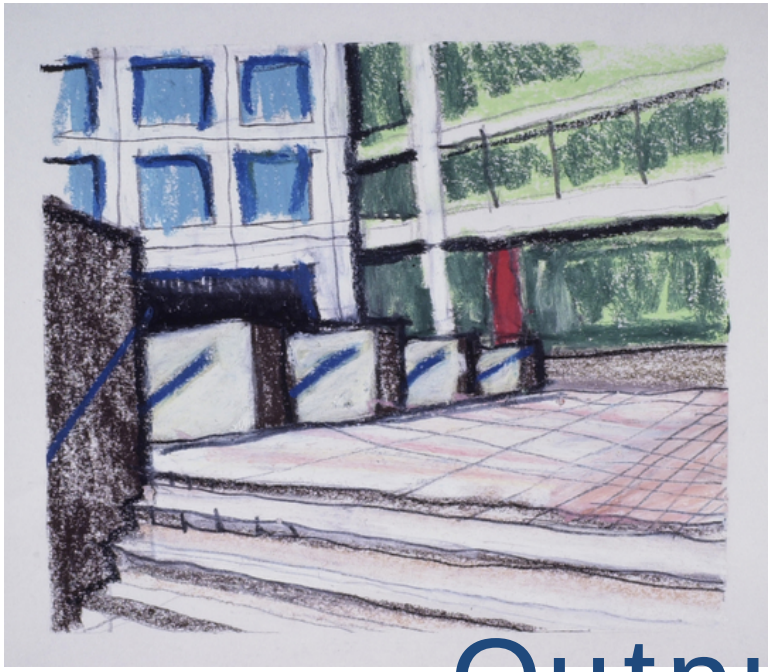


Output and Costs

Fei DING
HKUST ECON

Announcements

- Assigned reading:
  - Textbook, Chapter 11, 12
- Proposed date for quiz 3: Monday Nov. 5, 9-9:30pm
- Problem set 6
  - Ch10: 1-3, 5, 7, 10, 18
  - Ch11: 2-14, 19
  - Due date will be announced on CANVAS.

SR and LR

- Short Run (SR):
  - Some inputs (at least one input) are fixed, for example: production line, factory size, etc.
- Long Run (LR):
  - All inputs are variable.
- No “**rigid**” definition (time horizon / decision time frame)
- More important is the “variability” of inputs (factors of productions), which means a firm can **choose** any “combination of inputs” available for its production.

SHORT RUN PRODUCT CURVES

SR - Production Function

- Firm's plant is fixed:
  - Building (size)
  - No. Knitting machines
  - Computer admin system
- As the quantity of labor increases:
  - Total product increases.
  - Marginal product increases initially, but eventually decreases.
  - Average product increases then decreases.

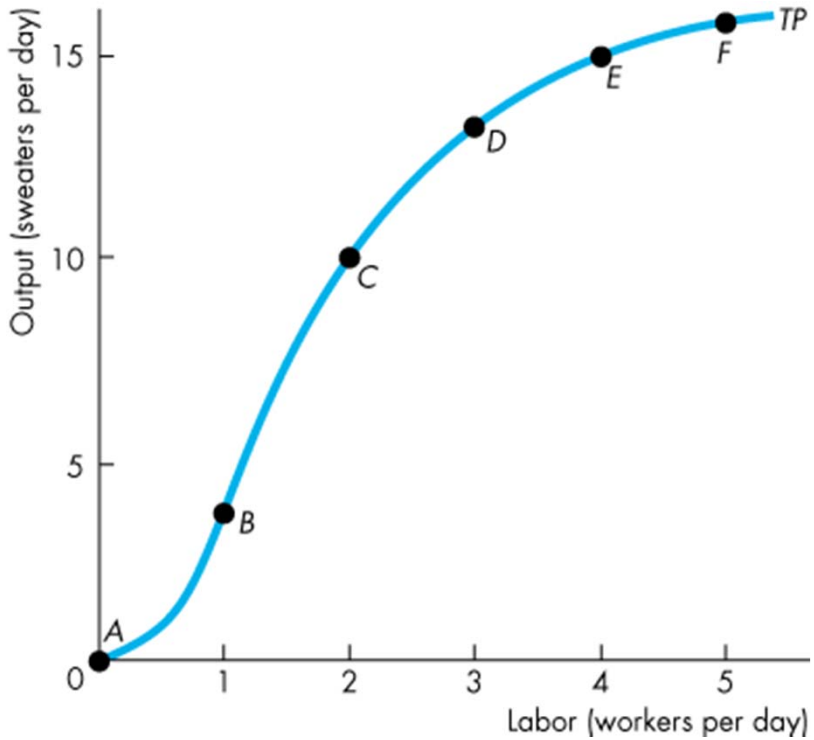
TABLE 11.1 Total Product, Marginal Product, and Average Product

	Labor (workers per day)	Total product (sweaters per day)	Marginal product (sweaters per additional worker)	Average product (sweaters per worker)
A	0	0		
			4	
B	1	4		4.00
			6	
C	2	10		5.00
			3	
D	3	13		4.33
			2	
E	4	15		3.75
			1	
F	5	16		3.20

SR - Production Curve

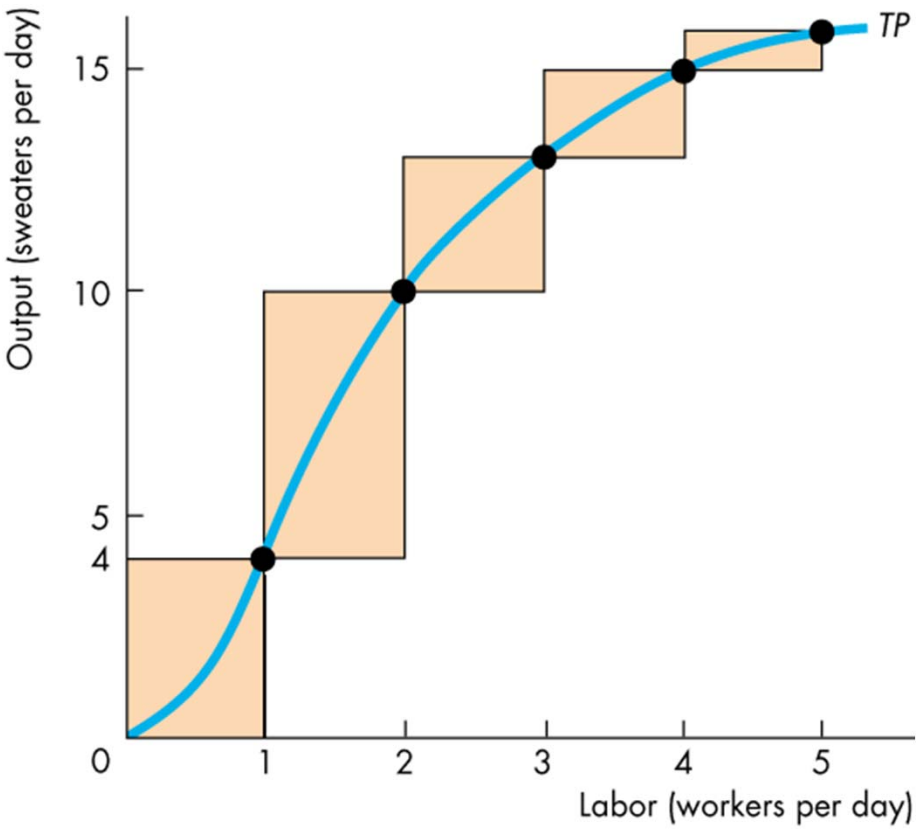
Total Product Curve

- The total product curve shows how total product changes with the quantity of labor employed.
- Note the shape of the curve!!!



Marginal Product of Labor

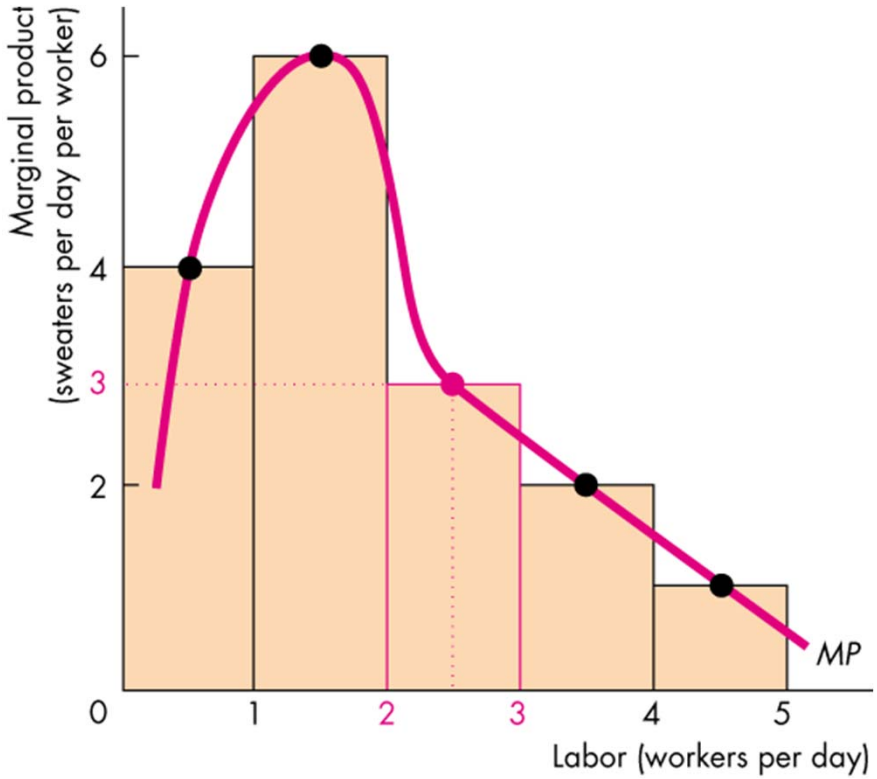
- The 1st worker hired produces 4 units of output (Marginal Product / "**MP**").
- The 2nd worker hired produces 6 units of output and total product becomes 10 units.
- The 3rd worker hired produces 3 units of output and total product becomes 13 units.



(a) Total product

Marginal Product of Labor

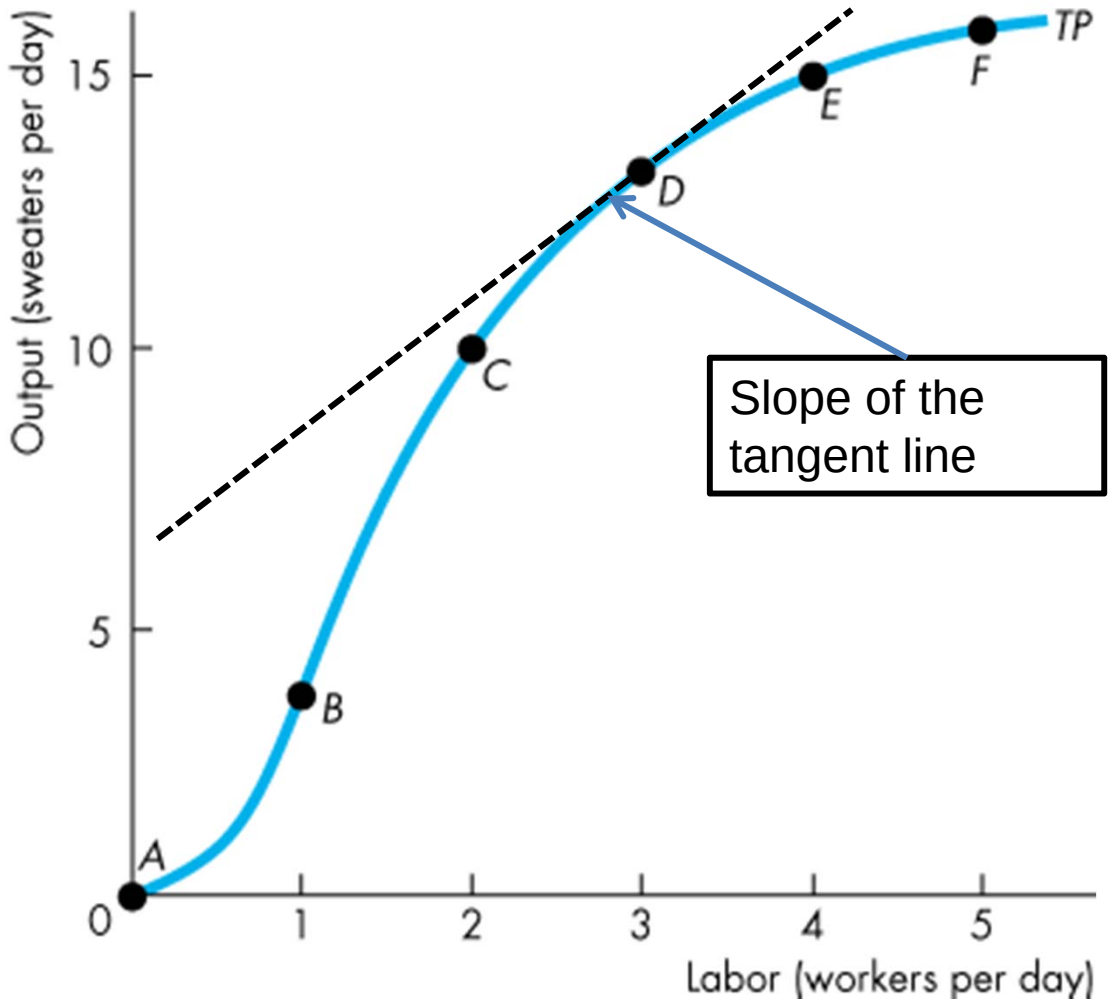
- To make a graph of the marginal product of labor, we can stack the bars in the previous graph side by side.
- The MPL curve passes through the mid-points of these bars.
- ***How does the shape of TP curve affect the shape of MP curve?***



(b) Marginal product

Marginal Product in a graph

MP of the *x*-**th** unit: represented by the slope.



Marginal Product of Labor

- The “marginal product” of “any input” is the increase in output arising from an additional unit of that input, **holding all other inputs constant**.
  - Labor: Marginal product of labor (MPL)
  - Capital: Marginal product of capital (MPK)
- Notion:

$$Y = Af(L, K)$$

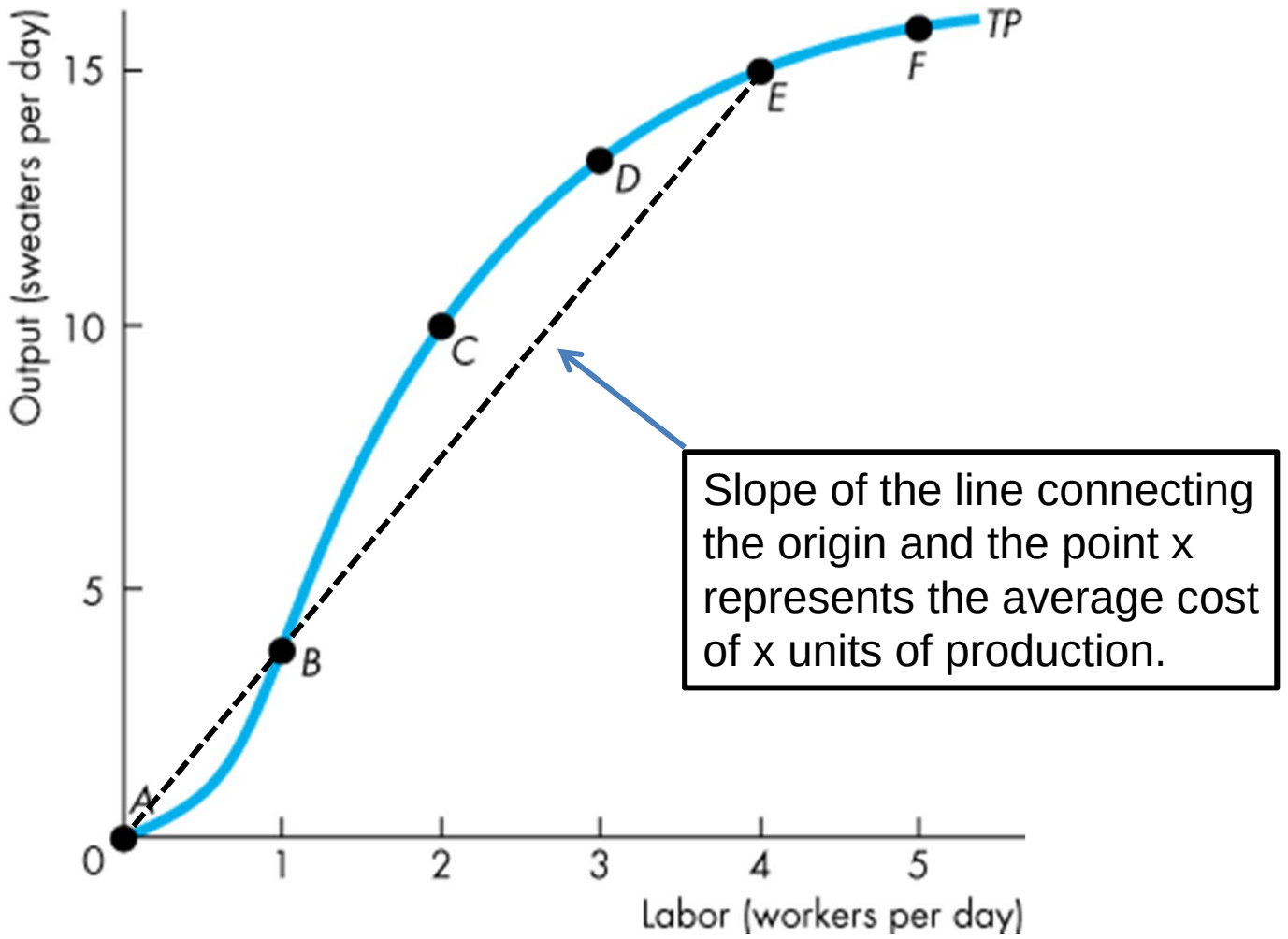
$$\frac{\Delta Y}{\Delta L} = \frac{\partial Y}{\partial L} = MPL\,;\ \frac{\Delta Y}{\Delta K} = \frac{\partial Y}{\partial K} = MPK$$

Diminishing MPL?

- Given certain fixed amount of input(s), MPL is diminishing … eventually.
- However, Inverted U-shape MPL is possible.
  - Increasing MP arises from increased specialization and division of labor.
  - Diminishing MP arises from less access to capital and less space to work.
- **Law of Diminishing Return:** MP of an variable input **eventually** diminishes when there is at least one fixed input.

Average Product in a graph

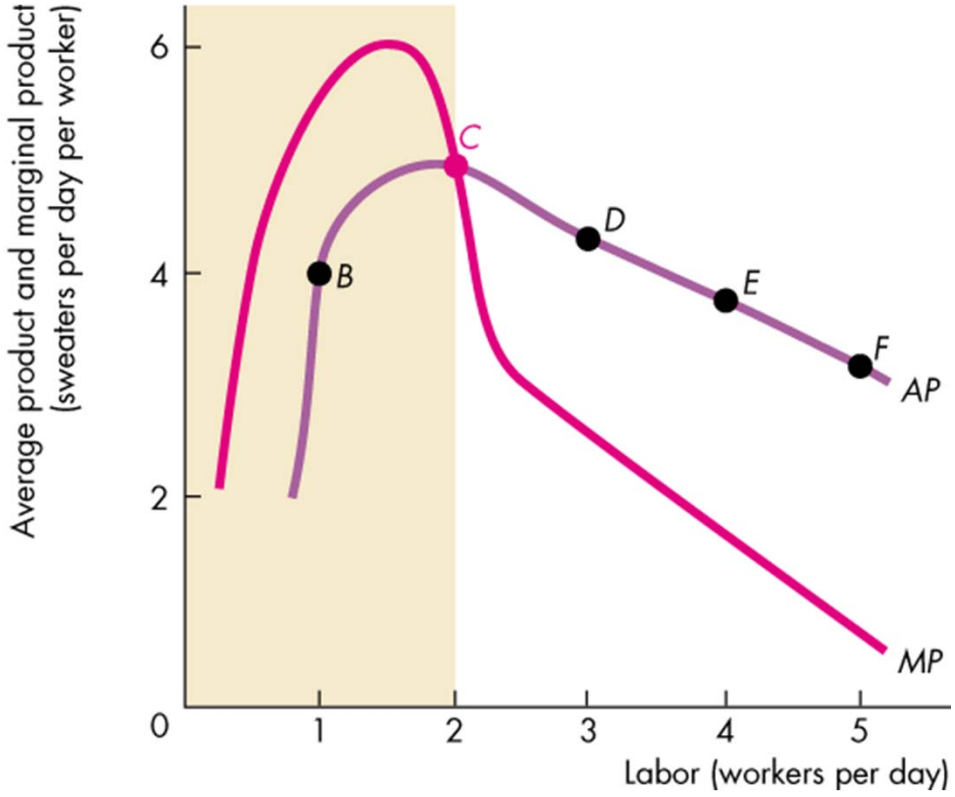
AP of x units: represented by the slope.



SR – MP and AP Curves

- Average Product Curve

- When MP exceeds AP, AP increases.
- When MP *is below* AP, AP decreases.
- When MP equals AP, AP is at its maximum.
- Why?



MP and AP Curves

- Why MP always cuts AP at AP's maximum?
- Math properties:
  - Average of x1, x2, … , x5 = average (x1,…,x5)
  - If x6 > average (x1,…,x5)
  - Average (x1,…,x5,x6) > = < Average (x1,…,x5)?

Quick check

Which of the following statements is TRUE for any marginal and average?

A) When the marginal is greater than the average, the average increases.

B) When the marginal is less than the average, the average increases.

C) When the marginal is rising, the average is increasing.

D) When the marginal is equal to the average, the average decreases.

Quick check

SHORT RUN COST

SR - Cost Function

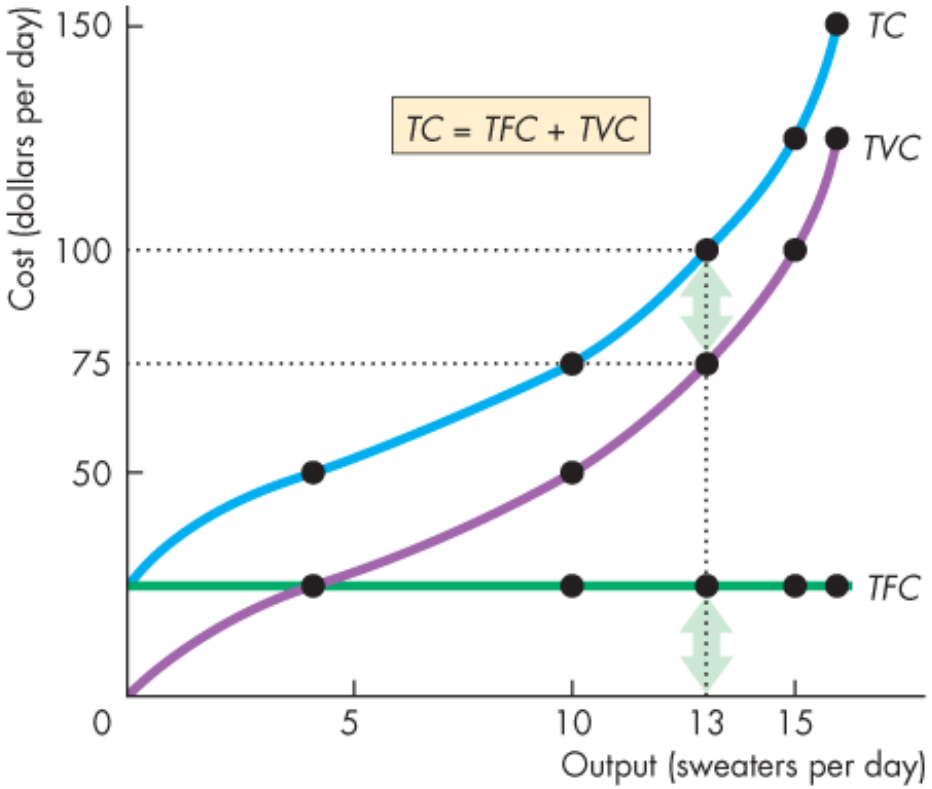
- **Total Fixed Costs (TFC): DO NOT** vary with the quantity of output produced.
  - Plant size, machineries, computer system, etc.
- TFC are costs that must be paid to allow production to begin.
  - Do not rise with the level of output.
- Some TFC are periodic (e.g. paid period by period).
  - After TFC are paid, they are “sunk”!
  - “Sunk” for that particular period.

SR - Cost Function

- **Total Variable Costs (TVC):** **Vary** with the quantity of output produced.
  - Wages for workers
  - Cost of materials
  - How about workers paid by month?
- Total variable costs can be calculated as the SUM of the MCs of the units produced.
  - 1st MC = 10; 2nd MC = 11; 3rd MC = 12,… then TVC = summation of all
- **Total Cost (TC) = TFC + TVC**

SR - Cost Function

	Labor (workers per day)	Output (sweaters per day)	Total fixed cost (*TFC*)	Total variable cost (*TVC*)	Total cost (*TC*)
			(dollars per day)		
A	0	0	25	0	25
B	1	4	25	25	50
C	2	10	25	50	75
D	**3**	**13**	**25**	**75**	**100**
E	4	15	25	100	125
F	5	16	25	125	150



Some definitions

- Marginal Cost (MC): Increase in Total Cost from producing one more unit

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

- Average Total Cost (ATC): Total Cost divided by the quantity of output

$$ATC = \frac{TC}{\boldsymbol{Q}}$$

Some definitions

- Average variable cost (AVC) is total variable cost per unit of output.

$$AVC = \frac{TVC}{Q}$$

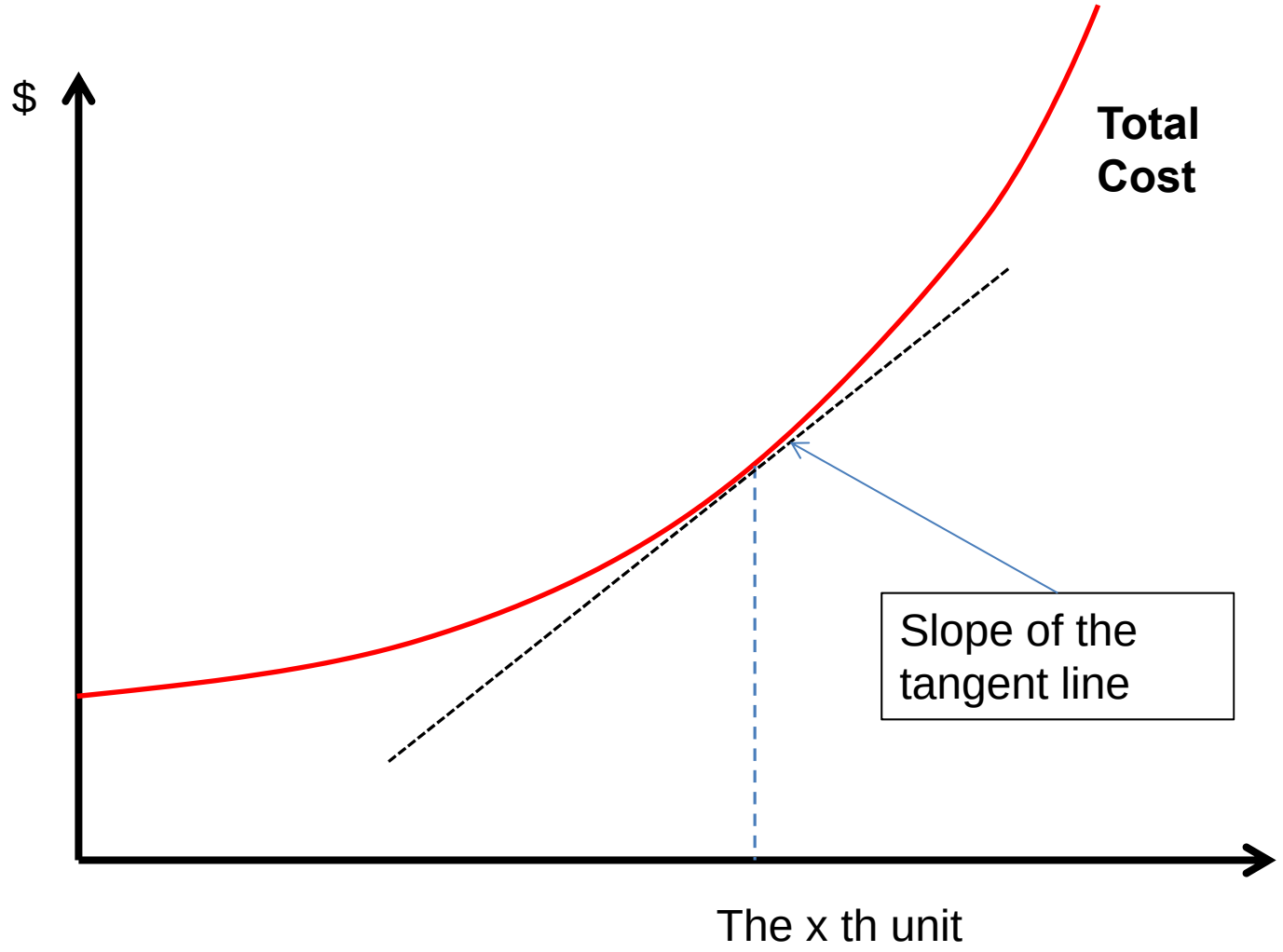
- Average fixed cost (AFC) is total fixed cost per unit of output.

$$AFC = \frac{TFC}{Q}$$

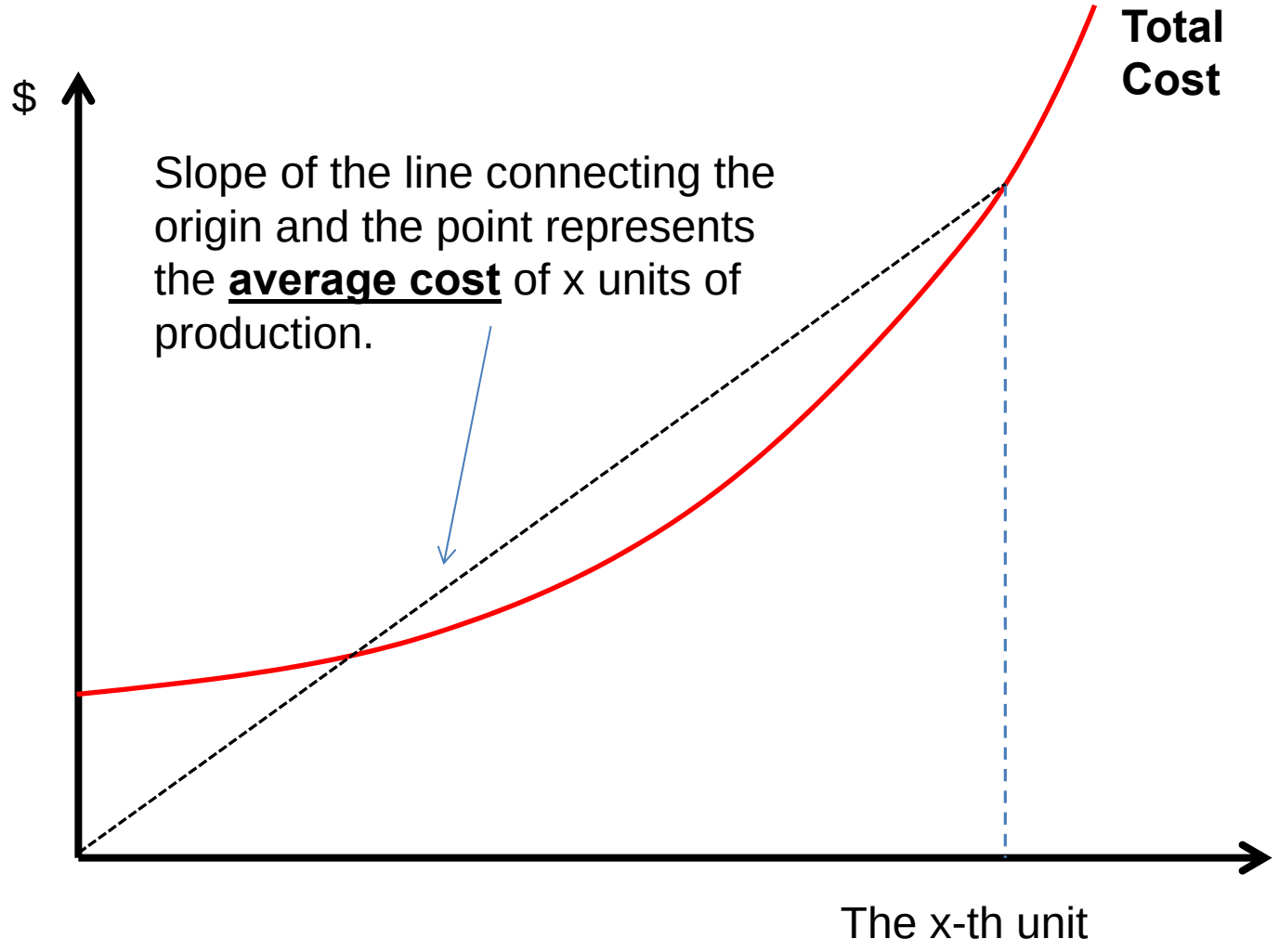
- Average total cost (ATC) is total cost per unit of output: ATC = AFC + AVC.

Marginal and Average in a graph

MC of the *x*-**th** unit: represented by the slope.

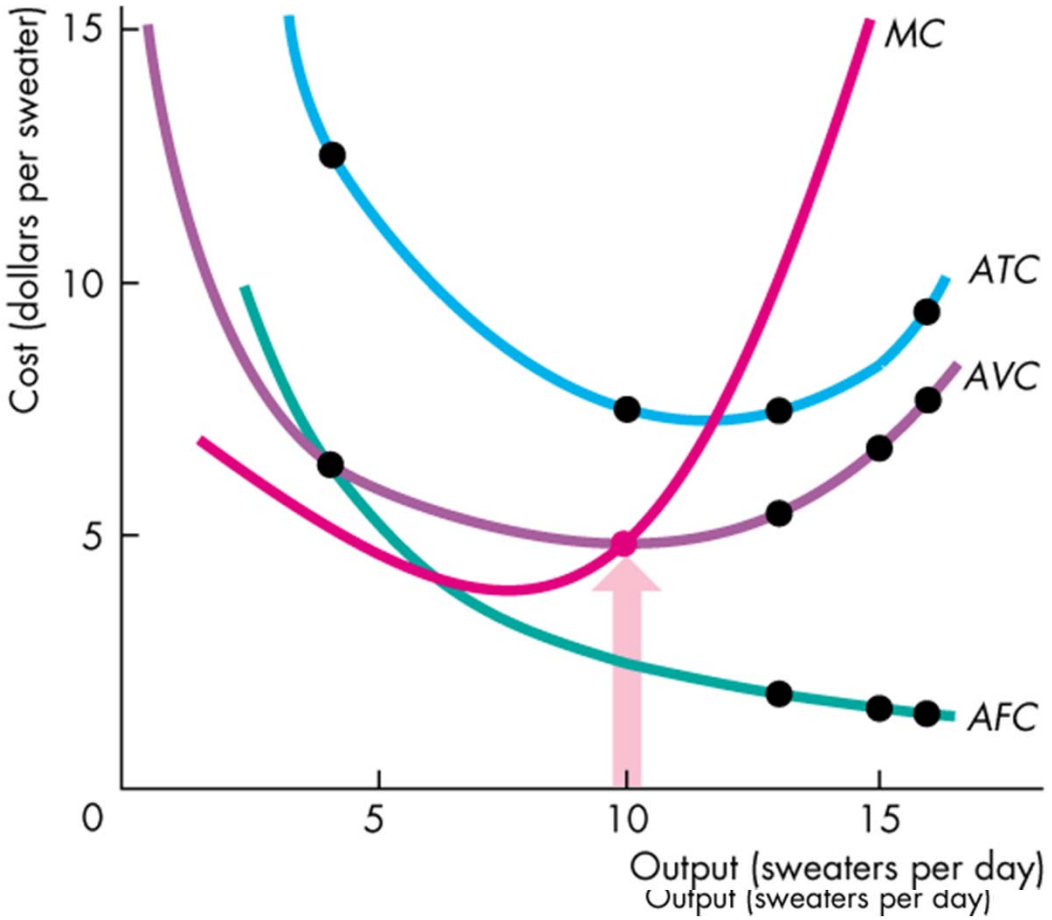


MC and AC in a graph



Cost Function

- AFC falls as output increases: AFC = TFC/Q
- AVC, ATC curves are U-shaped; MC is J-shaped.
- The outputs over which AVC is falling, MC is below AVC.
- The outputs over which AVC is rising, MC is above AVC.
- The output at which AVC is at the minimum, MC equals AVC.

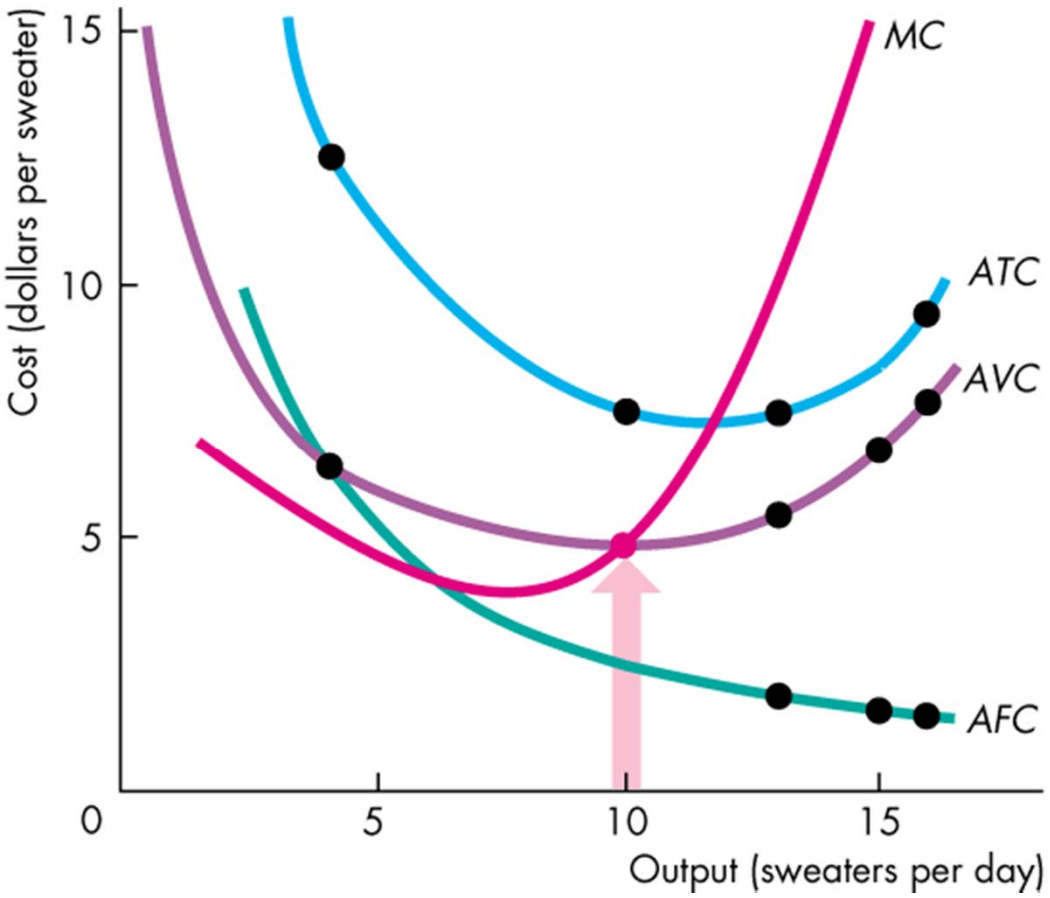


Shape of AC and MC

- The shape of TVC (TC) is the reason why
  - MC first drops then rises.
- In general, as more and more units are produced in SR, MC:
  - May decreases within certain output levels.
  - Sooner or later (eventually), it would become more and more difficult to increase production (output), and MC rises indefinitely.
- **Reasons: Same as for MP (you will see the link between MP and MC).**

Shape of MC

- The MC curve is very special.
  - J-shaped or U-shaped
- MC is the supply curve and is assumed to be upward sloping, but the shape here is???
  - You will see the downward sloping “part” will not be “meaningful”.



ATC is U-shaped

- The ATC curve is the vertical sum of the AFC curve and the AVC curve.
- The U-shape of the ATC curve arises from the influence of two opposing forces:
  - Spreading total fixed cost over a larger output—AFC curve slopes downward as output increases.
  - Eventually, diminishing returns—the AVC curve slopes upward and AVC increases more quickly than AFC is decreasing (add up the AFC and AVC, you will see this point).

Discussion

- Does the shape of TVC curve alone lead to U-shaped ATC? Or TFC also plays a role?
- If production is without FC (TFC=0), is it still possible for ATC/AVC to be U-shaped?
  - If TFC=0, what's the shape for TVC?
- **Please spend sometime to think about these.**
- **You will see U-shaped ATC would be an important characteristic for our analysis.**

Quick check

Which of the following statements is TRUE?

A) Average fixed cost equals average total cost plus average variable cost.

B) Average variable cost is always greater than average fixed cost.

C) Average fixed cost equals total fixed cost divided by total output.

D) Average total cost always falls as output increases.

E) None of the above.

Quick check

SHIFTS IN COST CURVES (SR)

Shifts in Cost Curves (SR)

- The positions of a firm's cost curves depend on two factors:
  - Prices of factors of production
  - Technology

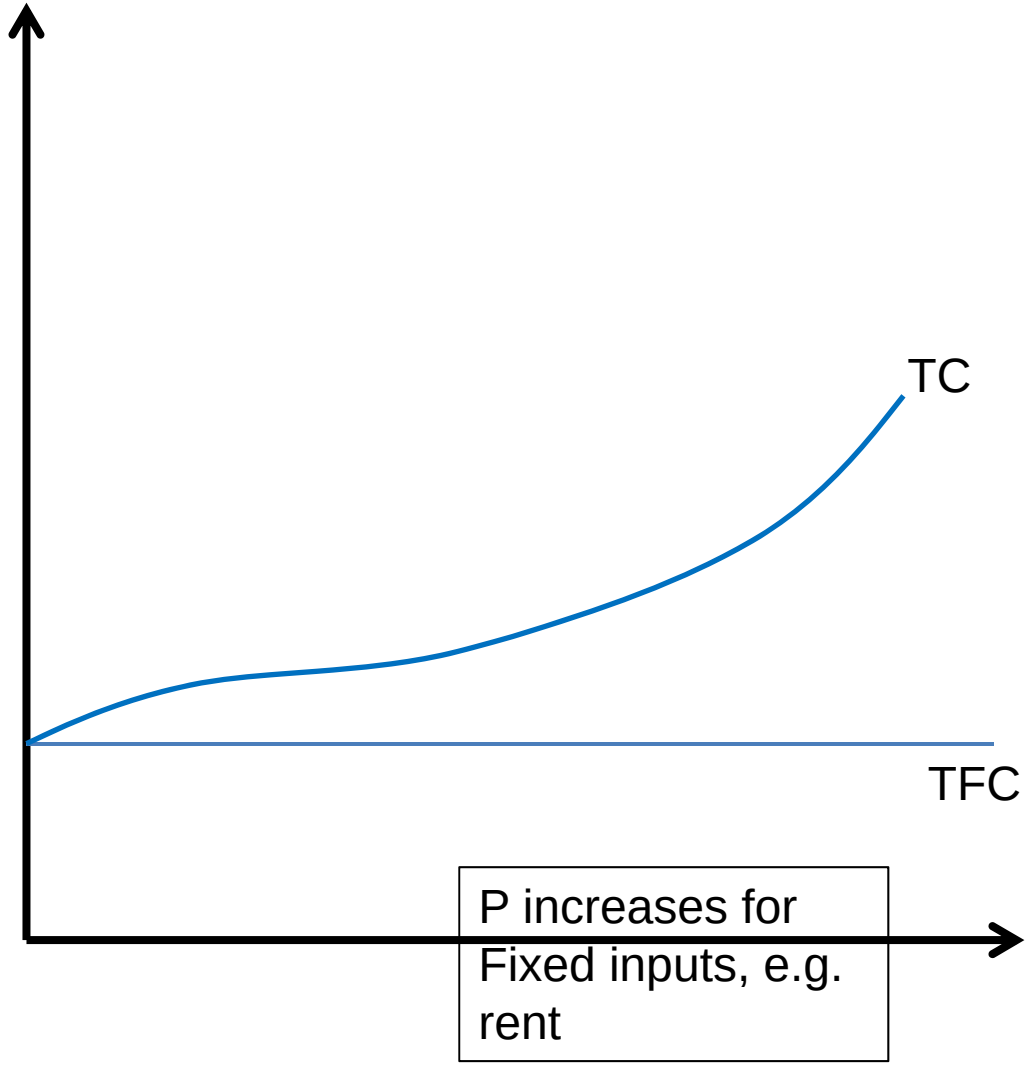
Shifts in Cost Curves (SR)

Prices of Factors of Production

- An increase in the price of a factor of production increases costs and shifts the cost curves.
  - FOR EXAMPLE: Rental for office space / wage for workers
  - TC, ATC and MC?
- An increase in a fixed cost…
- An increase in a variable cost…

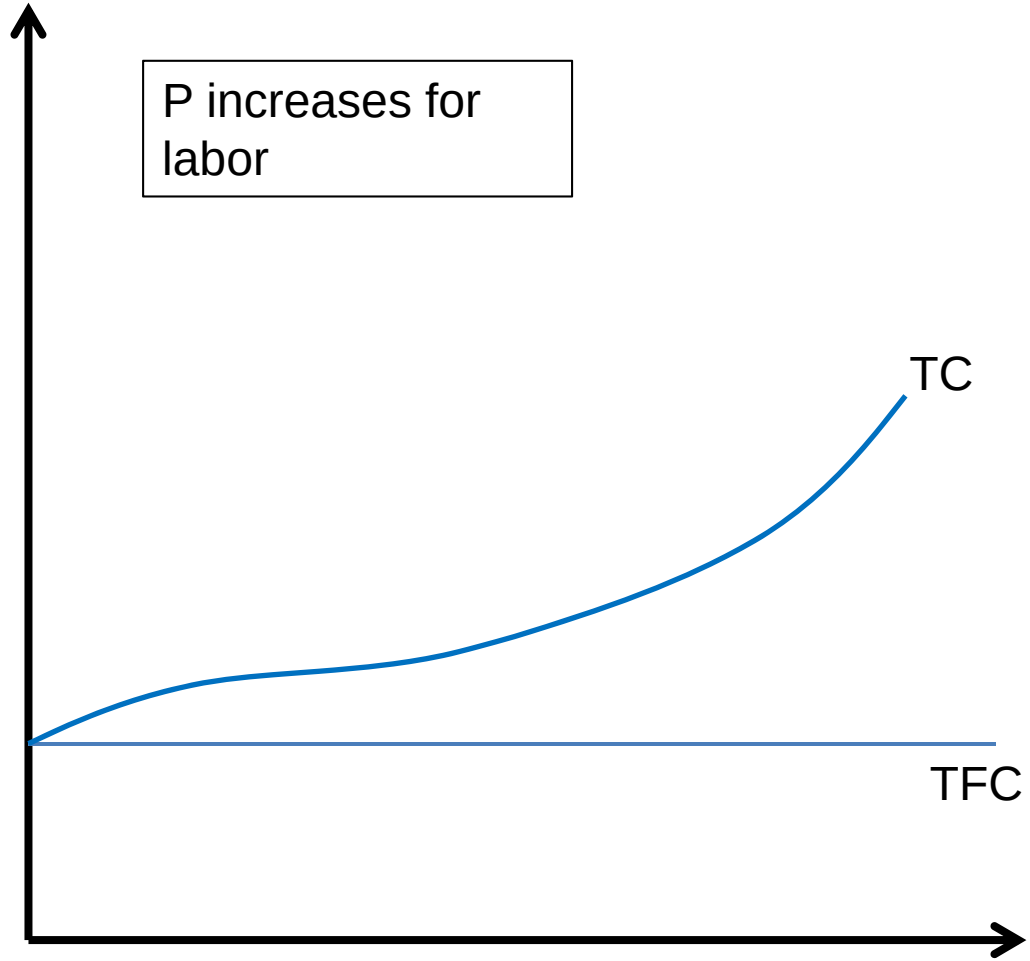
Shifts in Cost Curves (SR)

- Show: Increase of TFC
- Impact on MC, ATC, AVC?



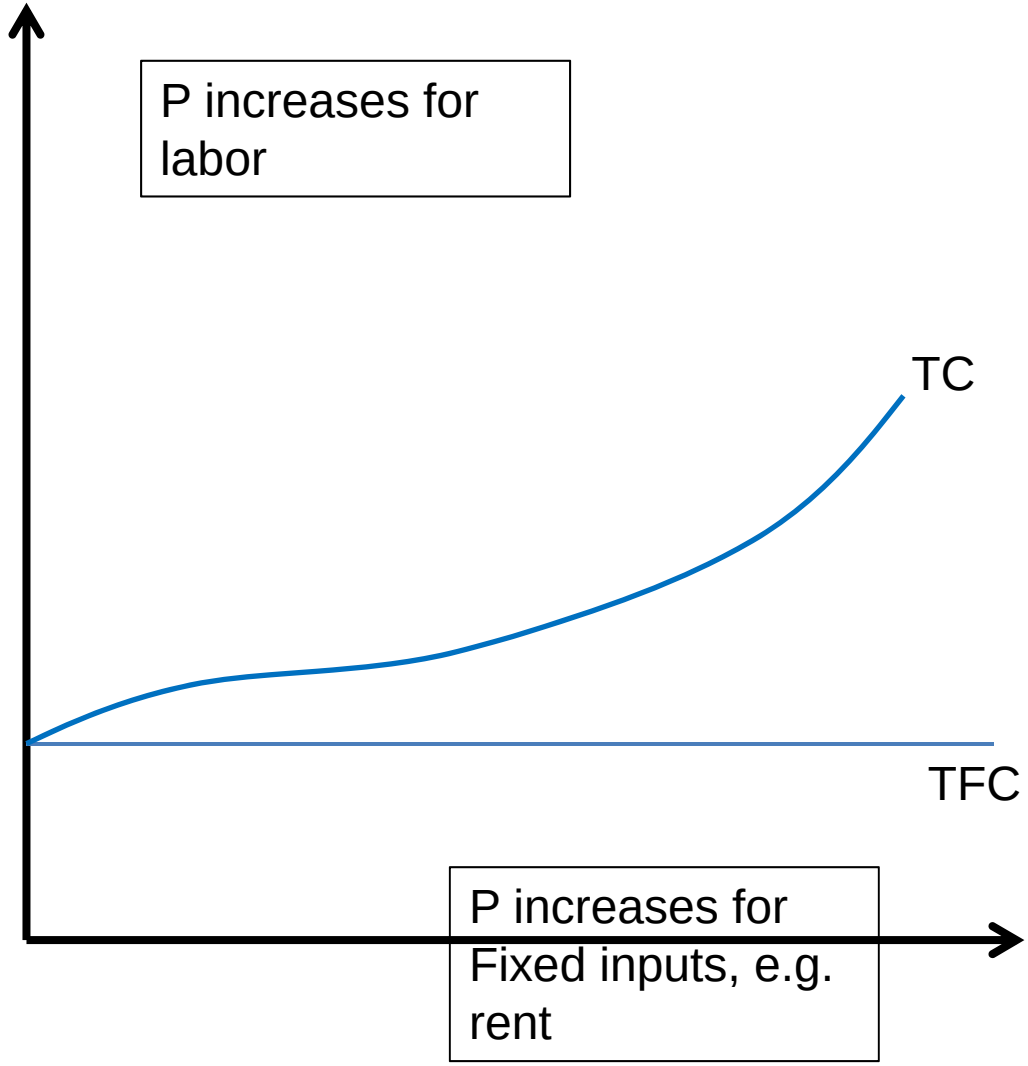
Shifts in Cost Curves (SR)

- Show: Wage of each worker increases
- Impact on MC, ATC, AVC?



Shifts in Cost Curves (SR)

- Blue: TFC and TC (old)
- Show: TFC and TC (new) when both fixed and variable costs increase.
- Try!!!



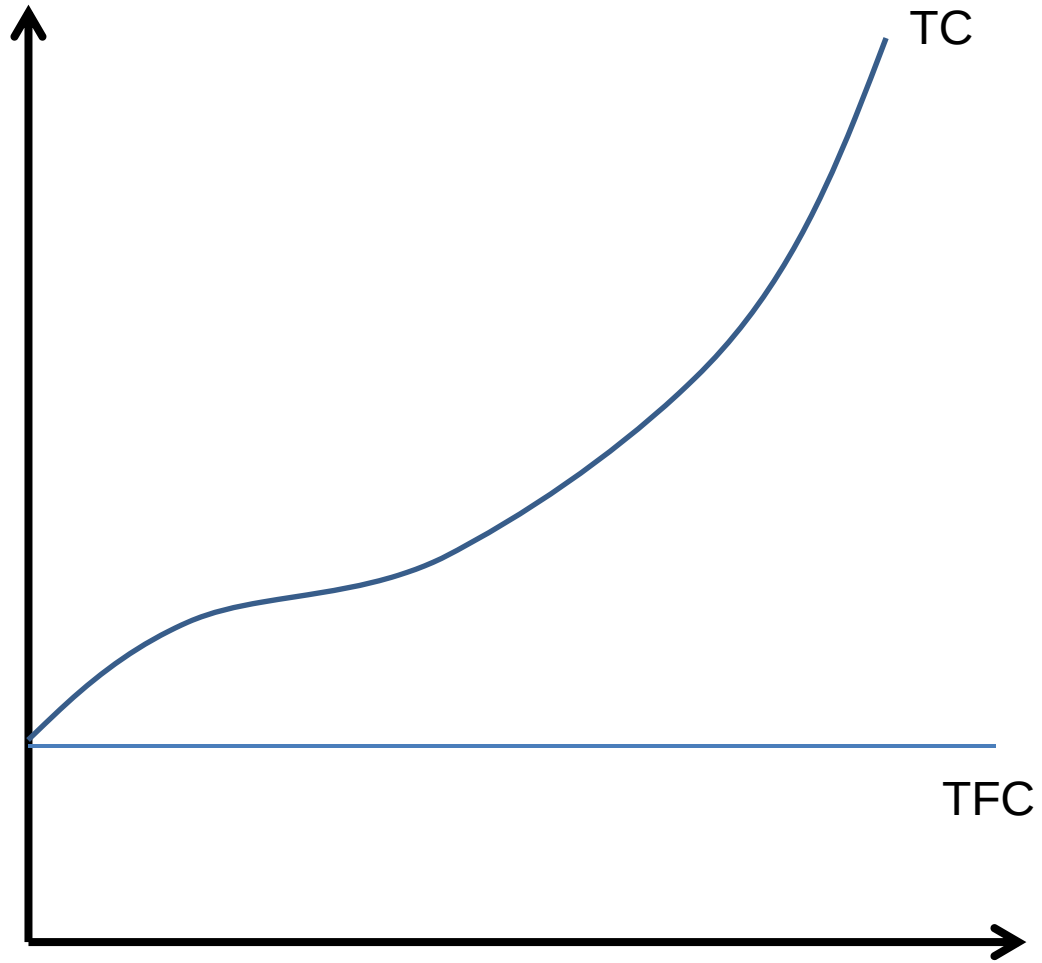
Shifts in Cost Curves (SR)

Technology

- Technological advance shift **BOTH** product and cost curves.
- An increase in productivity (increases in A) shifts the product curves upward & cost curves downward.
- One possibility: Technological advance results in the firm using more capital and less labor, fixed costs increase and variable costs decrease.
- ATC increases or decreases???

Shifts in Cost Curves (SR)

- Blue: TFC and TC (old)
- Show: TFC and TC (new, Tech advanced)
  - Can you see the AC and MC changes?



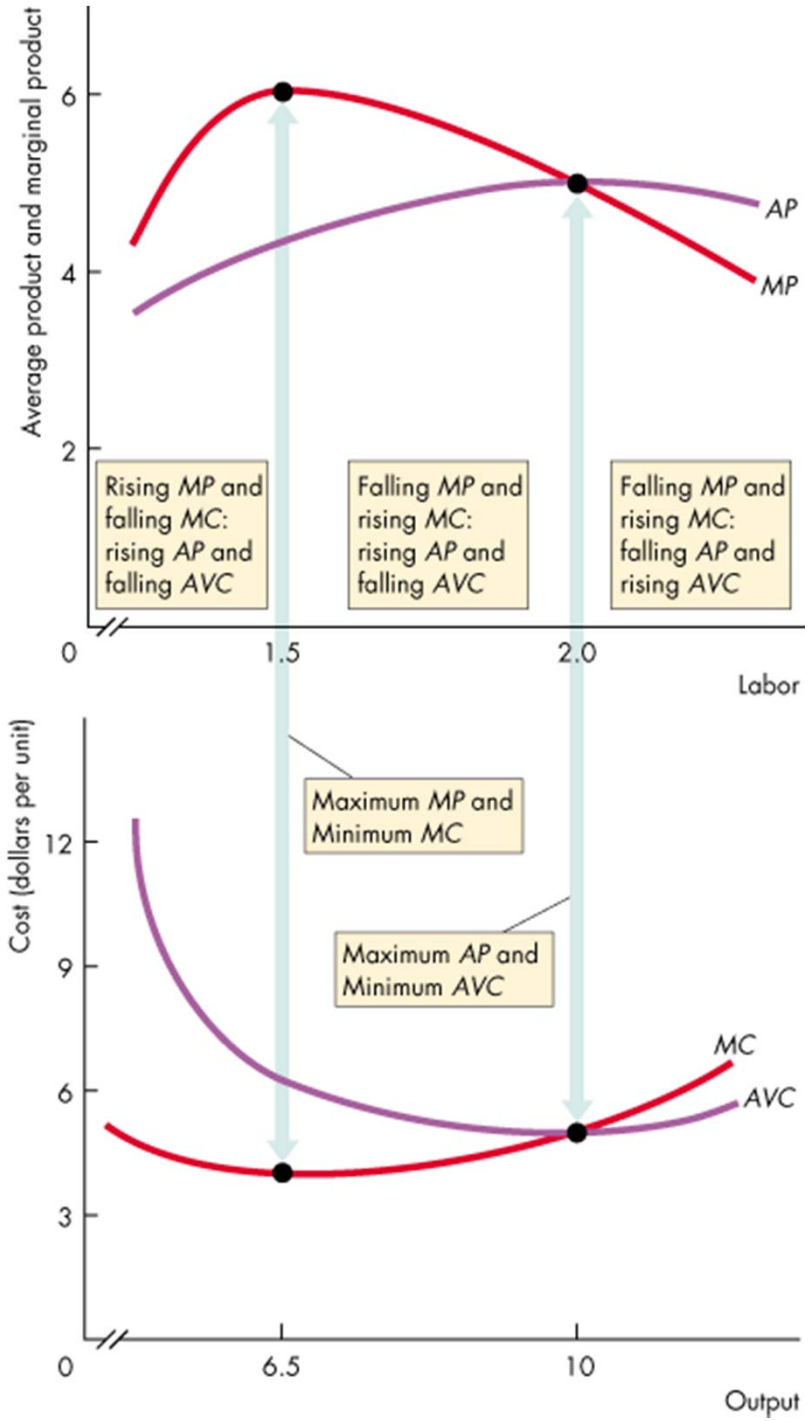
Cost Function and Firm's Decision

- Product Curve
  - Relationship between inputs and output level
  - Diminishing MP in SR
- Cost Curve
  - Relationship between cost level and output level
  - TFC, VC and TC, their relationship, average and marginal
- How are Production and Cost Functions linked together?

	Labor (workers per day)	Output (sweaters per day)	Total fixed cost (*TFC*)	Total variable cost (*TVC*)	Total cost (*TC*)	Marginal cost (*MC*)	Average fixed cost (*AFC*)	Average variable cost (*AVC*)	Average total cost (*ATC*)
			(dollars per day)			(dollars per additional sweater)	(dollars per sweater)		
A	0	0	25	0	25		—	—	—
						..... 6.25			
B	1	4	25	25	50		6.25	6.25	12.50
						..... 4.17			
C	2	10	25	50	75		2.50	5.00	7.50
						..... 8.33			
D	3	13	25	75	100		1.92	5.77	7.69
						.....12.50			
E	4	15	25	100	125		1.67	6.67	8.33
						.....25.00			
F	5	16	25	125	150		1.56	7.81	9.38

- When “wage” is fixed for worker (labor)
- MP for 1st worker = 4 units
- “MC for these 4 units” = $25, which means
- MC for 1 units = $25/4 = $6.25 (on average)

- MC is at its minimum at the same output level at which MP is at its maximum.
- When MP is rising, MC is falling.
- AVC is at its minimum at the same output level at which AP is at its maximum.
- When AP is rising, AVC is falling.



LONG RUN COST

Costs in LR

LR Production function

- Size of plant increases, output at a given no. of labor increases.
- At each plant size (scale), diminishing returns to labor.
- At each labor level, diminishing returns to capital.
- Can you see that?

TABLE 11.3 The Production Function

Labor (workers per day)	Output (sweaters per day)			
	Plant 1	Plant 2	Plant 3	Plant 4
1	4	10	13	15
2	10	15	18	20
3	13	18	22	24
4	15	20	24	26
5	16	21	25	27
Knitting machines	1	2	3	4

Costs in LR

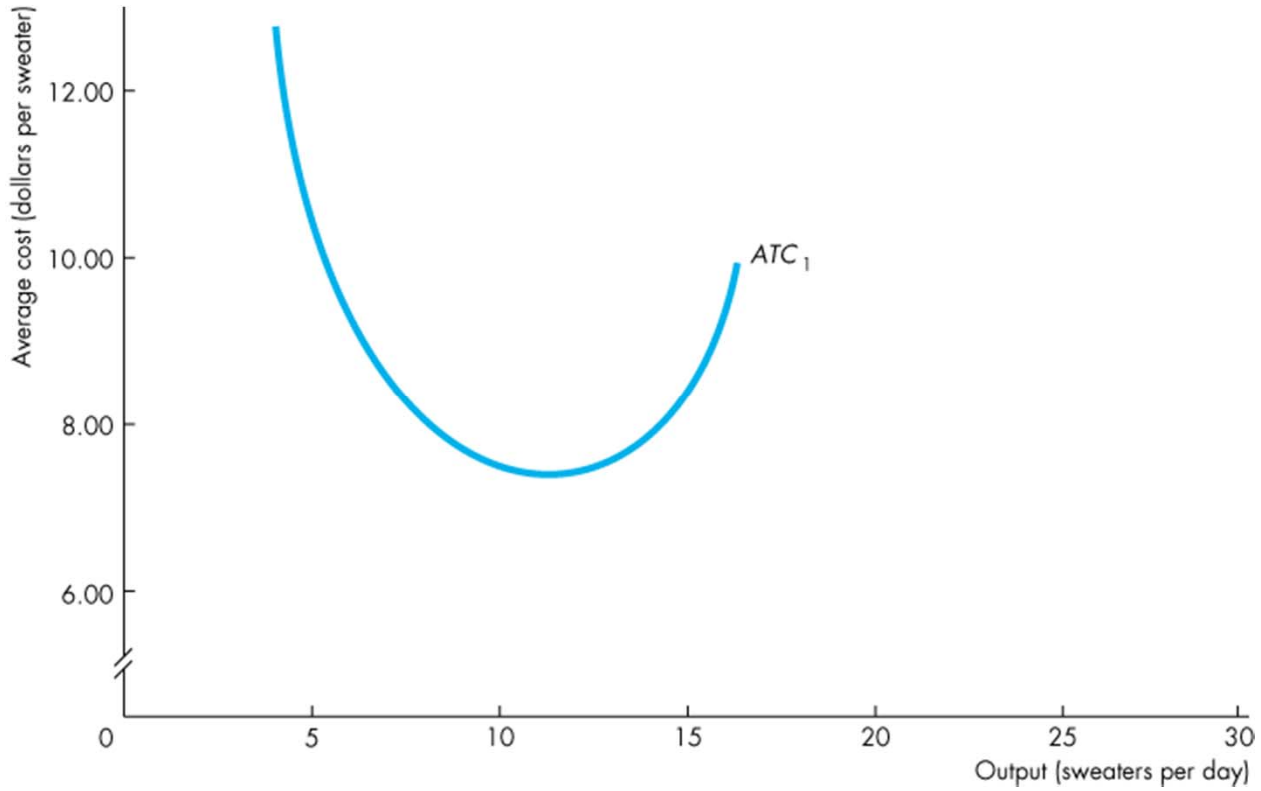
- If **ALL** inputs are variable: The "combination of inputs" with lowest ATC will be chosen to produce each Q level.
- For a particular Q level (e.g. Q'), there may be a number of different combinations of capital and labor that make production of Q' feasible, then you pick the lowest cost one (lowest ATC).
- EXAMPLE:

LR: An example

- The larger the plant (more machineries), the greater is the output at which ATC is at its minimum (the lowest point of the U-shaped ATC).
- The firm has 4 different plants: 1, 2, 3, or 4 knitting machines.
- Each plant has a SR ATC curve.
- The firm can compare the ATC for each output at different plant size.

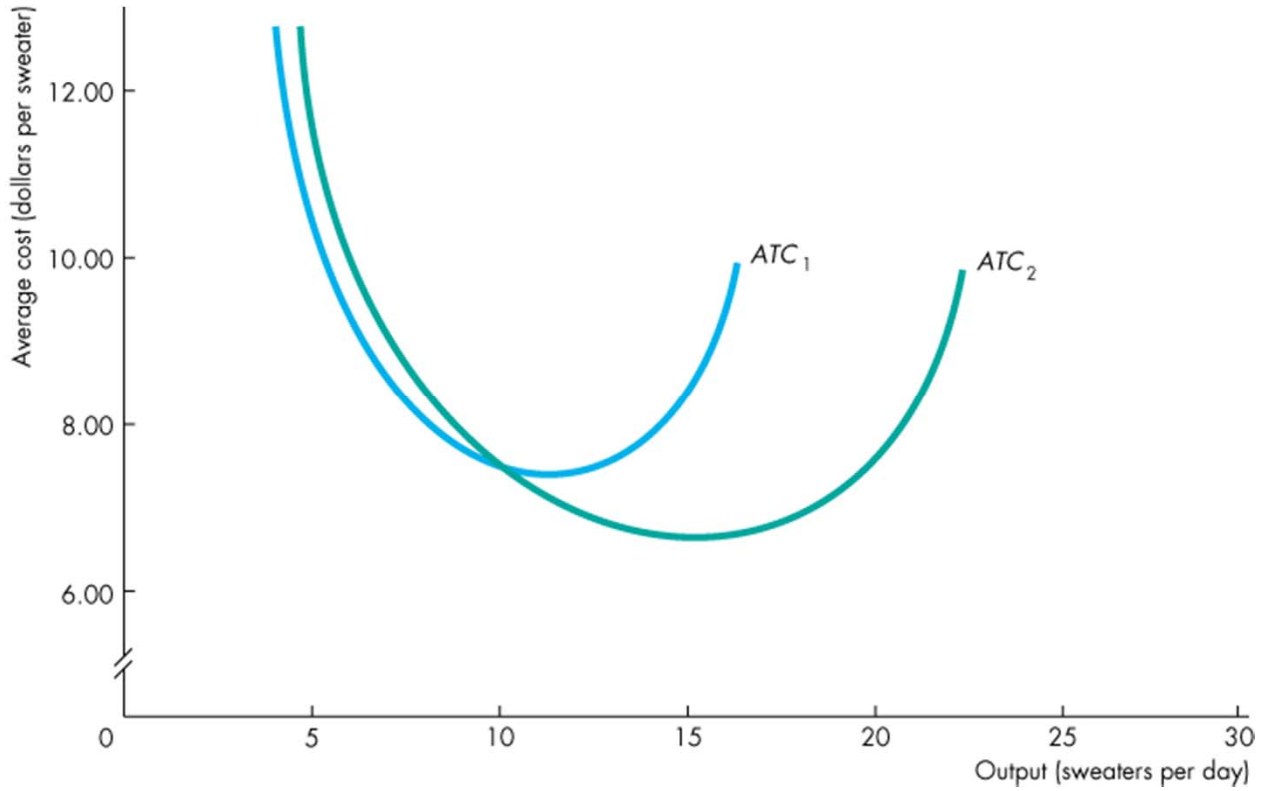
Cost in LR – An example

ATC_1 is the *ATC* curve for a plant with 1 knitting machine.



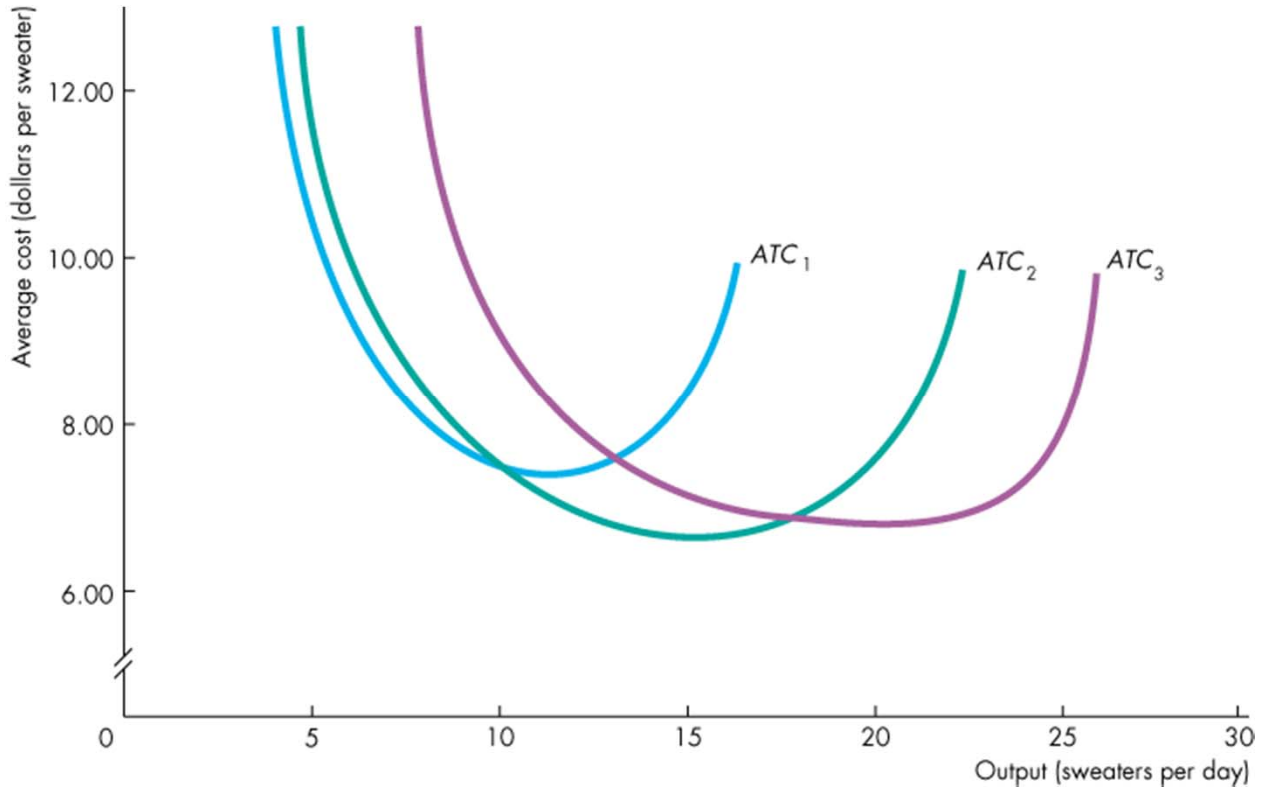
Cost in LR – An example

ATC_2 is the *ATC* curve for a plant with 2 knitting machines.



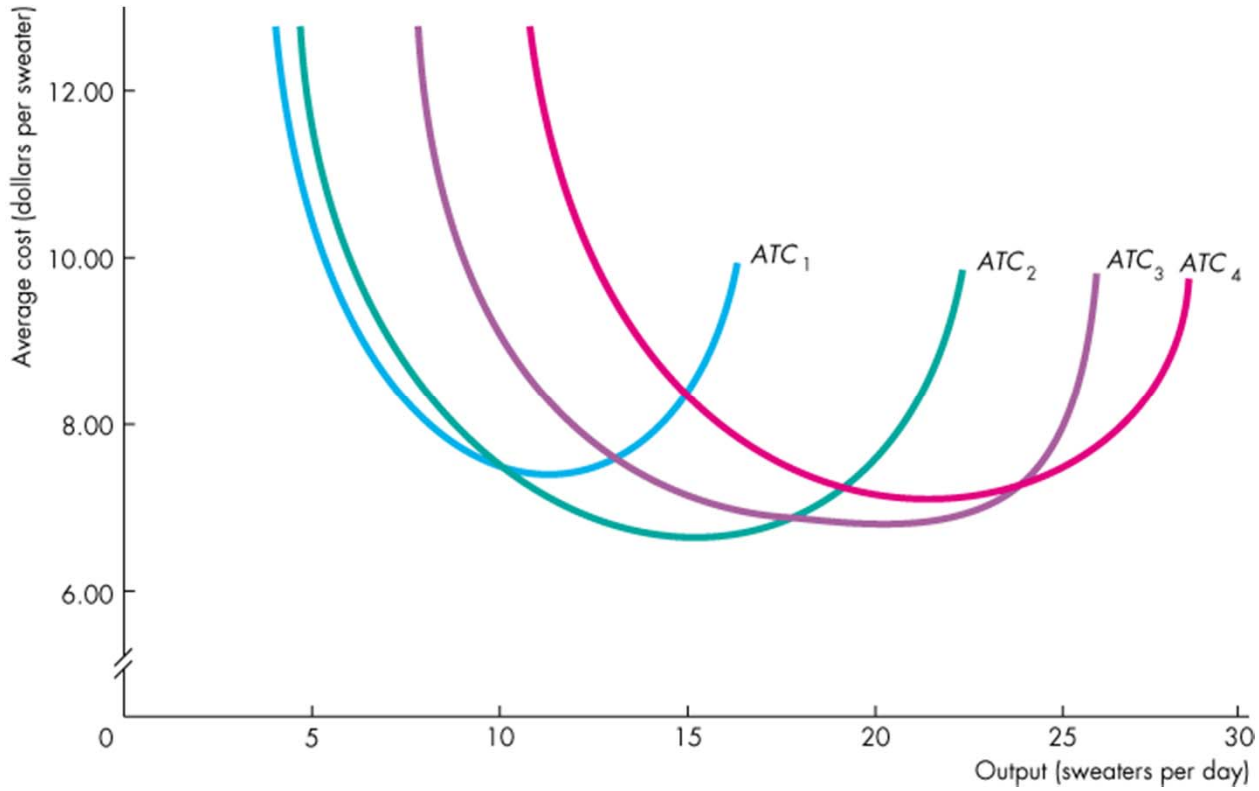
Cost in LR – An example

ATC_3 is the *ATC* curve for a plant with 3 knitting machines.



Cost in LR – An example

ATC_4 is the *ATC* curve for a plant with 4 knitting machines.



Cost in LR

- The **Long-Run ATC Curve** is made up from the lowest ATC for each output level.
- We want to decide which plant has the lowest cost for producing each output level.
- FOR EXAMPLE: Suppose that the firm wants to produce 13 sweaters a day.

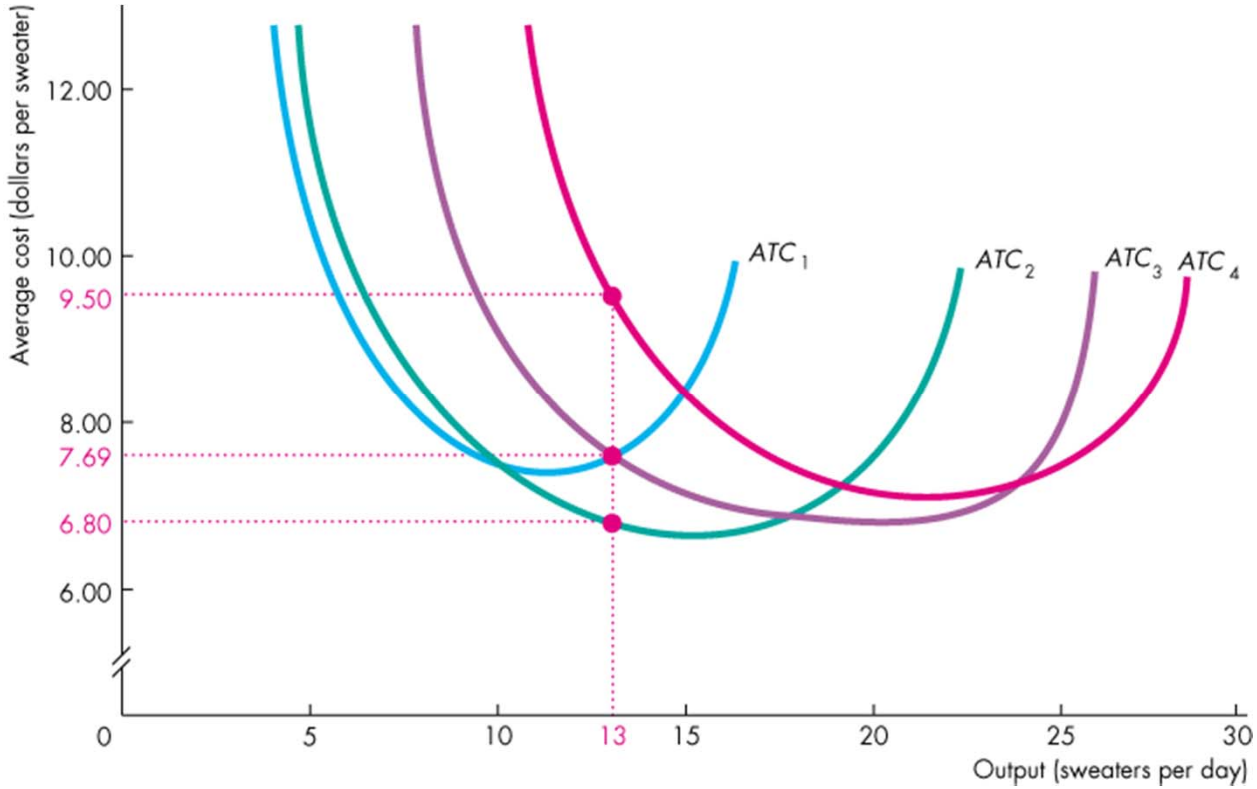
Cost in SR and LR

13 sweaters a day cost \$7.69 each on ATC_1.

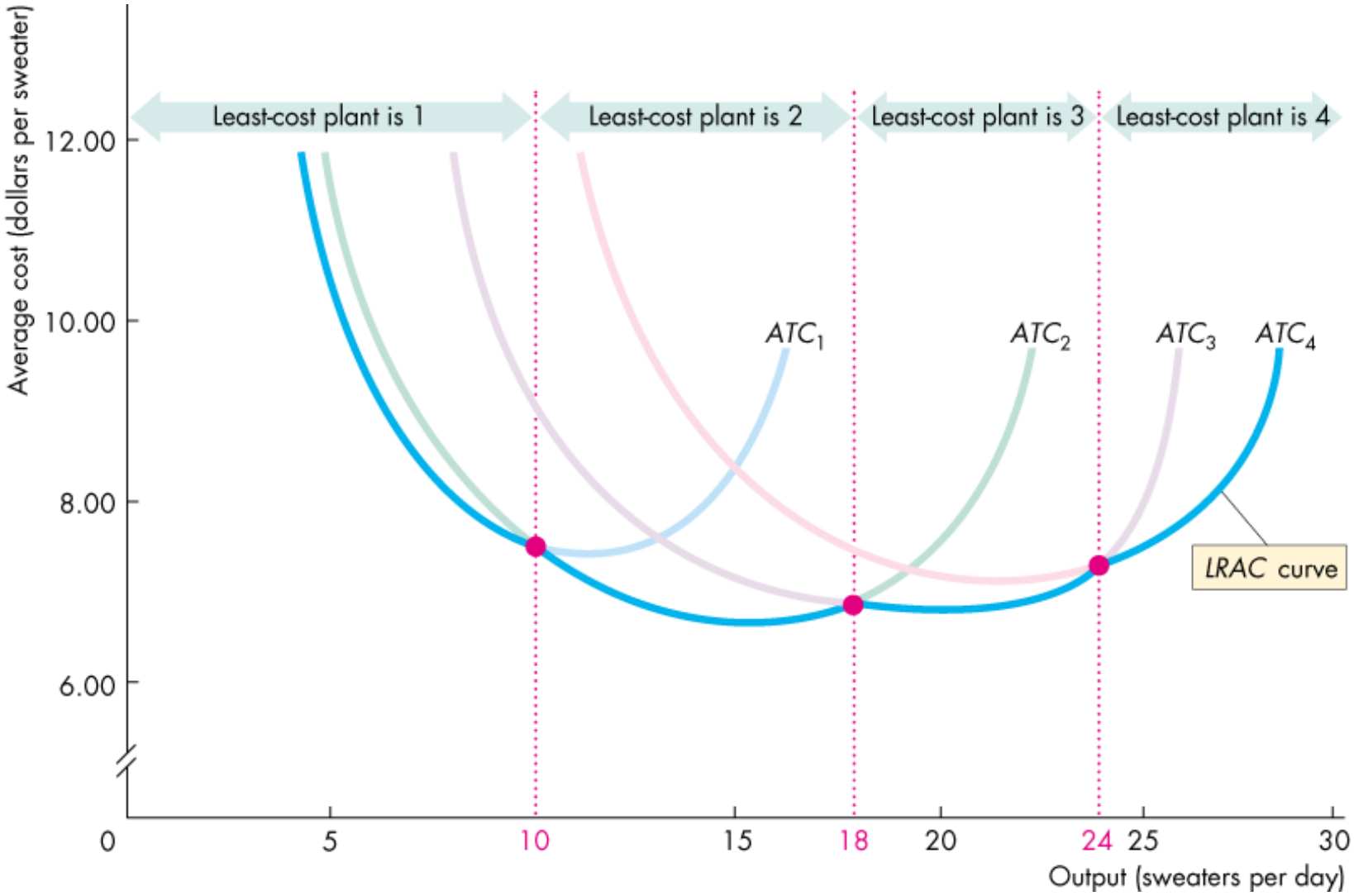
13 sweaters a day cost \$6.80 each on ATC_2.

13 sweaters a day cost \$7.69 each on ATC_3.

13 sweaters a day cost \$9.50 each on ATC_4.



LR ATC

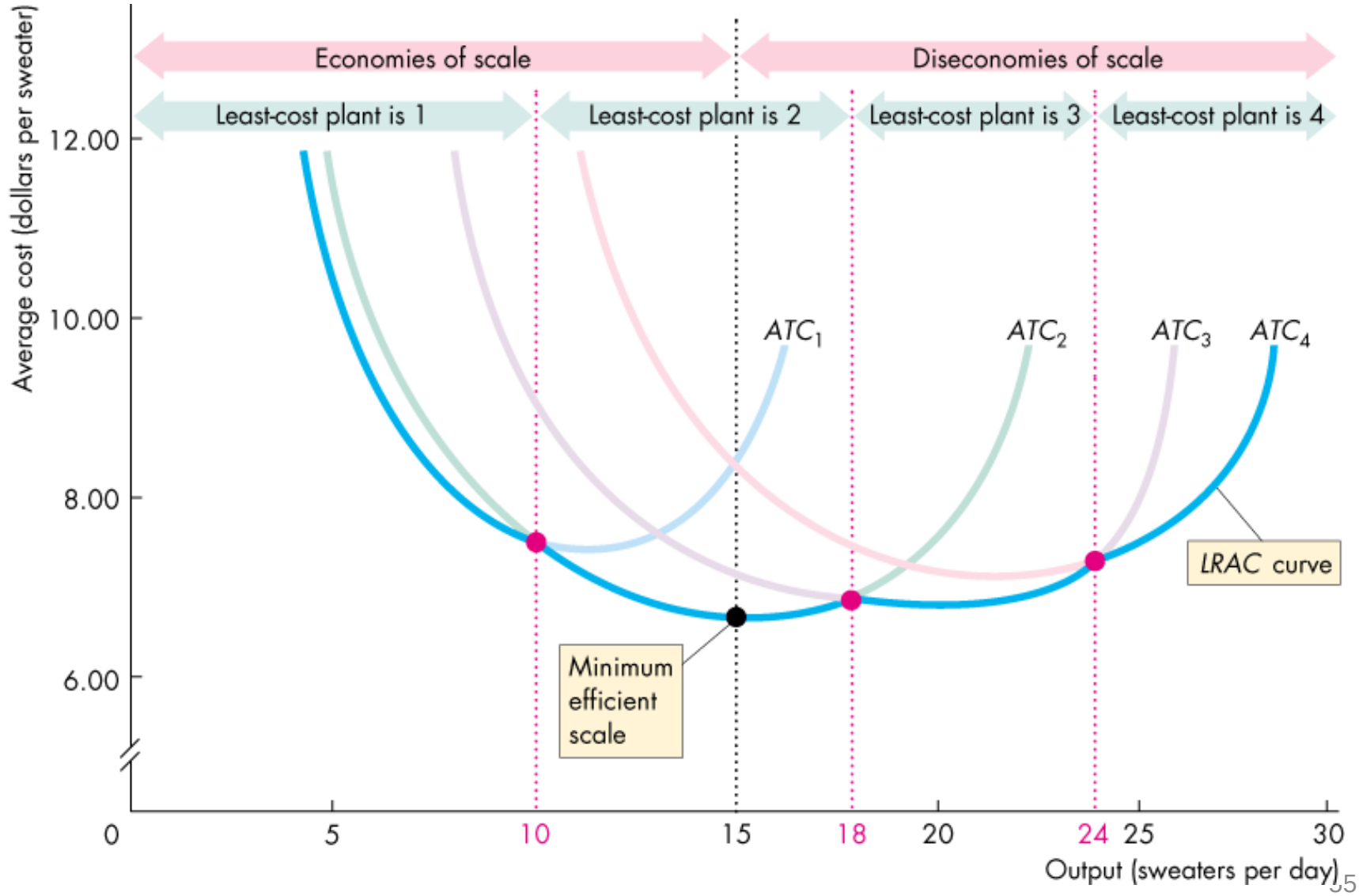

Least-cost plant is 1
Least-cost plant is 2
Least-cost plant is 3
Least-cost plant is 4
Average cost (dollars per sweater)
12.00
10.00
8.00
6.00
ATC_1
ATC_2
ATC_3
ATC_4
LRAC curve
0
5
10
15
18
20
24
25
30
Output (sweaters per day)

Economies and Diseconomies of Scale

Double all inputs, will output double as well?

- **Economies of scale**: When output increases, LR ATC falls.
- **Diseconomies of scale**: When output increases, LR ATC rises.
- **Constant returns to scale**: When output increases, LR ATC remains unchanged.

Economies and Diseconomies of Scale



How ATC changes as the Scale of Production Changes

- **Economies of scale**:
  - Specialization: workers and capital become more efficient when focusing on a small set of tasks.
  - More options or flexibility (different combination of inputs) in organizing production activities.
  - Procure raw materials in bulk with discount.
- **Diseconomies of scale:**
  - Coordination problems in large organizations.
  - For example: Managing a large firm may become more complex and less effective (inefficient).

Minimum Efficient Scale

- **Efficient scale** is an output level (Q), at which the LR ATC reaches its lowest level.
- For a U-shaped LR ATC, its minimum point identifies the **minimum efficient scale output level** (or **optimal scale**).
- Now, you realized that a U-shape ATC makes "efficient scale" exist.
- What if ATC is decreasing (forever/monotone)?
- What if ATC is increasing (forever/monotone)?

Quick check

A firm's long-run average cost curve

A) shows the lowest attainable average total cost of producing any level of output when the plant and labor are variable.

B) is U-shaped.

C) tells the firm which plant size to use and which quantity of labor to use to minimize the cost of producing any level of output.

D) all of the above

E) None of the above

Quick check

Quick check

A firm is operating in its range of economies of scale and is on both its *LRAC* curve and its short-run *ATC* curve. At that level of output, the slope of its *LRAC* curve is

A) zero and the slope of its *ATC* curve is zero.

B) zero and the slope of its *ATC* curve is negative.

C) negative and the slope of its *ATC* curve is zero.

D) negative and the slope of its *ATC* curve is negative.

Quick check

End for today ☺

Thank you very much

See you next time !