LECTURE 4: Production 생산이론

- The Technology of Production
- Production with One Variable Input (Labor)
- Isoquants
- Production with Two Variable Inputs
- Returns to Scale

The Theory of Production 생산이론

- The Theory of Production 생산이론

  describes how a firm makes cost-minimizing production decisions and how the firm's resulting cost varies with its output.

- The Production Decisions of a Firm

  are analogous to the purchasing decisions of consumers, and can likewise be understood in three steps:

1. Production Technology
2. Cost Constraints
3. Input (생산요소) Choices

Production Decisions of a Firm

1. Production Technology
   - Describe how *inputs* can be transformed into *outputs*
     - Inputs: land, labor, capital & raw materials
     - Outputs: cars, desks, books, etc.
   - Firms can produce different amounts of outputs using different combinations of inputs

Production Decisions of a Firm

2. Cost Constraints
   - Firms must consider *prices* of labor, capital and other inputs
   - Firms want to minimize total production costs partly determined by input prices
   - As consumers must consider budget constraints, firms must be concerned about costs of production

Production Decisions of a Firm

3. Input (생산요소) Choices
   - Given input prices and production technology, the firm must choose *how much of each input* to use in producing output
   - Given prices of different inputs, the firm may choose different combinations of inputs to minimize costs
     - If labor is cheap, may choose to produce with more labor and less capital

Production Decisions of a Firm

- If a firm is a cost minimizer, we can also study
  - How total costs of production varies with output
  - How does the firm choose the quantity to maximize its profits
- We can represent the firm's production technology in the form of a production function

The Technology of Production

- Production Function 생산함수:
  - Indicates the highest output (q) that a firm can produce for every specified combination of inputs.
  - For simplicity, we will consider only labor (L) and capital (K)
  - Shows what is technically feasible when the firm operates efficiently
  - *Basically it is an input-output relation* 투입 산출 관계

The Technology of Production

- The production function for two inputs:

$$q = F(K,L)$$

  - Contrast production function with utility function,
  - Output (q) is a function of capital (K) and Labor (L)
  - The production function is true for a given technology
    - If technology increases, more output can be produced for a given level of inputs

The Technology of Production

- Short Run versus Long Run
  - It takes time for a firm to adjust production from one set of inputs to another
  - Firms must consider not only what inputs can be varied but over what period of time that can occur
  - We must distinguish between long run and short run

The Short Run versus the Long Run

The Short Run versus the Long Run

short run: Period of time in which quantities of one or more production factors cannot be changed.

- **fixed input** 고정생산요소

  Production factor that cannot be varied.

- **variable input** 변동생산요소

  Production factor that can be varied.in short run

long run : Amount of time needed to make all production inputs variable.

Production: One Variable Input

- We will begin looking at the short run when only one input can be varied
- We assume capital is fixed and labor is variable
  - Output can only be increased by increasing labor
  - Must know how output changes as the amount of labor is changed

Production: One Variable Input

Amount of Labor (L)	Amount of Capital (K)	Total Output (q)
0	10	0
1	10	10
2	10	30
3	10	60
4	10	80
5	10	95
6	10	108
7	10	112
8	10	112
9	10	108
10	10	100

Production: One Variable Input

- Observations:
  1. When labor is zero, output is zero as well
  2. With additional workers, output (q) increases up to 8 units of labor.
  3. Beyond this point, output declines
     - Increasing labor can make better use of existing capital initially
     - After a point, more labor is not useful and can be counterproductive

Production: One Variable Input

- Firms make decisions based on the benefits with the costs of production
- Sometimes useful to look at benefits and costs on an *incremental basis*
  - How much more can be produced when at incremental units of an input
- Sometimes useful to make comparison on an *average basis*

Production: One Variable Input

- AP 평균생산 :Average product of Labor - Output per unit of a particular product
- Measures the productivity of a firm's labor in terms of how much, on average, each worker can produce

$$AP = \frac{Output}{Labor\ Input} = \frac{q}{L}$$

Production: One Variable Input

- Marginal Product of Labor – additional output produced when labor increases by one unit
- Change in output divided by the change in labor

$$MP_L = \frac{\Delta Output}{\Delta Labor\ Input} = \frac{\Delta q}{\Delta L}$$

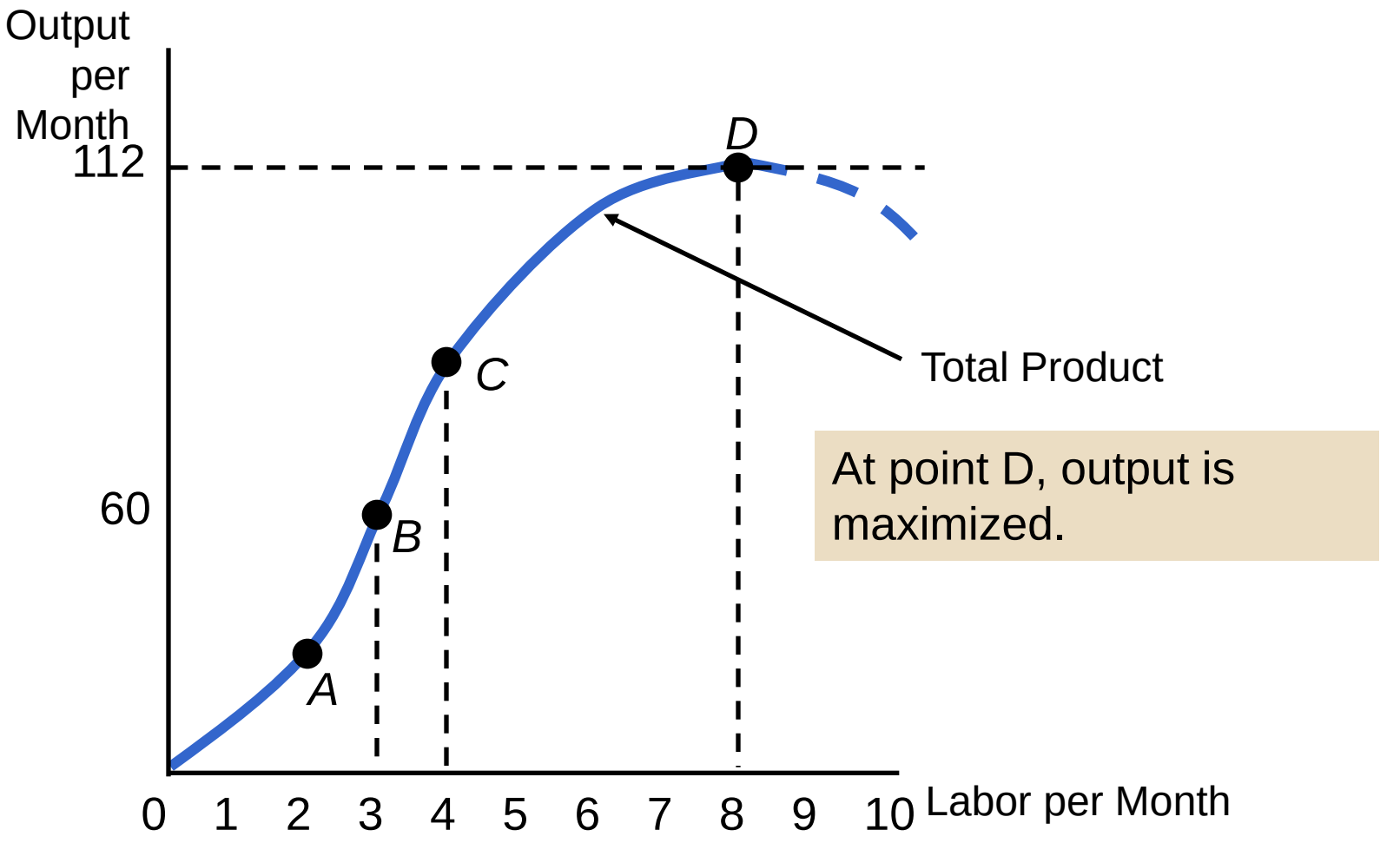
Average and Marginal Products

- **AP: average product 평균생산**
  - Output per unit of a particular input.
- **MP: marginal product 한계생산**
  - Additional output produced as an input is increased by one unit.

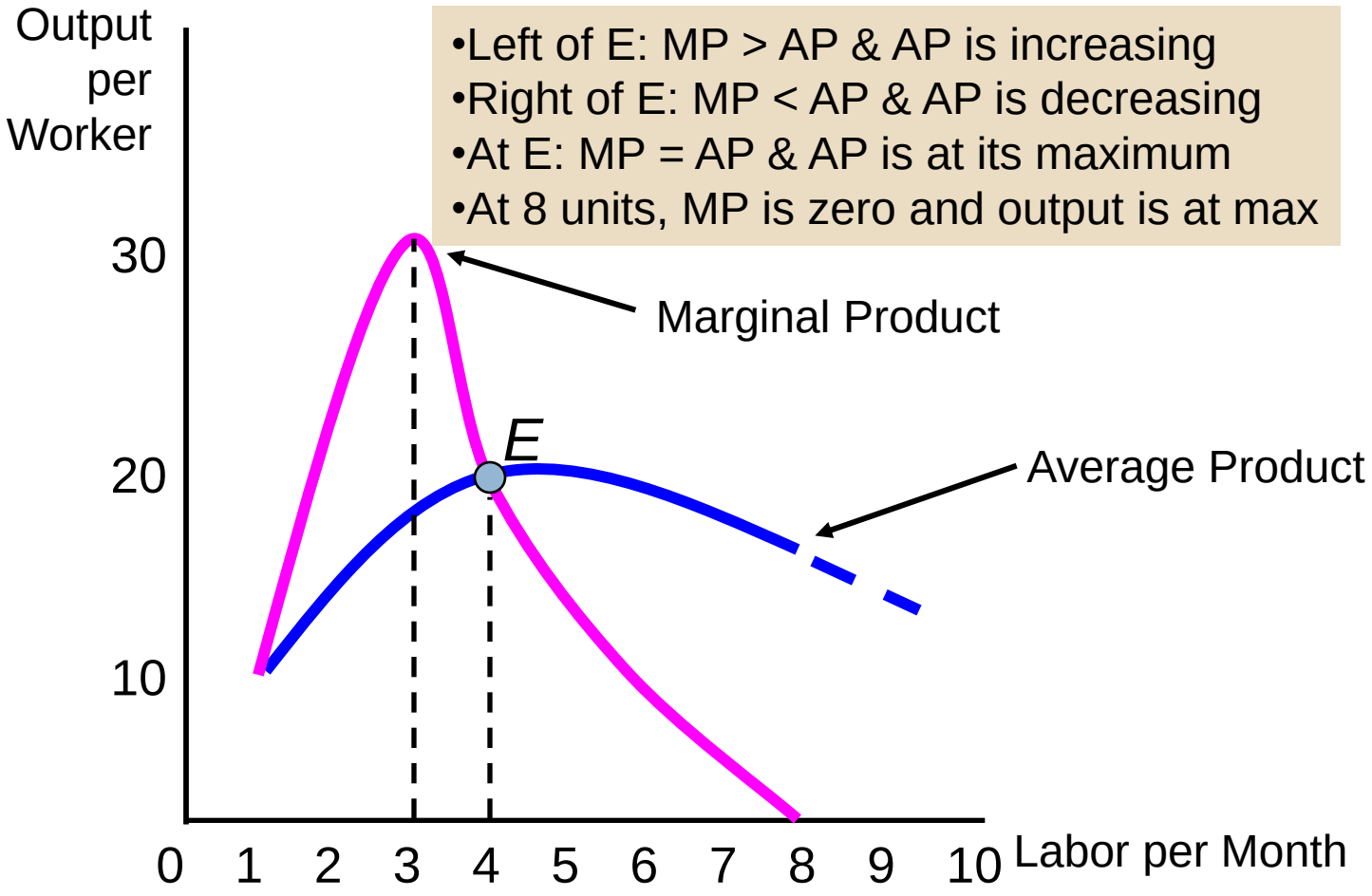
Average product of labor = Output/labor input = q/L

Marginal product of labor = Change in output/change in labor input
= $\Delta q/\Delta L$

Production: One Variable Input



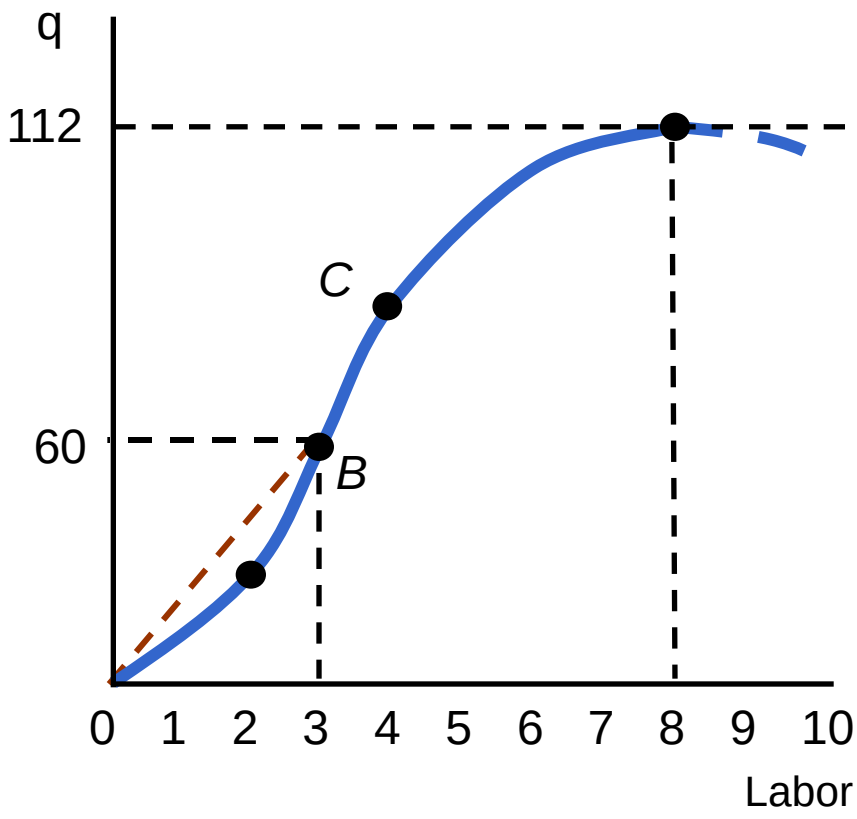
Production: One Variable Input



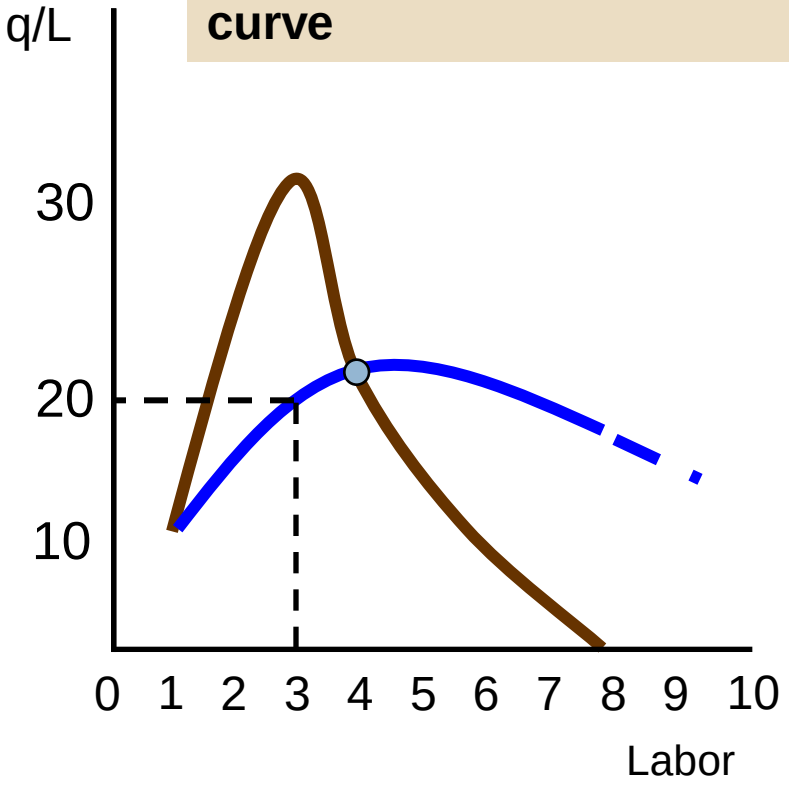
Marginal & Average Product

- When marginal product is greater than the average product, the average product is increasing
- When marginal product is less than the average product, the average product is decreasing
- When marginal product is zero, total product (output) is at its maximum
- Marginal product crosses average product at its maximum

Product Curves

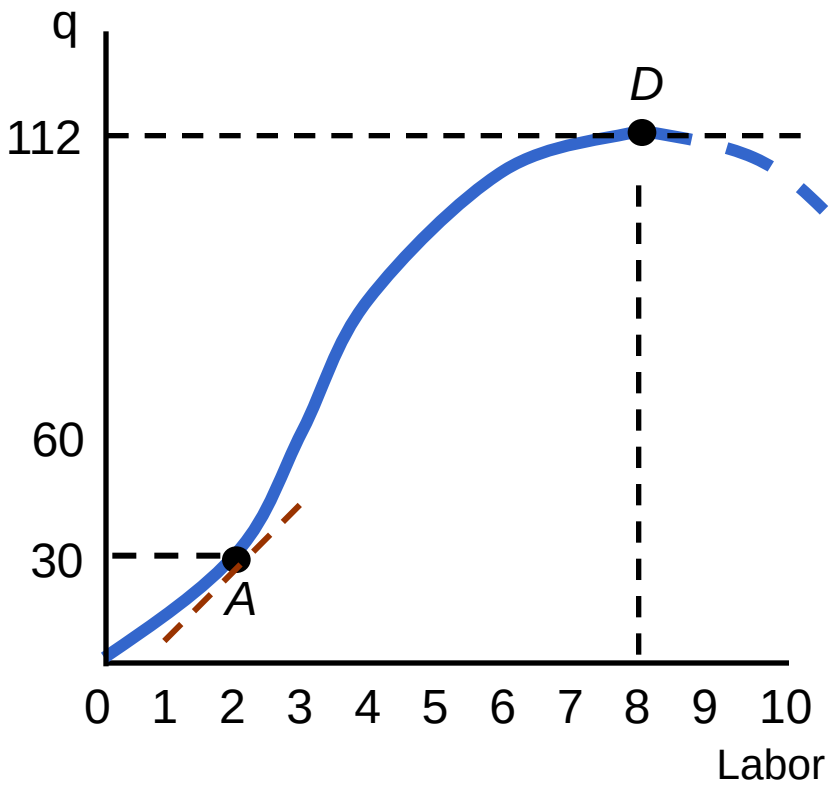


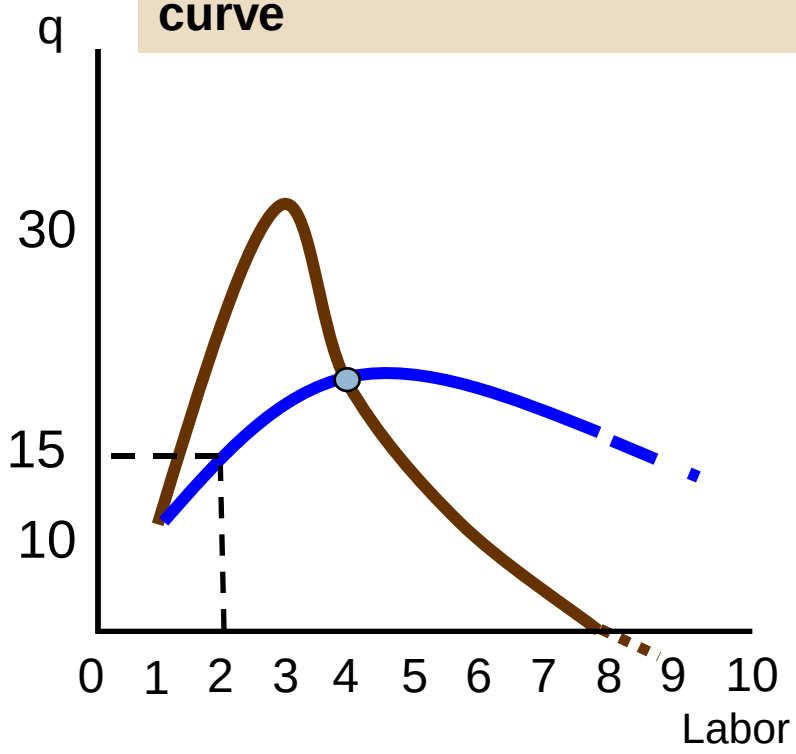
AP is slope of line from origin to point on TP curve



Product Curves

MP is slope of line tangent to corresponding point on TP curve





Production: One Variable Input

- From the previous example, we can see that as we increase labor the additional output produced declines
- Law of Diminishing Marginal Returns
  한계수확체감의 법칙: As the use of an input increases with other inputs fixed, the resulting additions to output will eventually decrease.

Law of Diminishing Marginal Returns
한계수확(익체감)의 법칙

- When the labor input is small and capital is fixed, output increases considerably since workers can begin to specialize and MP of labor increases
- When the labor input is large, some workers become less efficient and MP of labor decreases

Law of Diminishing Marginal Returns

- Usually used for short run when one variable input is fixed
- Can be used for long-run decisions to evaluate the trade-offs of different plant configurations
- Assumes the quality of the variable input is constant

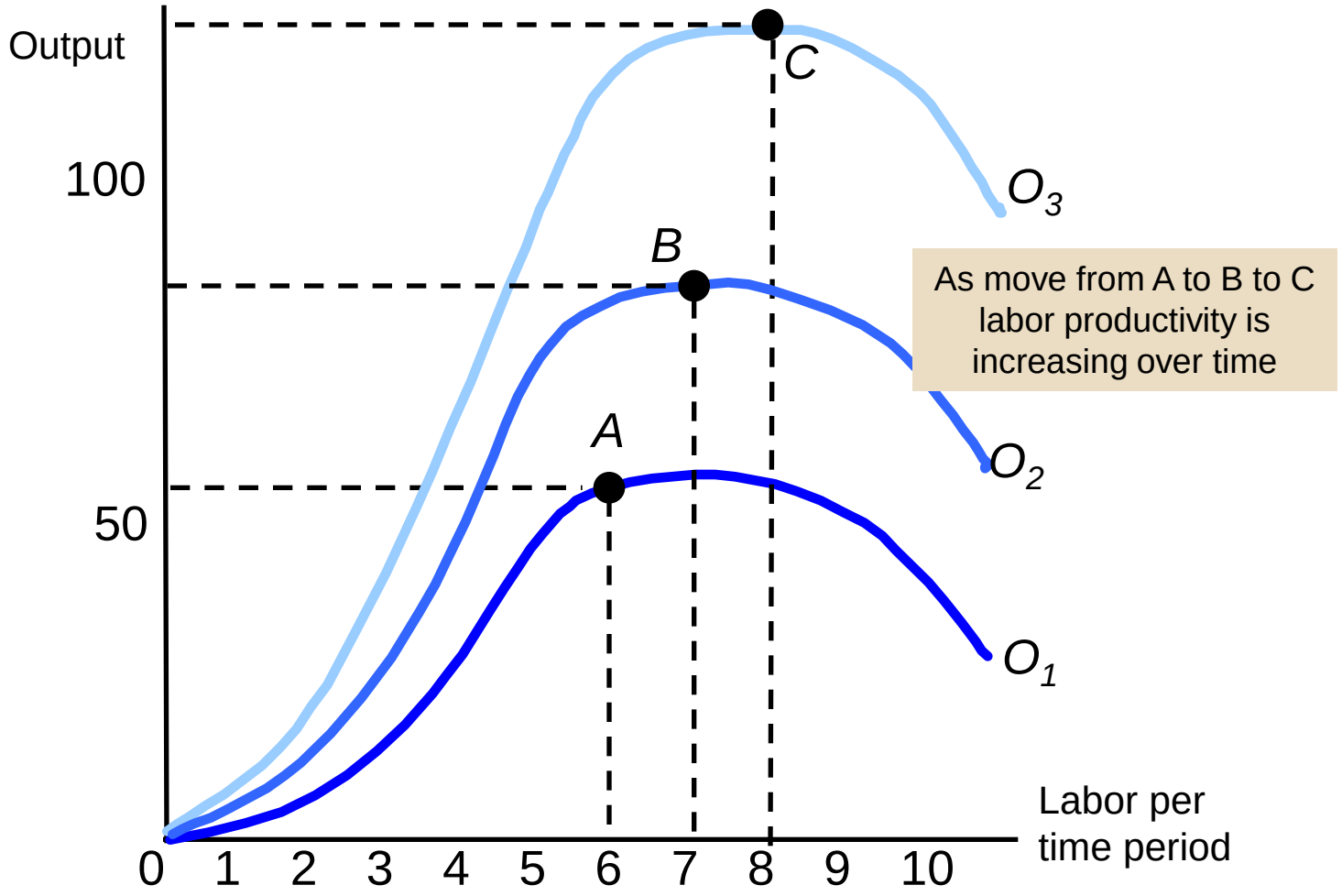
Law of Diminishing Marginal Returns

- Easily confused with negative returns – decreases in output.
- Explains a *declining* marginal product, **not** necessarily a negative one
  - *Additional* output can be declining while *total* output is increasing

Law of Diminishing Marginal Returns

- Assumes a constant technology
  - Changes in technology will cause shifts in the total product curve
  - More output can be produced with same inputs
  - Labor productivity can increase if there are improvements in technology, even though any given production process exhibits diminishing returns to labor.

The Effect of Technological Improvement



Malthus and the Food Crisis

- Malthus predicted mass hunger and starvation as diminishing returns limited agricultural output and the population continued to grow.
- Why did Malthus' prediction fail?
  - Did not take into account changes in technology
  - Although he was right about diminishing marginal returns to labor

Labor Productivity

- Macroeconomics are particularly concerned with labor productivity
  - The average product of labor for an entire industry or the economy as a whole
  - Links macro and microeconomics
  - Can provide useful comparisons across time and across industries

$$\text{Average Productivity} = \frac{q}{L}$$

Labor Productivity

- Link between labor productivity and standard of living
  - Consumption can increase only if productivity increases.
  - Growth of Productivity
    1. Growth in stock of capital – total amount of capital available for production
    2. Technological change – development of new technologies that allow factors of production to be used more efficiently

Production: Two Variable Inputs

- Firm can produce output by combining different amounts of labor and capital
- In the long-run, capital and labor are both variable.
- We can look at the output we can achieve with different combinations of capital and labor

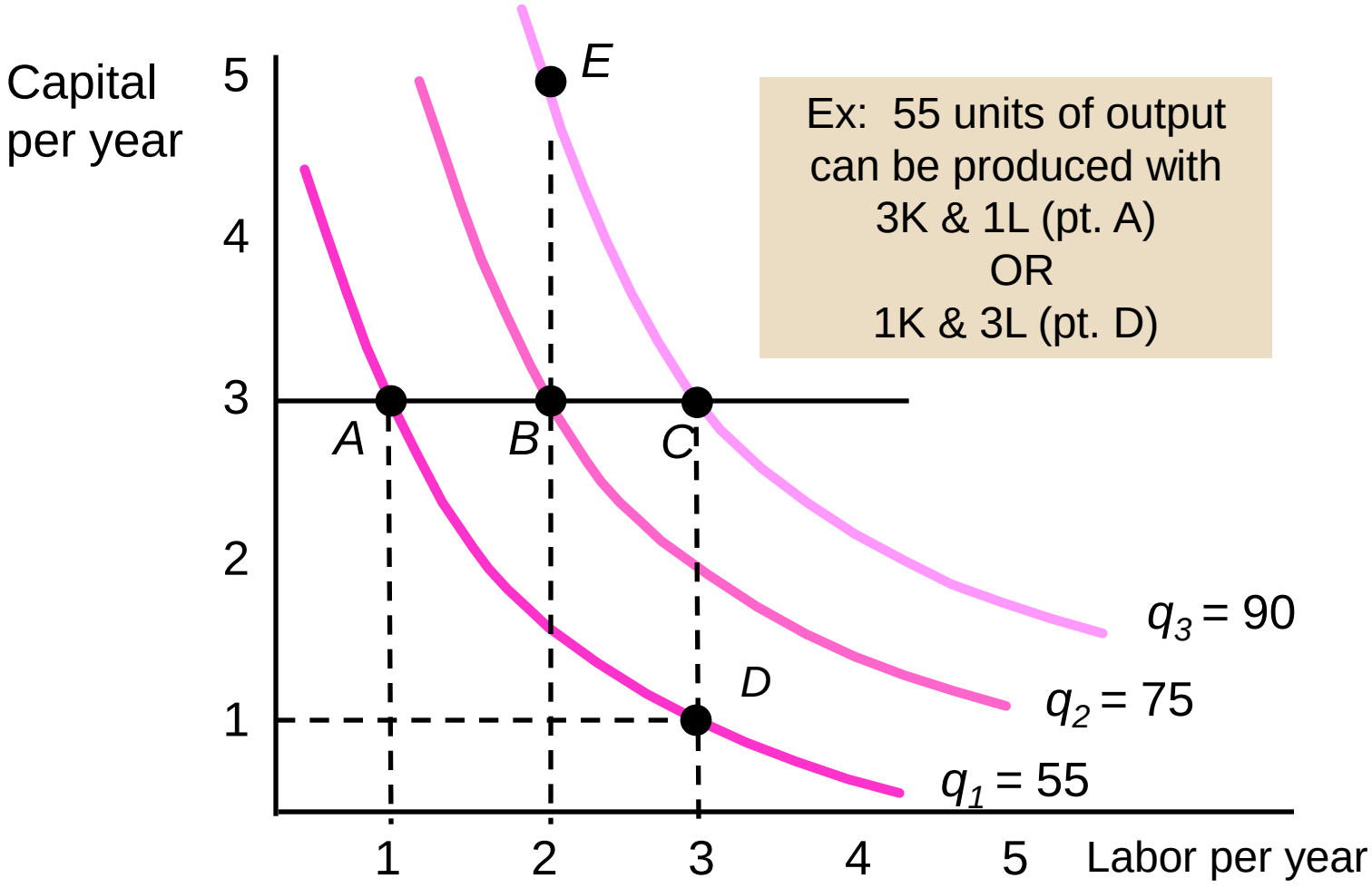
Production: Two Variable Inputs

Capital Input	Labor Input 1	2	3	4	5
1	20	40	55	65	75
2	40	60	75	85	90
3	55	75	90	100	105
4	65	85	100	110	115
5	75	90	105	115	120

Production: Two Variable Inputs

- The information can be represented graphically using isoquants 등생산(량) 곡선, 또는 등량곡선
  - Curves showing all possible combinations of inputs that yield the same output
- Curves are smooth to allow for use of fractional inputs
  - Curve 1 shows all possible combinations of labor and capital that will produce 55 units of output

Isoquant Map



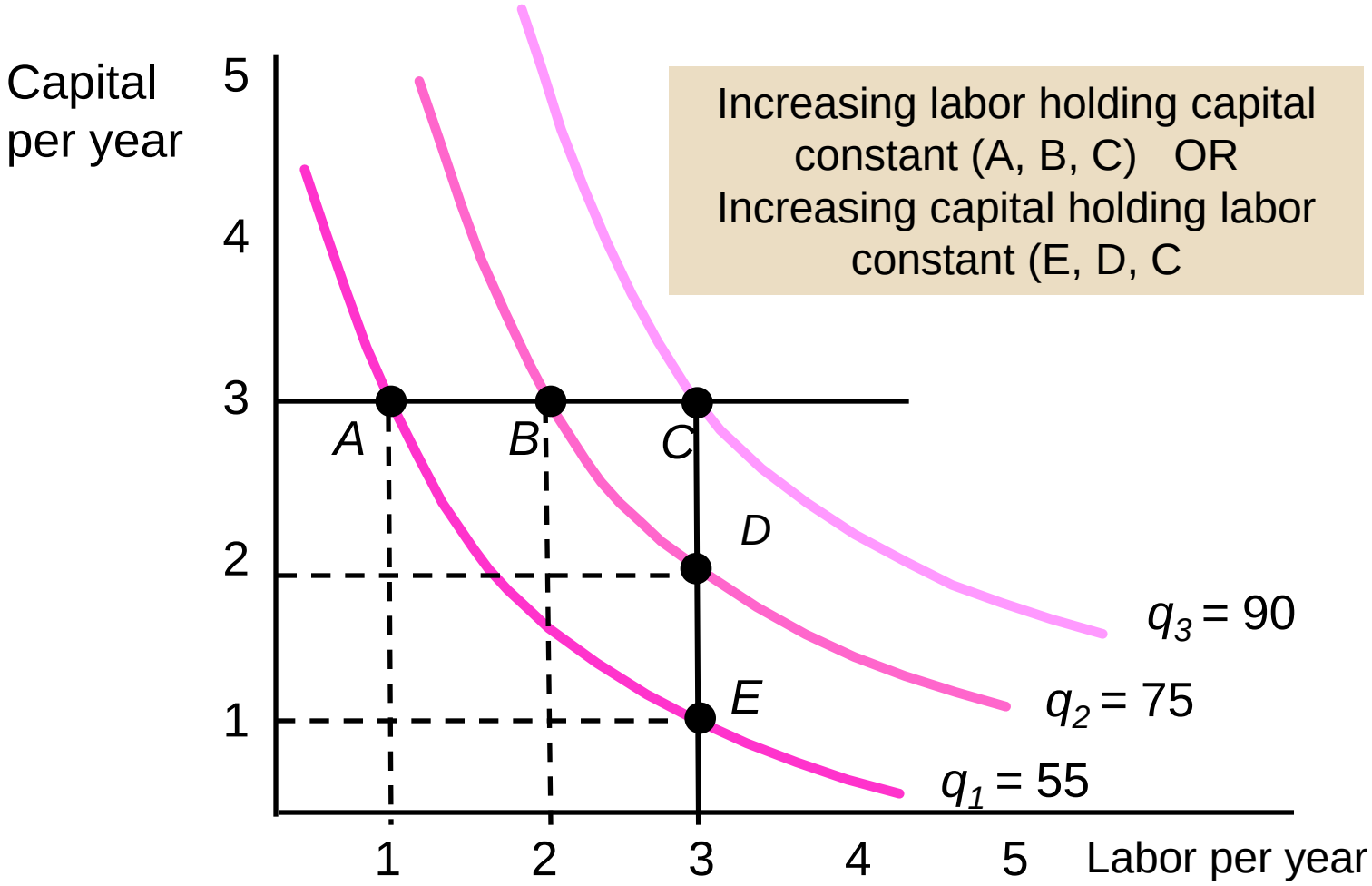
Production: Two Variable Inputs

- Diminishing Returns to Labor with Isoquants
- Holding capital at 3 and increasing labor from 0 to 1 to 2 to 3.
  - Output increases at a decreasing rate (0, 55, 20, 15) illustrating diminishing marginal returns from labor in the short-run and long-run.

Production: Two Variable Inputs

- Diminishing Returns to Capital with Isoquants
- Holding labor constant at 3 increasing capital from 0 to 1 to 2 to 3.
  - Output increases at a decreasing rate (0, 55, 20, 15) due to diminishing returns from capital in short-run and long-run.

Diminishing Returns



Production: Two Variable Inputs

- Substituting Among Inputs
  - Companies must decide what combination of inputs to use to produce a certain quantity of output
  - There is a trade-off between inputs allowing them to use more of one input and less of another for the same level of output.

Production: Two Variable Inputs

- Substituting Among Inputs
  - Slope of the isoquant shows how one input can be substituted for the other and keep the level of output the same.
  - Positive slope is the marginal rate of technical substitution (MRTS)
    - Amount by which the quantity of one input can be reduced when one extra unit of another input is used, so that output remains constant.

Production: Two Variable Inputs

- MRTS 한계기술대체율 the marginal rate of technical substitution equals:

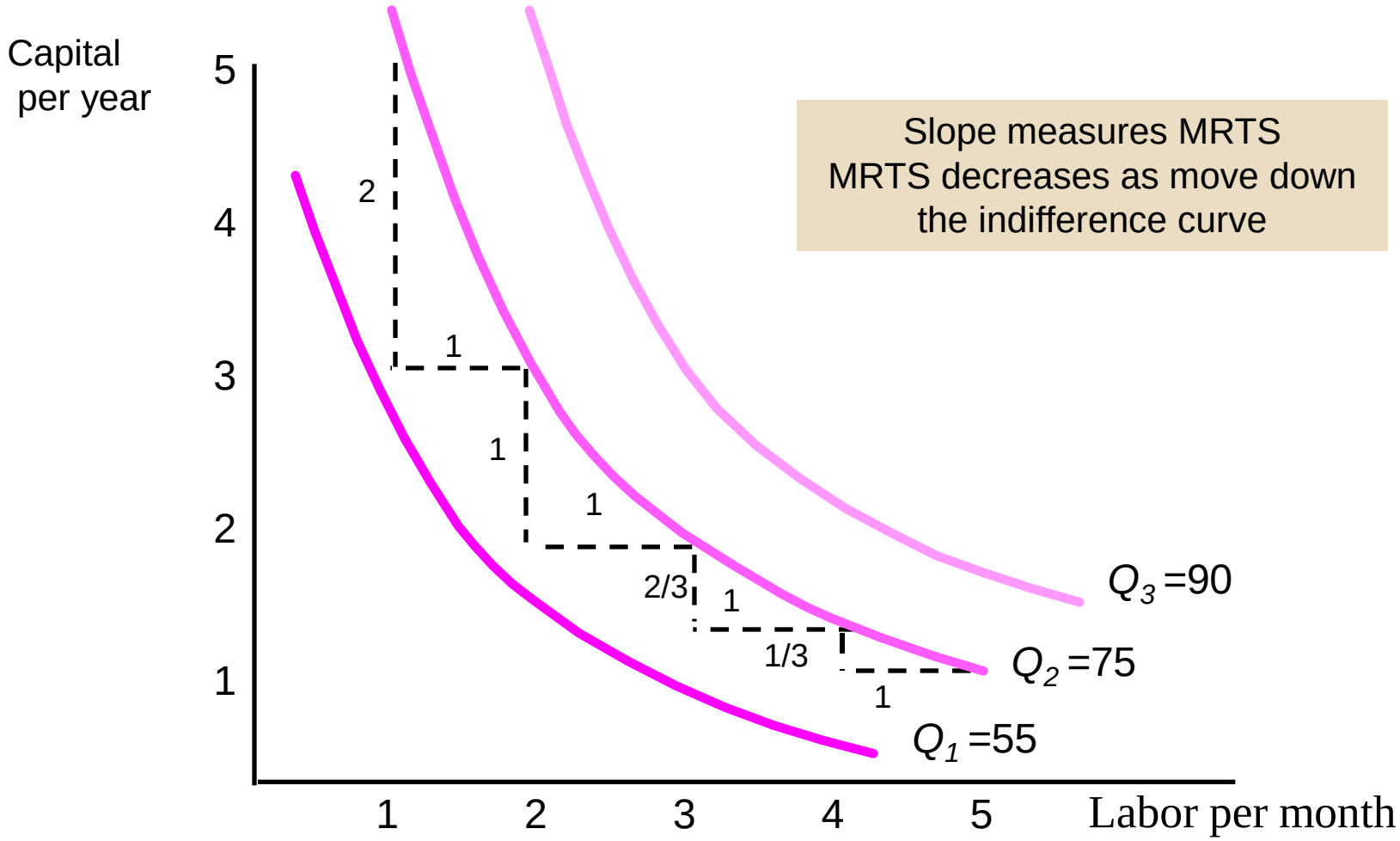
$$MRTS = \frac{Change\ in\ Capital\ input}{Change\ in\ Labor\ input}$$

$$MRTS = -\Delta K / \Delta L \text{ (for a fixed level of } q)$$

Production: Two Variable Inputs

- As increase labor to replace capital
  - Labor becomes relatively less productive
  - Capital becomes relatively more productive
  - Need less capital to keep output constant
  - Isoquant becomes flatter

Marginal Rate of Technical Substitution 한계기술대체율



Slope measures MRTS
MRTS decreases as move down the indifference curve

MRTS and Isoquants

- We assume there is diminishing MRTS
  - Increasing labor in one unit increments from 1 to 5 results in a decreasing MRTS from 1 to 1/2.
  - Productivity of any one input is limited
- Diminishing MRTS occurs because of diminishing returns and implies isoquants are convex.
- There is a relationship between MRTS and marginal products of inputs

MRTS and Marginal Products

- If we increase labor and decrease capital to keep output constant, we can see how much the increase in output is due to the increased labor
  - Amount of labor increased times the marginal productivity of labor

$$= (MP_L)(\Delta L)$$

MRTS and Marginal Products

- Similarly, the decrease in output from the decrease in capital can be calculated
  - Decrease in output from reduction of capital times the marginal produce of capital

$$= (MP_K)(\Delta K)$$

MRTS and Marginal Products

- If we are holding output constant, the net effect of increasing labor and decreasing capital must be zero
- Using changes in output from capital and labor we can see

$$(MP_L)(\Delta L) + (MP_K)(\Delta K) = 0$$

MRTS and Marginal Products

- Rearranging equation, we can see the relationship between MRTS and MPs

$$(MP_L)(\Delta L)+(MP_K)(\Delta K)=0$$

$$(MP_L)(\Delta L)=-(MP_K)(\Delta K)$$

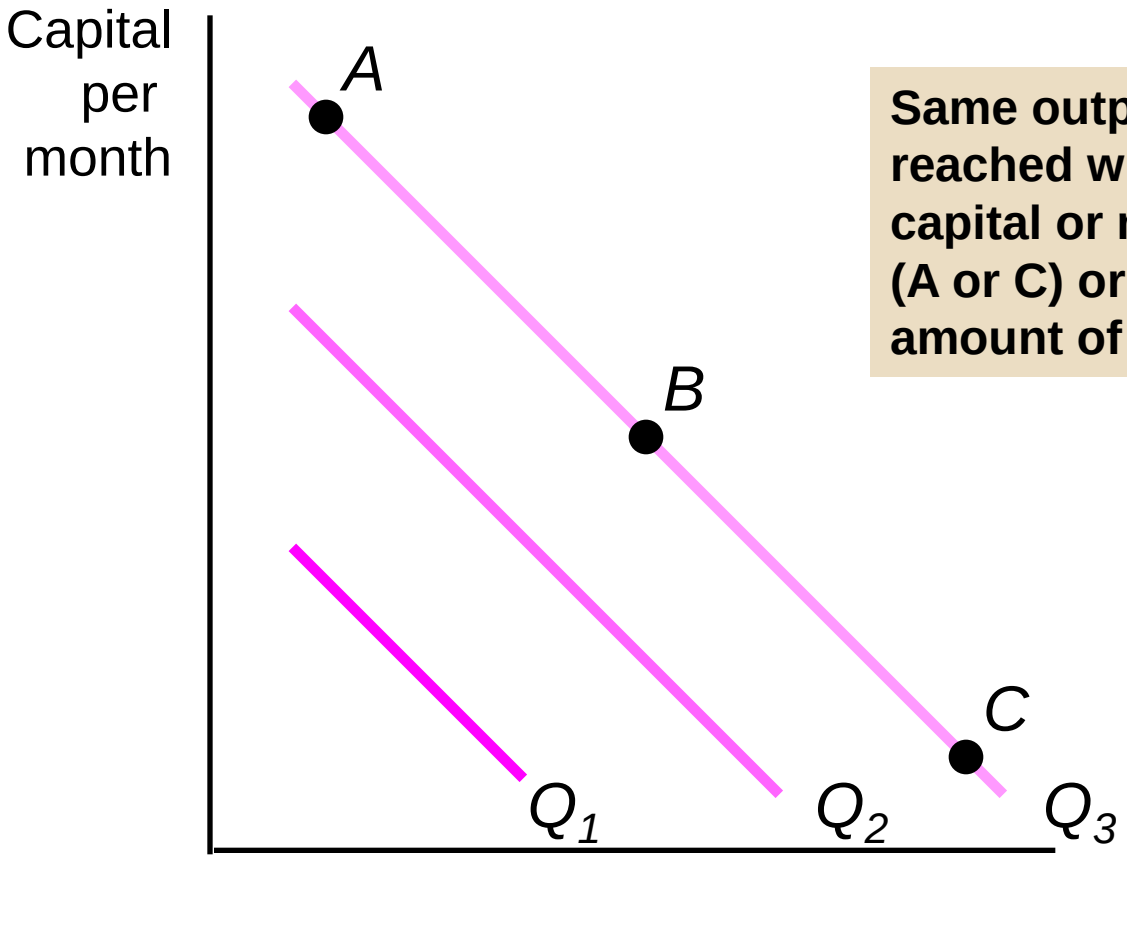
$$\frac{(MP_L)}{(MP_K)}=-\frac{\Delta L}{\Delta K}=MRTS$$

Isoquants: Special Cases

- Two extreme cases show the possible range of input substitution in production

1. Perfect substitutes
   - MRTS is constant at all points on isoquant
   - Same output can be produced with a lot of capital or a lot of labor or a balanced mix

Perfect Substitutes



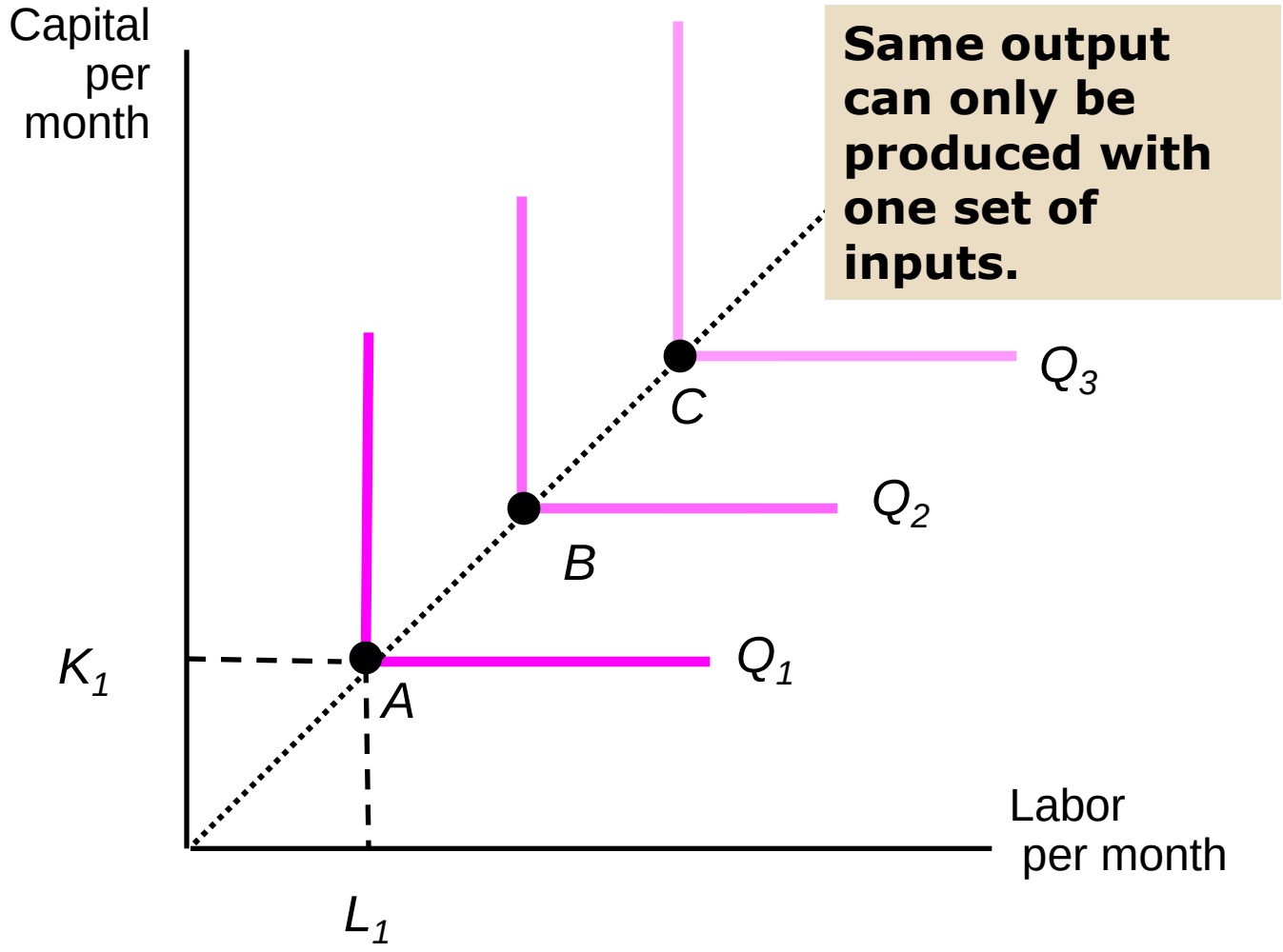
Same output can be reached with mostly capital or mostly labor (A or C) or with equal amount of both (B)

Isoquants: Special Cases

- Extreme cases (cont.)

2. Perfect Complements
   - Fixed proportions production function
   - There is no substitution available between inputs
   - The output can be made with only a specific proportion of capital and labor
   - Cannot increase output unless increase both capital and labor in that specific proportion

Fixed-Proportions Production Function



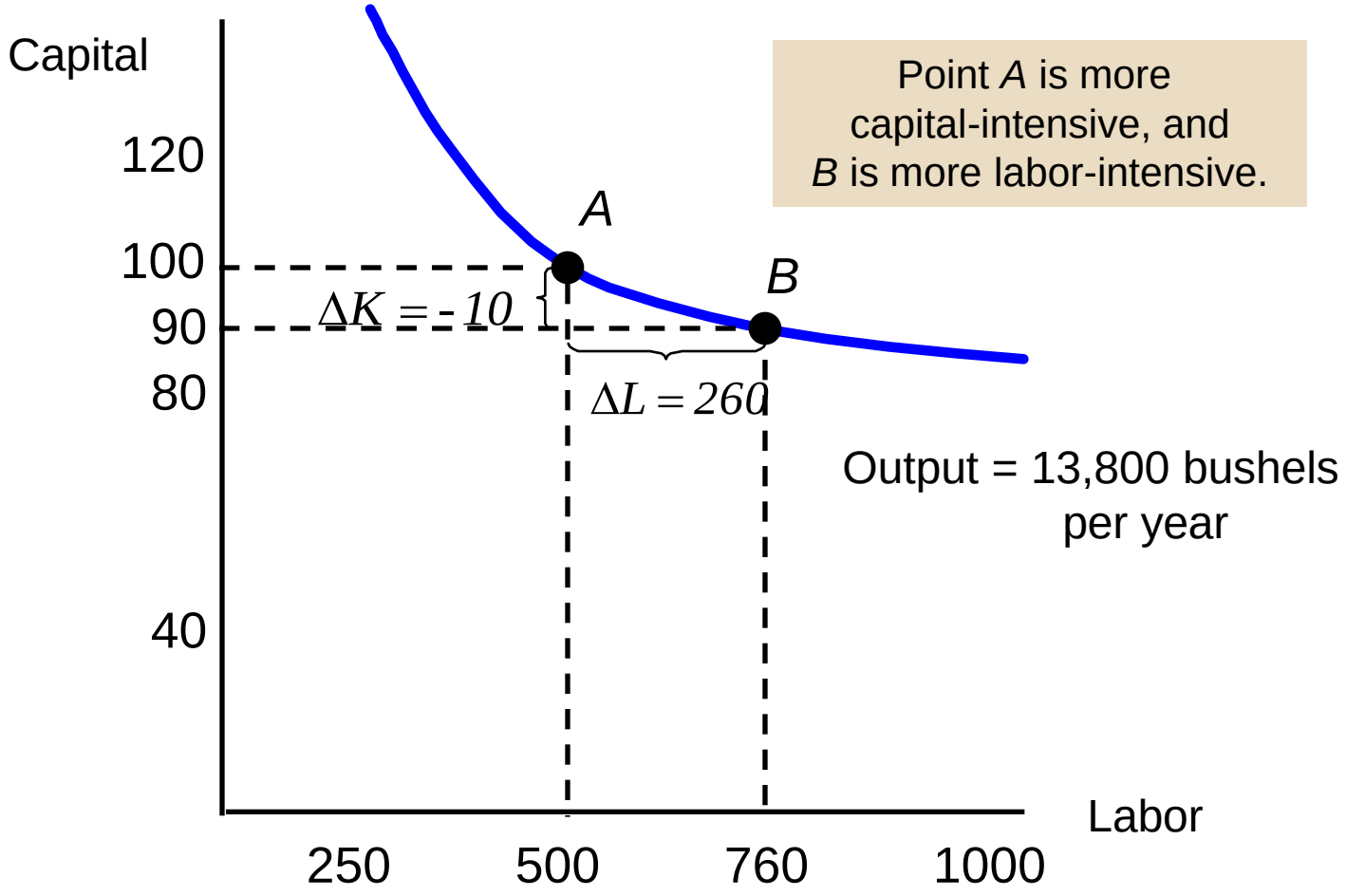
A Production Function for Wheat

- Farmers can produce crops with different combinations of capital and labor.
  - Crops in US are typically grown with capital-intensive technology
  - Crops in developing countries grown with labor intensive productions
- Can show the different options of crop production with isoquants

A Production Function for Wheat

- Manger of a farm can use the isoquant to decide what combination of labor and capital will maximize profits from crop production
  - A: 500 hours of Labor, 100 units of capital
  - B: decreases unit of capital to 90, but must increase hours of labor by 260 to 760 hours.
  - This experiment shows the farmer the shape of the isoquant

Isoquant Describing the Production of Wheat



A Production Function for Wheat

- Increase L to 760 and decrease K to 90 the MRTS =0.04 < 1

$$MRTS = -\Delta K / \Delta L = -(10/260) = 0.04$$

  - When wage is equal to cost of running a machine, more capital should be used
  - Unless labor is much less expensive than capital, production should be capital intensive

Returns to Scale 규모수확

- In addition to discussing the tradeoff between inputs to keep production the same
- How does a firm decide, in the long run, the best way to increase output
  - Can change the scale of production by increasing all inputs in proportion
  - If double inputs, output will most likely increase but by how much?

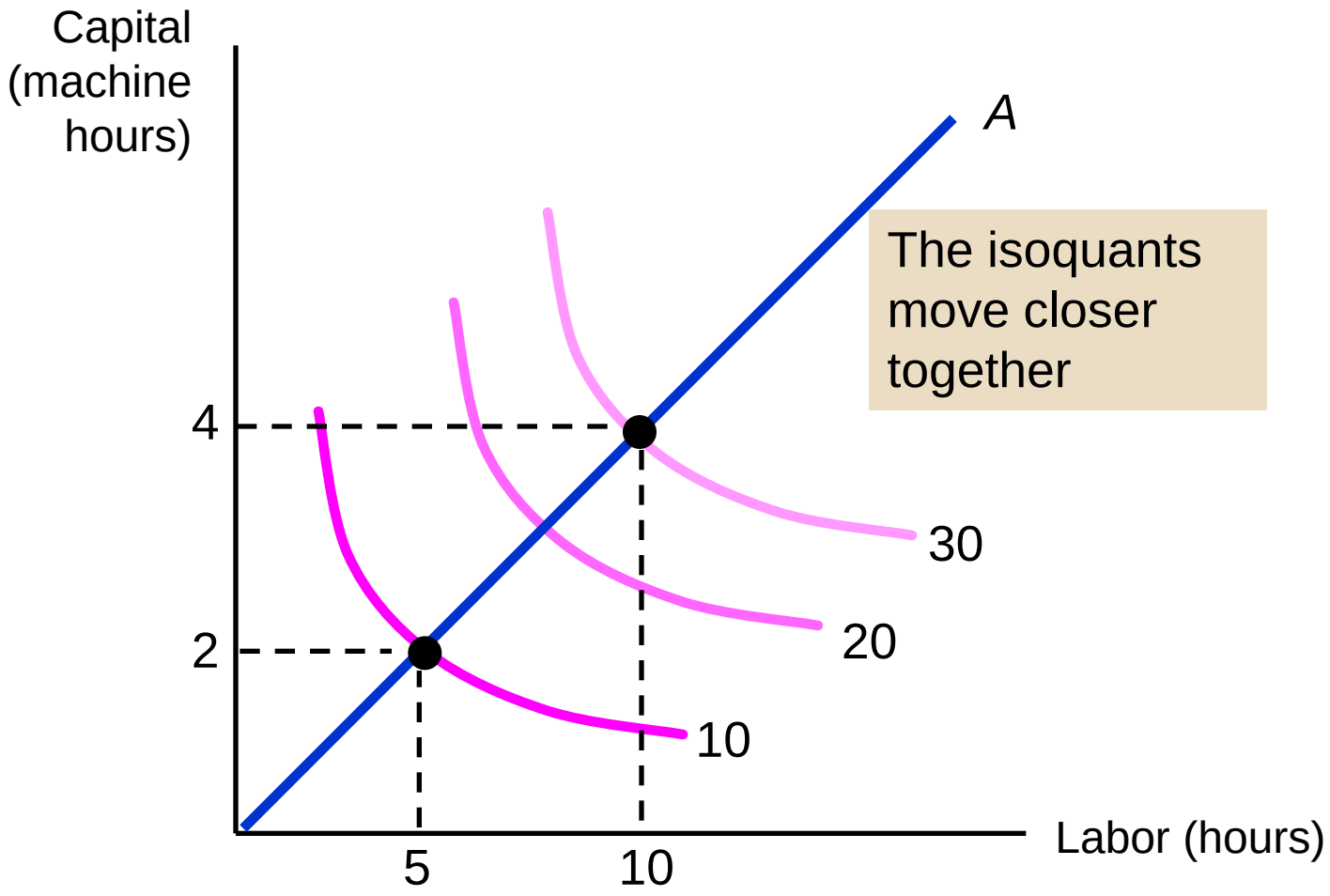
Returns to Scale

- Rate at which output increases as inputs are increased proportionately
  - Increasing returns to scale 체증규모수확
  - Constant returns to scale 일정 (불변) 규모수확
  - Decreasing returns to scale 체감규모수확

Returns to Scale

- Increasing returns to scale: output more than doubles when all inputs are doubled
  - Larger output associated with lower cost (cars)
  - One firm is more efficient than many (utilities)
  - The isoquants get closer together

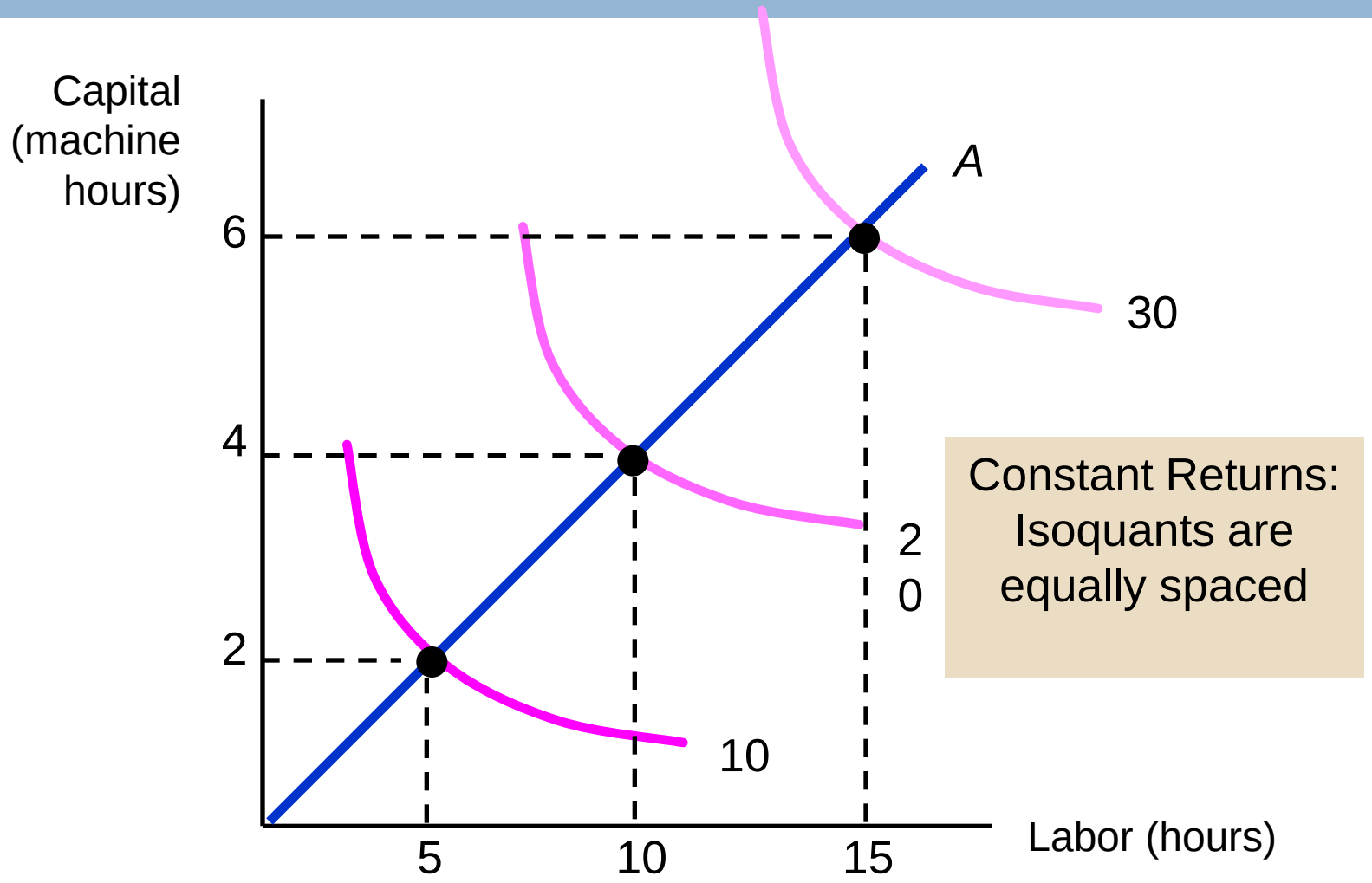
Increasing Returns to Scale 체증규모수확



Constant Returns to Scale 일정 (불변) 규모수확

- Constant returns to scale: output doubles when all inputs are doubled
  - Size does not affect productivity
  - May have a large number of producers
  - Isoquants are equidistant apart

Returns to Scale



Decreasing Returns to Scale 체감 규모수확

- Decreasing returns to scale: output less than doubles when all inputs are doubled
  - Decreasing efficiency with large size
  - Reduction of entrepreneurial abilities
  - Isoquants become farther apart

Returns to Scale