Ch. 6 Production

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

Introduction

- Our study of consumer behavior was broken down into 3:
  - Describing consumer preferences
  - Consumers face budget constraints
  - Consumers choose to maximize utility
- The same applies for the production decisions of a firm
  - Production Technology
  - Cost Constraints
  - Input Choices

  We will study each in turn

Production Decisions of a Firm

1. Production Technology
   - Describe how *inputs* can be transformed into *outputs*
     - Inputs: land, labor, capital and 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 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, firm 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 vary with output
  - How the firm chooses 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:
  - 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

The Technology of Production

- The production function for two inputs:

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

  - 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 Technology of Production

- Short Run
  - Period of time in which quantities of one or more production factors cannot be changed
  - These inputs are called fixed inputs
- Long Run
  - Amount of time needed to make all production inputs variable
- Short run and long run are not time specific

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 (Table 6.1)

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 and 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

- 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

$$AP_L = \frac{Output}{Labor\ Input} = \frac{\boldsymbol{q}}{\boldsymbol{L}}$$

Production: One Variable Input

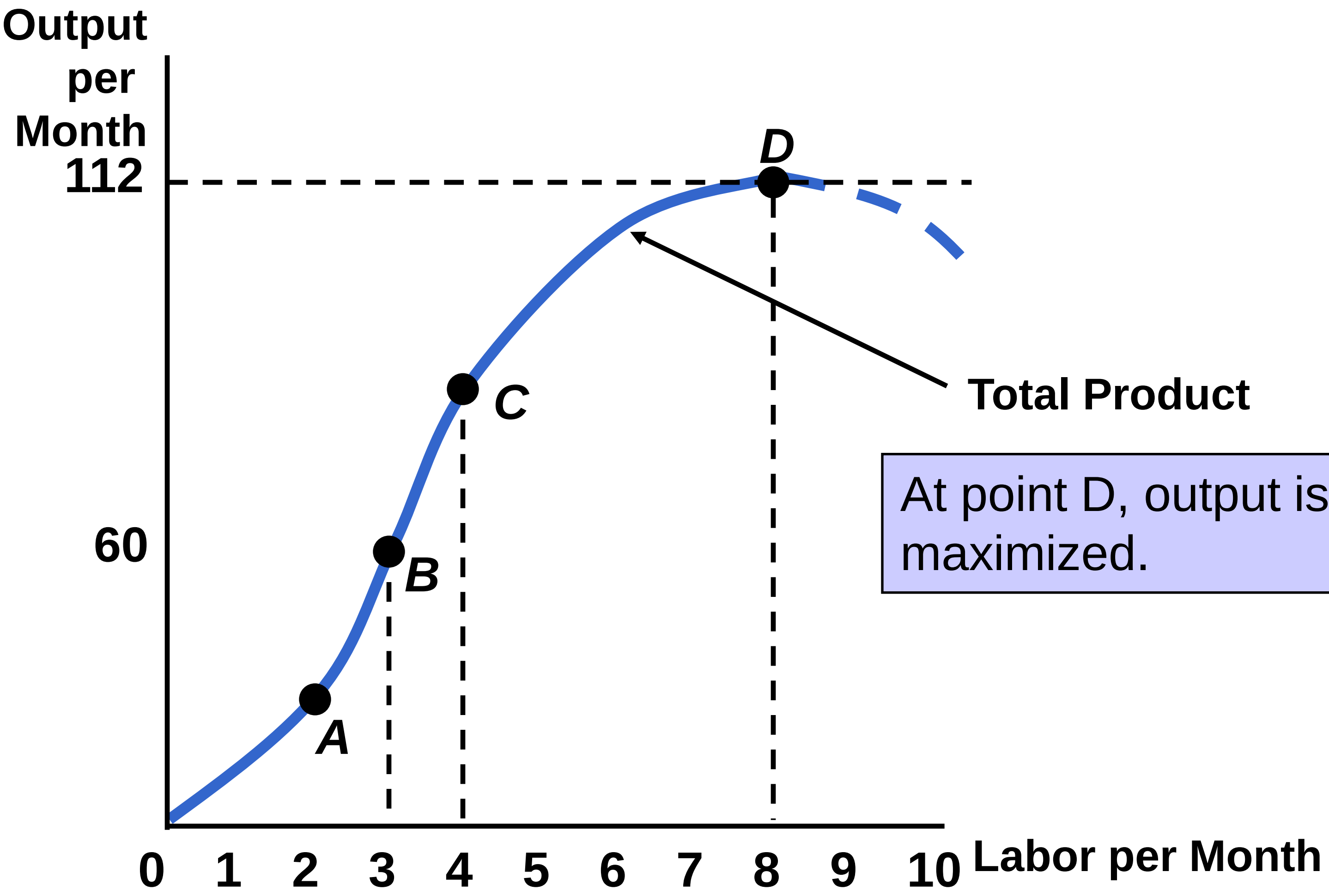
- Marginal Product of Labor – additional output produced when labor increases by one unit
- Change in output divided by the change in labor

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

Production: One Variable Input

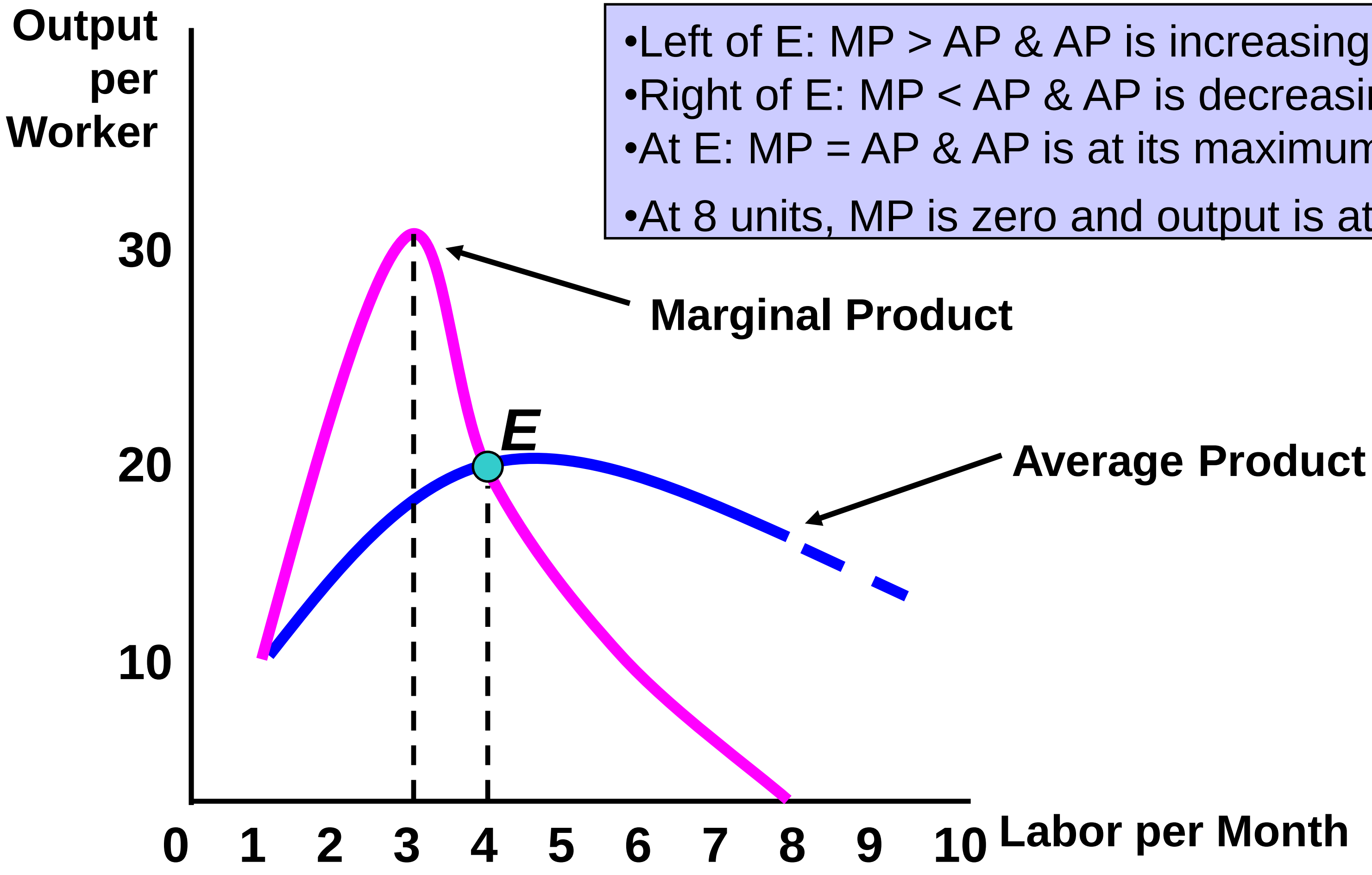
- We can graph the information in Table 6.1 to show
  - How output varies with changes in labor
    - Output is maximized at 112 units
  - Average and Marginal Products
    - Marginal Product is positive as long as total output is increasing
    - Marginal Product crosses Average Product at its maximum

Production: One Variable Input



At point D, output is maximized.

Production: One Variable Input



- Left of E: MP > AP & AP is increasing
- Right of E: MP < AP & AP is decreasing
- At E: MP = AP & AP is at its maximum
- At 8 units, MP is zero and output is at max

Marginal and 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

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**: As the use of an input increases with other inputs fixed, the resulting additions to output will eventually decrease

Law of Diminishing Marginal Returns

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

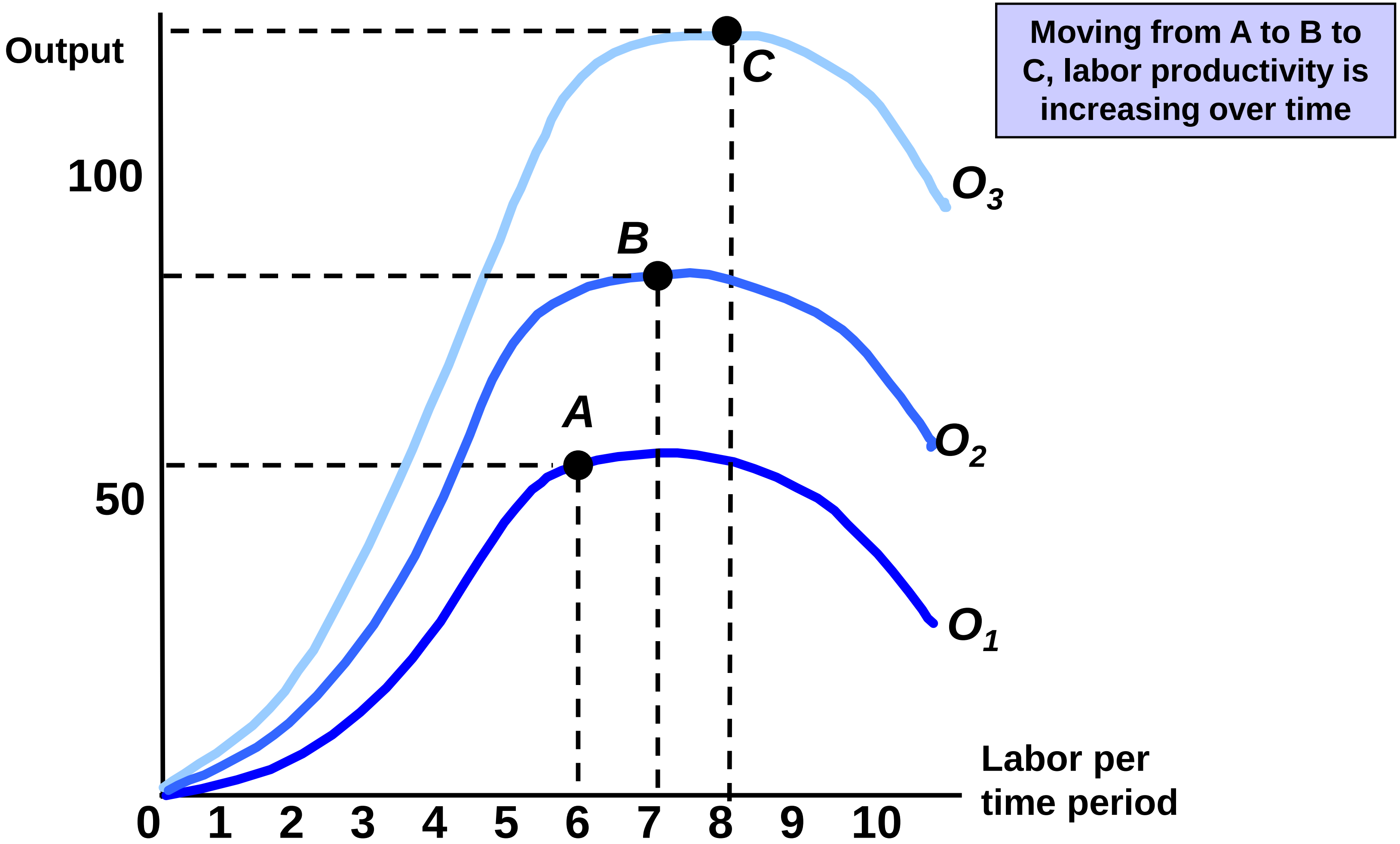
Law of Diminishing Marginal Returns

- Typically applies only for the 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

- 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



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 – Table 6.4

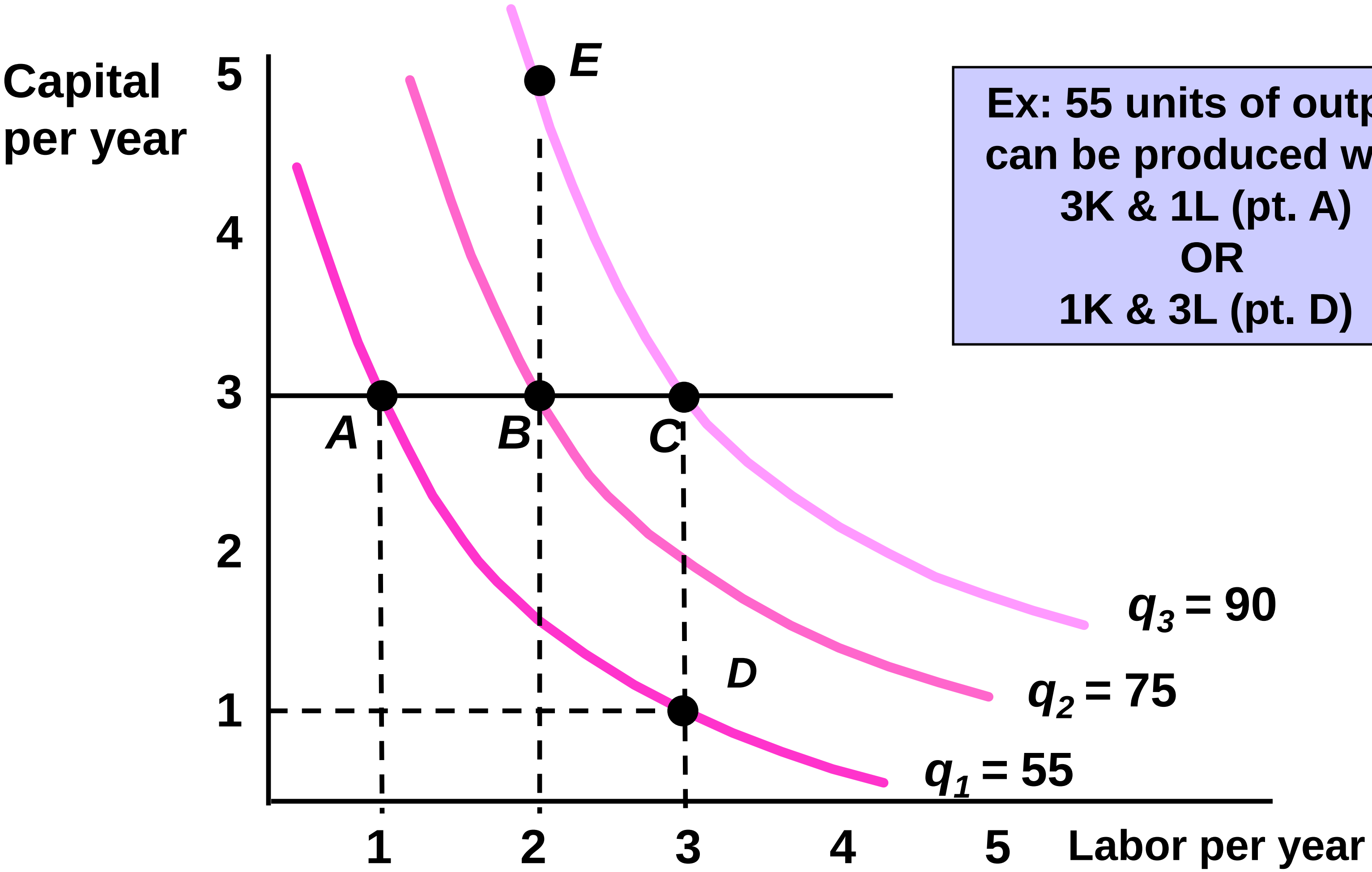
Production: Two Variable Inputs

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**
  - 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



Ex: 55 units of output can be produced with 3K & 1L (pt. A)
OR
1K & 3L (pt. D)

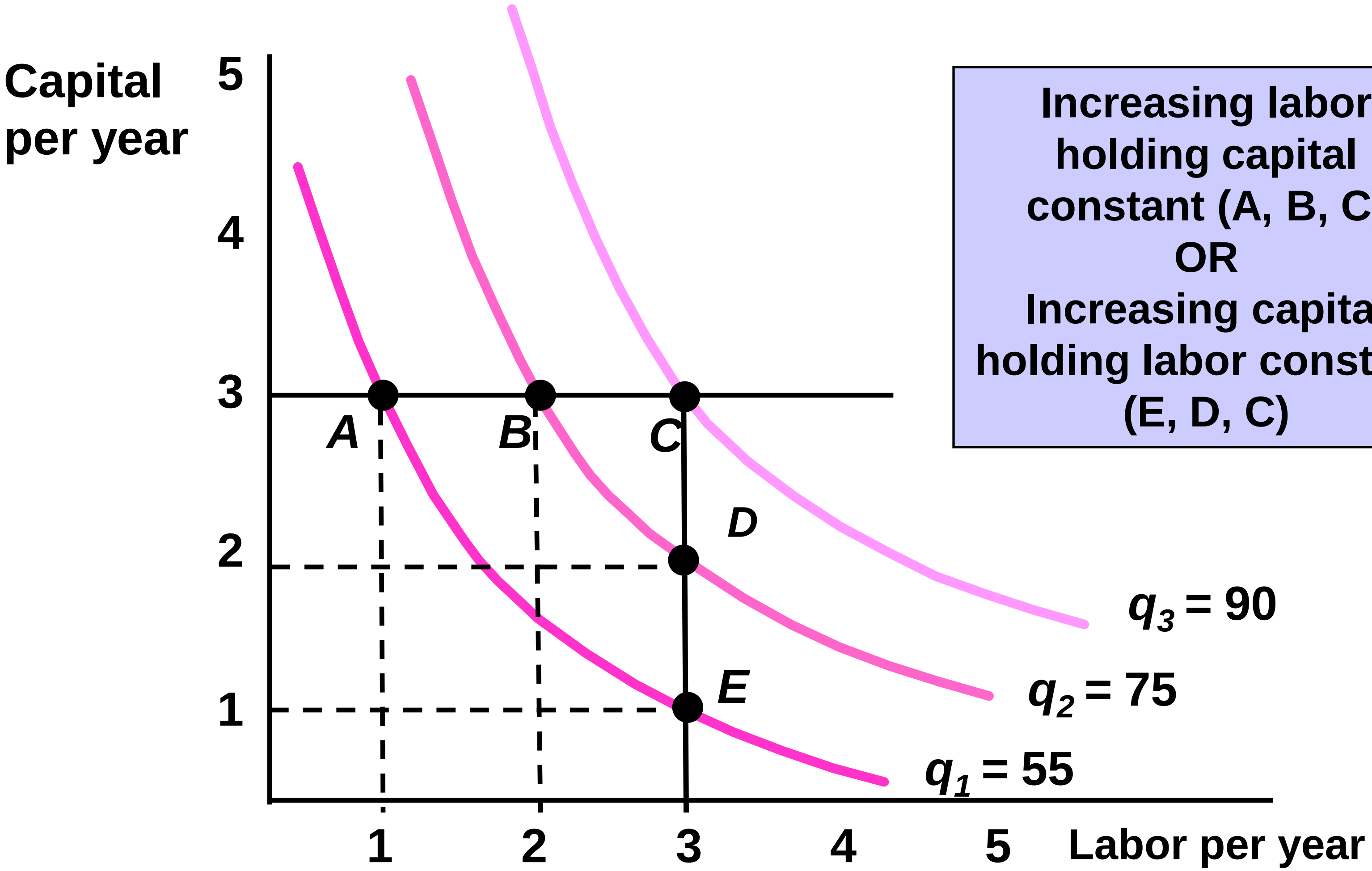
Production: Two Variable Inputs

- 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



Increasing labor holding capital constant (A, B, C)
OR
Increasing capital holding labor constant (E, D, C)

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
  - The negative of the 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

- The marginal rate of technical substitution equals:

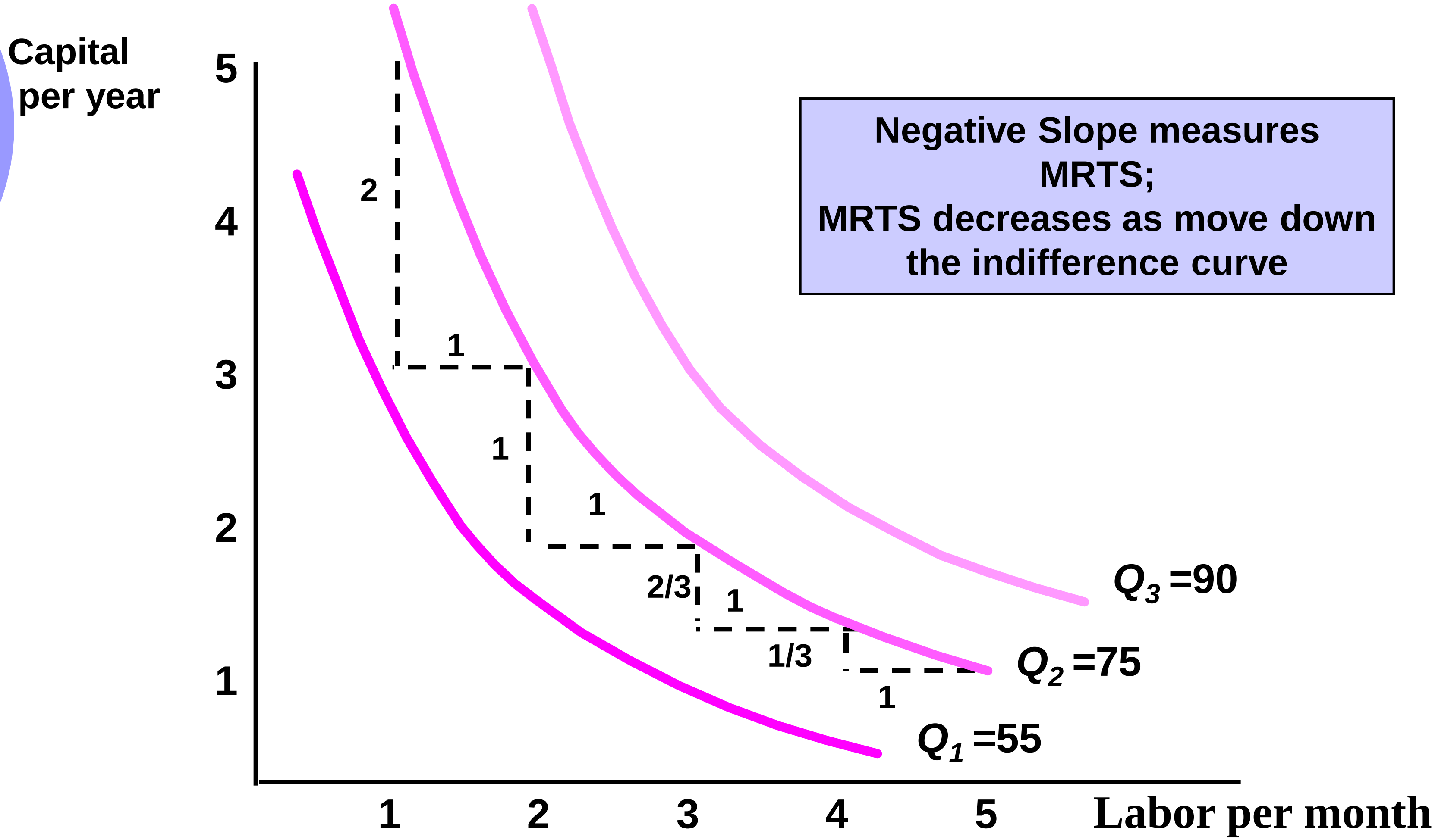
$$MRTS = -\frac{\textit{Change in Capital Input}}{\textit{Change in Labor Input}}$$

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

Production: Two Variable Inputs

- As labor increases 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



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 (read text pg. 203)

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

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

MRTS and Marginal Products

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

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

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

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

Returns to Scale

- 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?

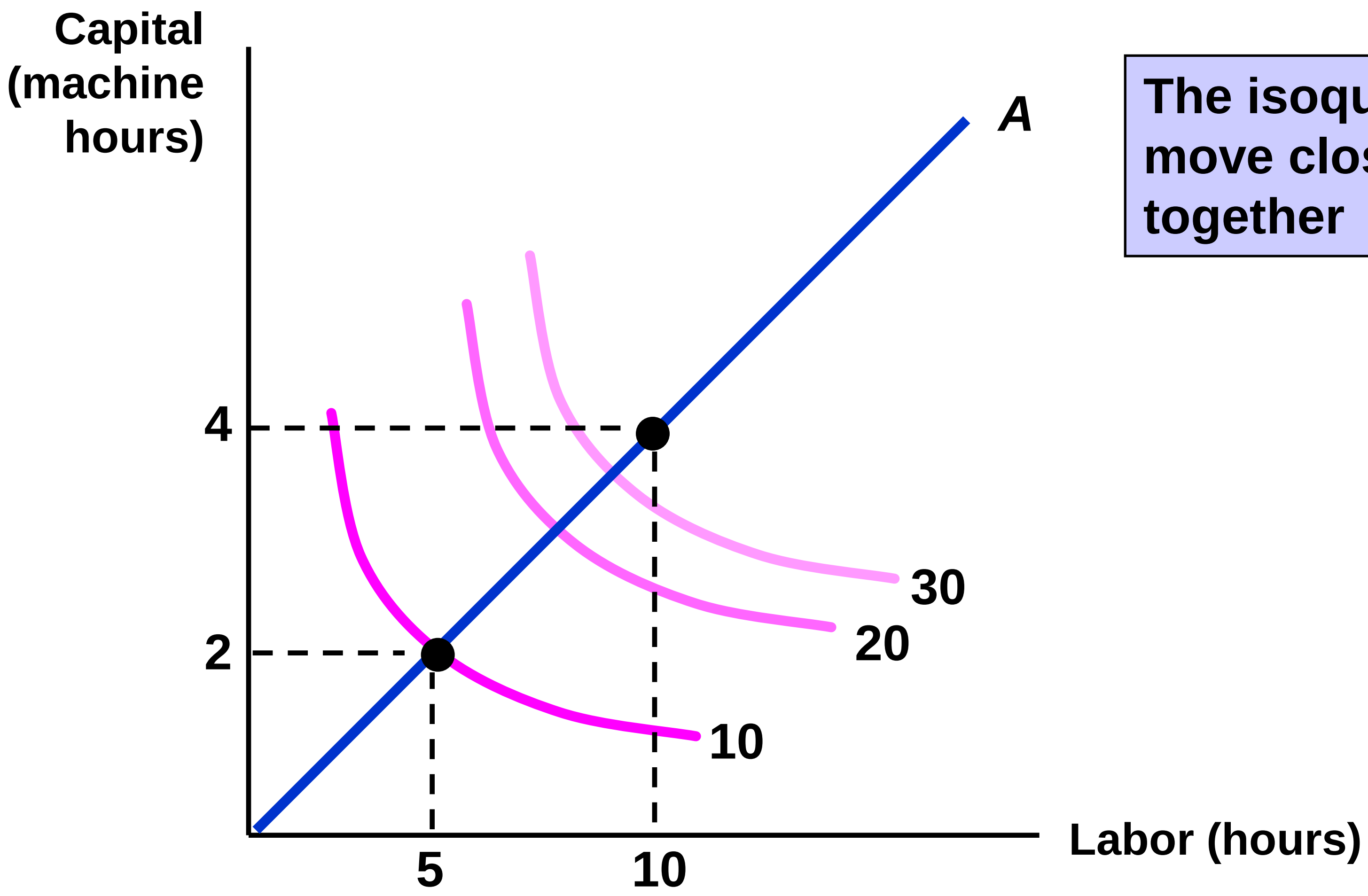
Returns to Scale

- Rate at which output increases as inputs are increased proportionately
  - Increasing returns to scale
  - Constant returns to scale
  - Decreasing returns to scale

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

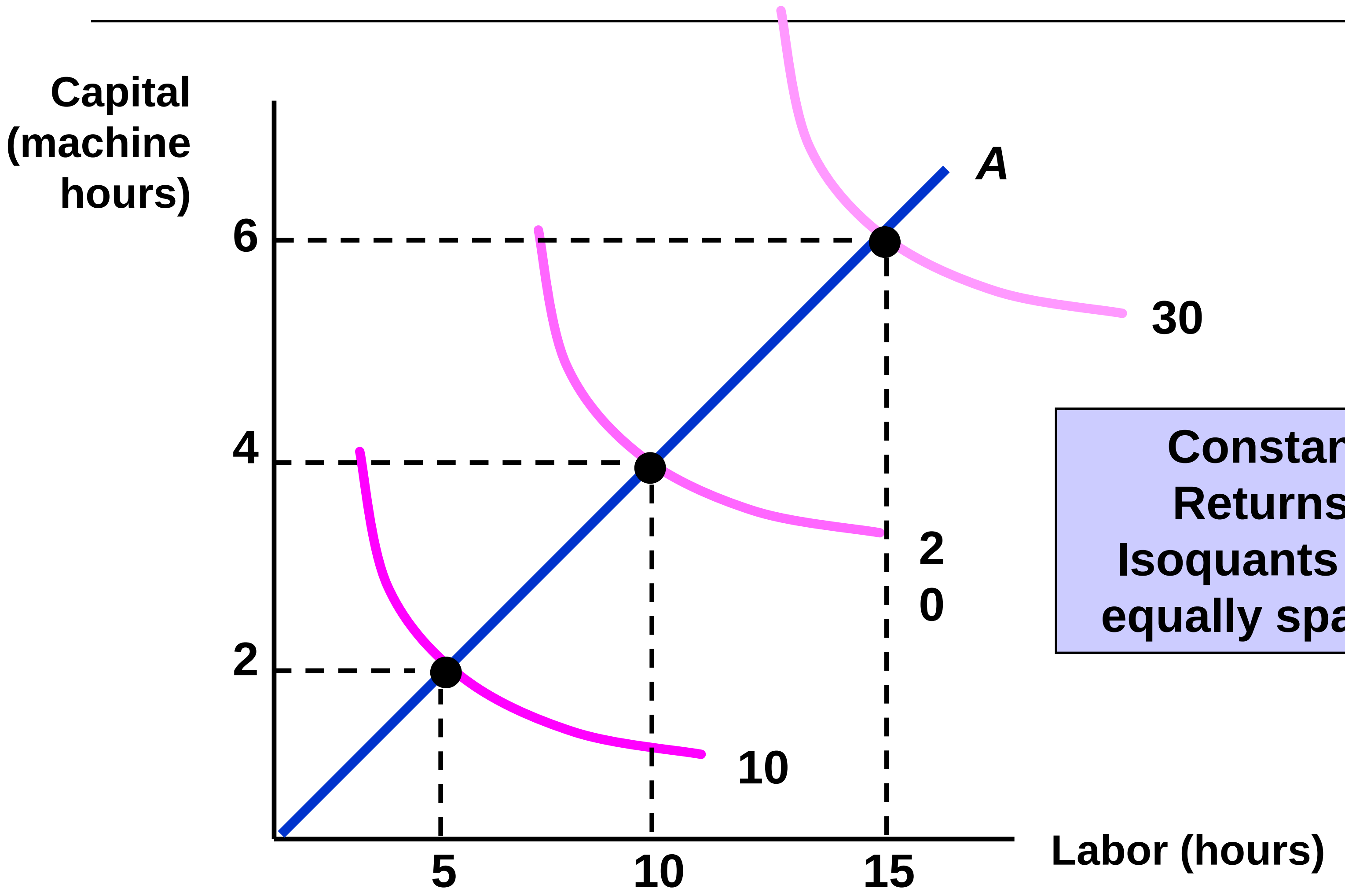


The isoquants move closer together

Returns to Scale

- **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

Constant Returns to Scale

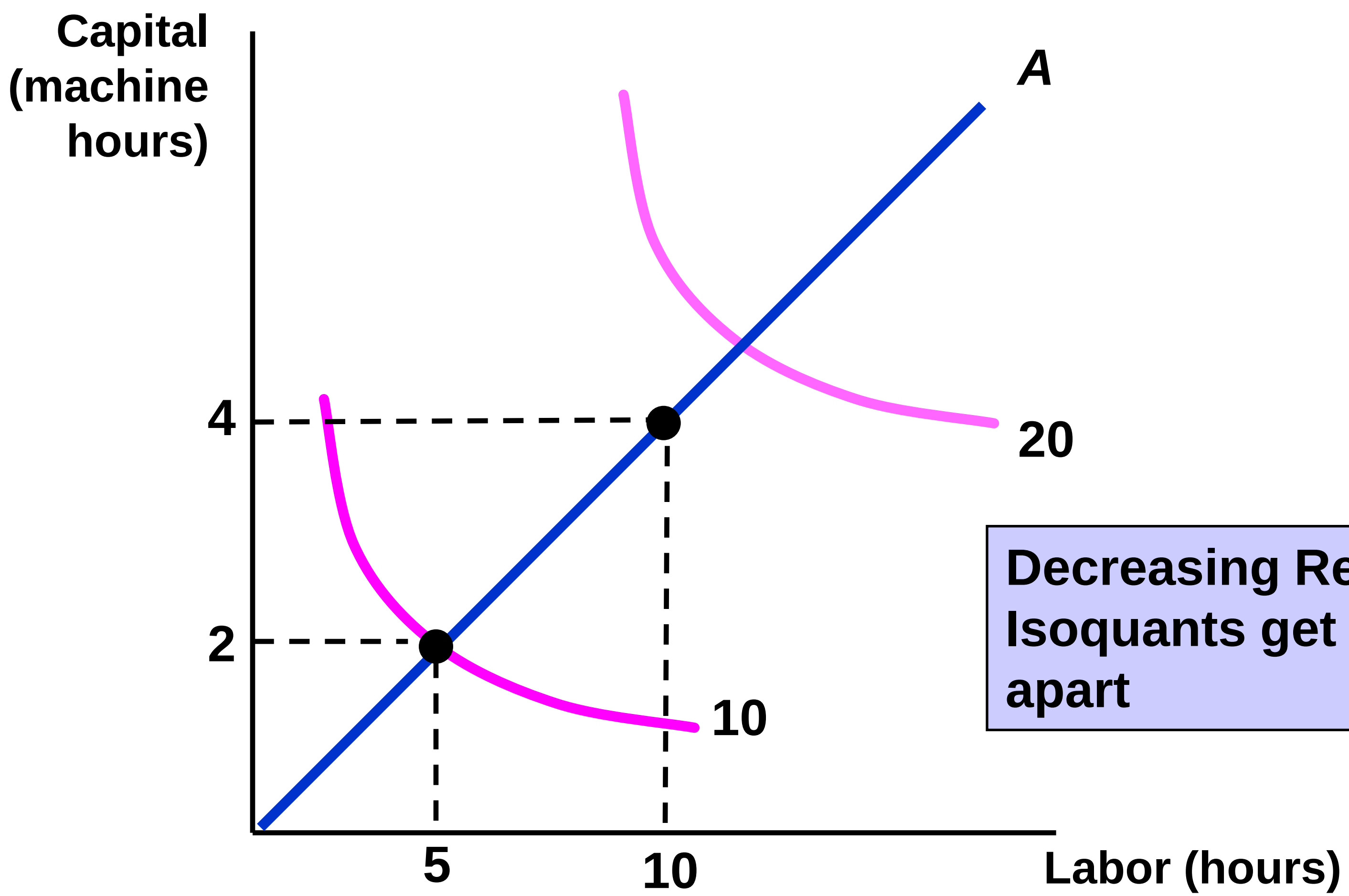


Constant Returns: Isoquants are equally spaced

Returns to Scale

- **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

Decreasing Returns to Scale



Decreasing Returns: Isoquants get further apart