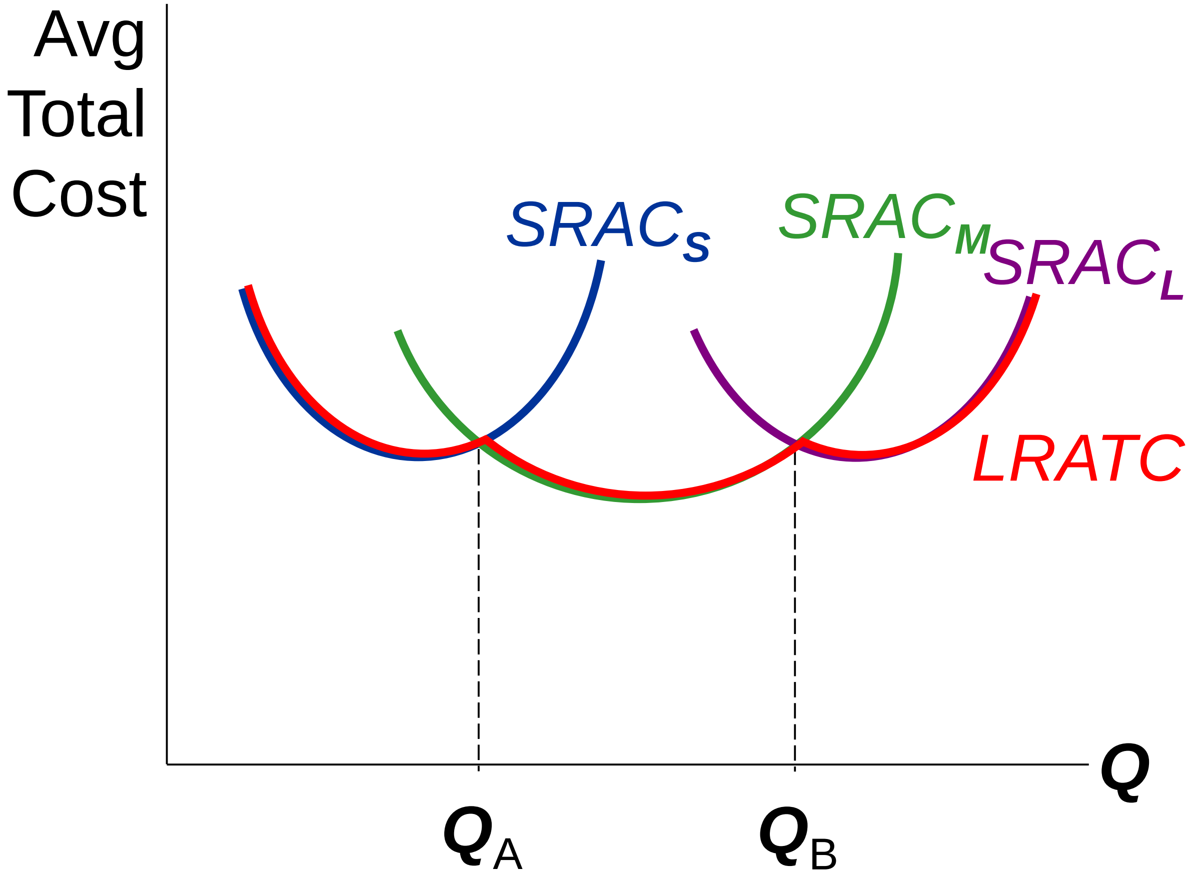
Graph credit: Ajarn Nantavut Phipatseritham

Relationship between Long-run and Short-run Costs

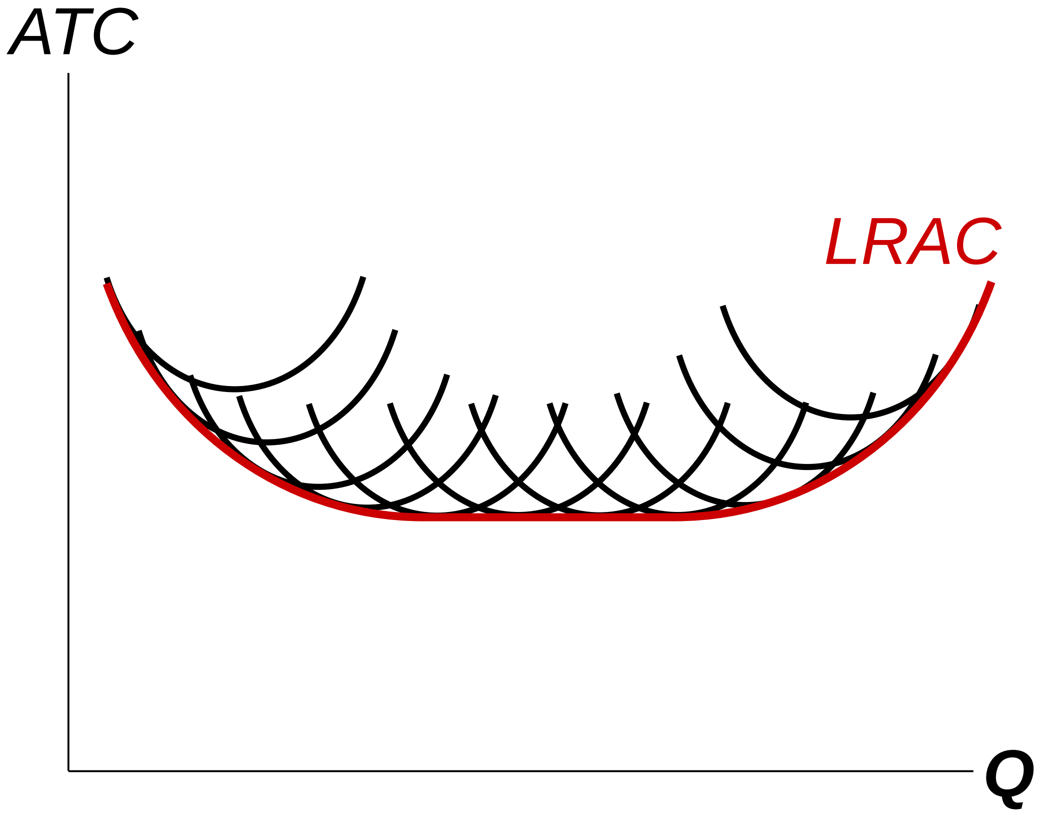


Graph credit: Ajarn Nantavut Phipatseritham

Example: Firm with 3 factory sizes



LRAC & SRAC



Economies of Scale

- Economies of scale:
  - *ATC* falls as *Q* increases.
- Constant returns to scale:
  - *ATC* stays the same as *Q* increases.
- Diseconomies of scale:
  - *ATC* rises as *Q* increases.

Graph: Economies of Scale