Chapter 6

Production

Topics to be Discussed

- The Technology of Production
- Production with One Variable Input
- Production with Two Variable Inputs
- Returns to Scale

Introduction

- Our study of consumer behavior was broken down into 3 steps:
  - Describing consumer preferences
  - Consumers face budget constraints
  - Consumers choose to maximize utility
- Production decisions of a firm are similar to consumer decisions
  - Can also be broken down into three steps

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
- 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

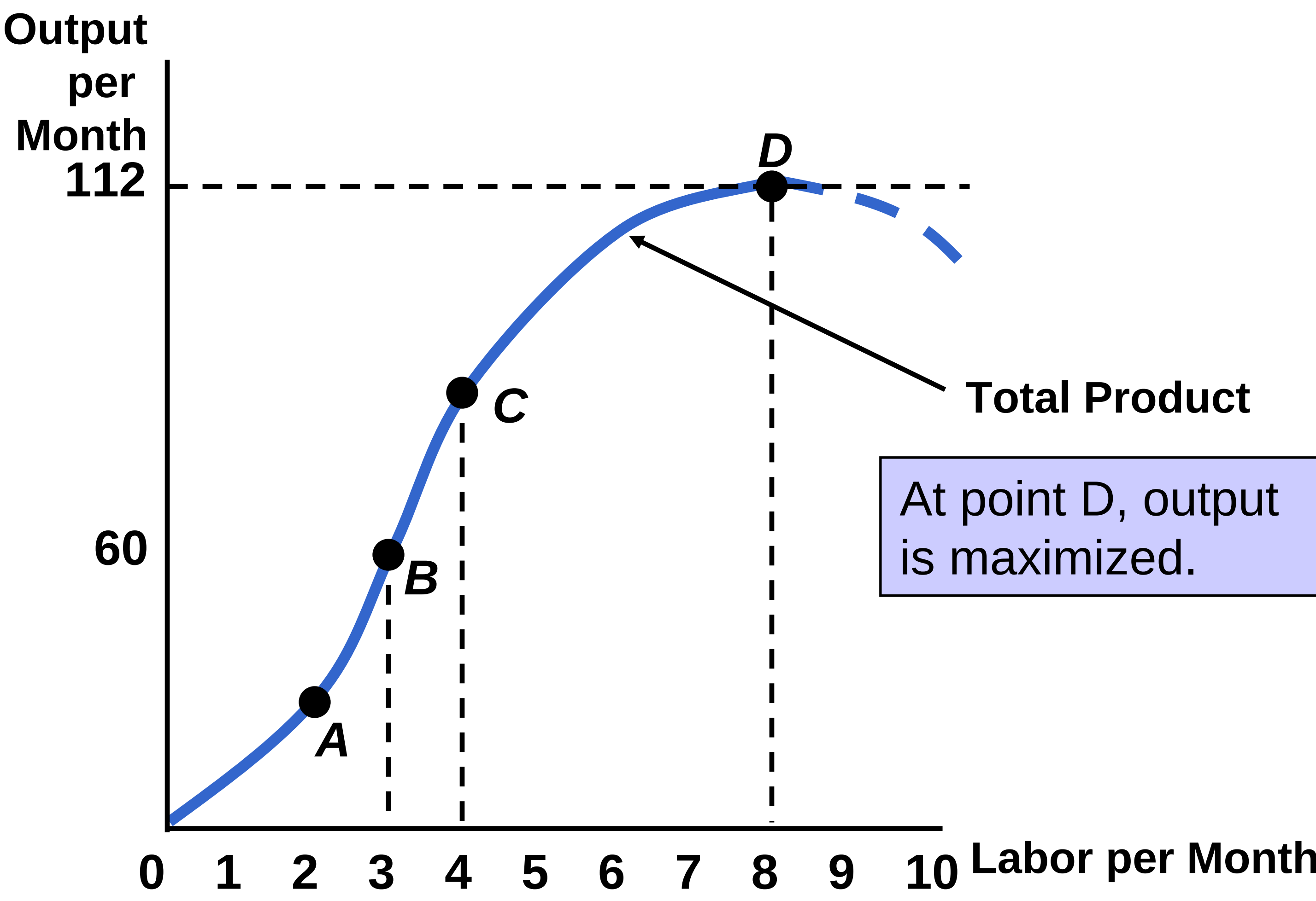
Production: One Variable Input

- 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



At point D, output is maximized.

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

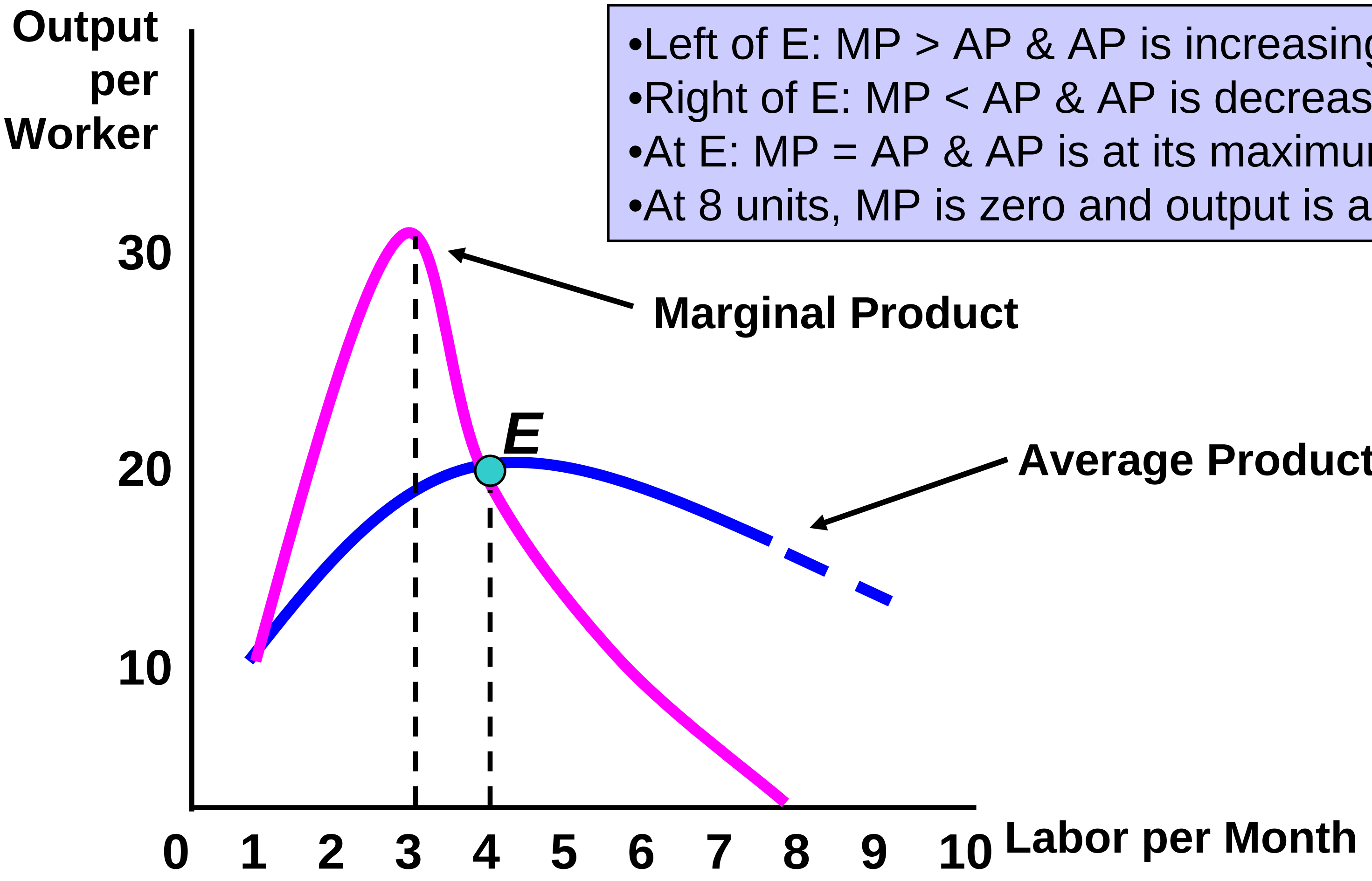
- Marginal Product of Labor – additional output produced when labor increases by one unit
- Change in output divided by the change in labor

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

Production: One Variable Input

Amount of Labor (L)	Amount of Capital (K)	Total Output (q)	Average Product (q/L)	Marginal Product (Δq/ΔL)
0	10	0	—	—
1	10	10	10	10
2	10	30	15	20
3	10	60	20	30
4	10	80	20	20
5	10	95	19	15
6	10	108	18	13
7	10	112	16	4
8	10	112	14	0
9	10	108	12	–4
10	10	100	10	–8

Production: One Variable Input



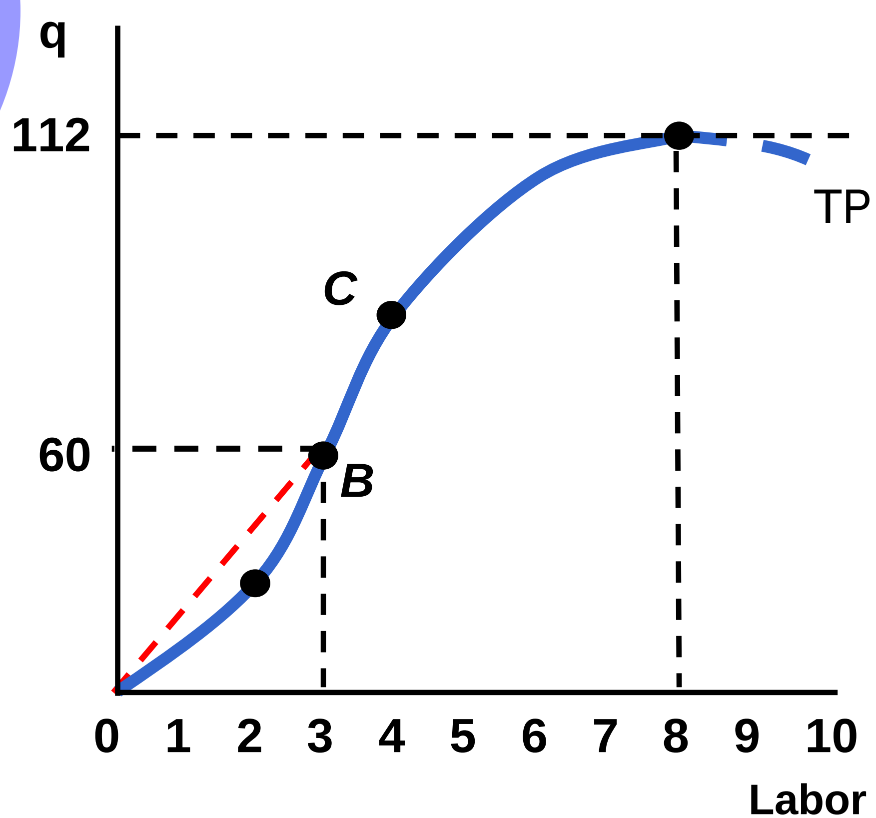
- Left of E: MP > AP & AP is increasing
- Right of E: MP < AP & AP is decreasing
- At E: MP = AP & AP is at its maximum
- At 8 units, MP is zero and output is at max

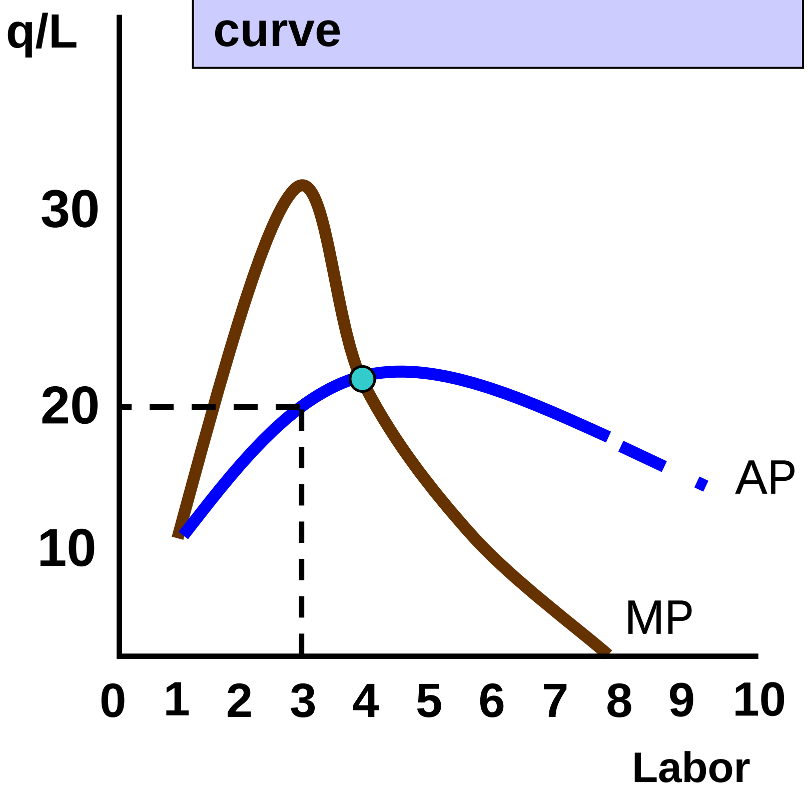
Marginal and Average Product

- 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

Product Curves

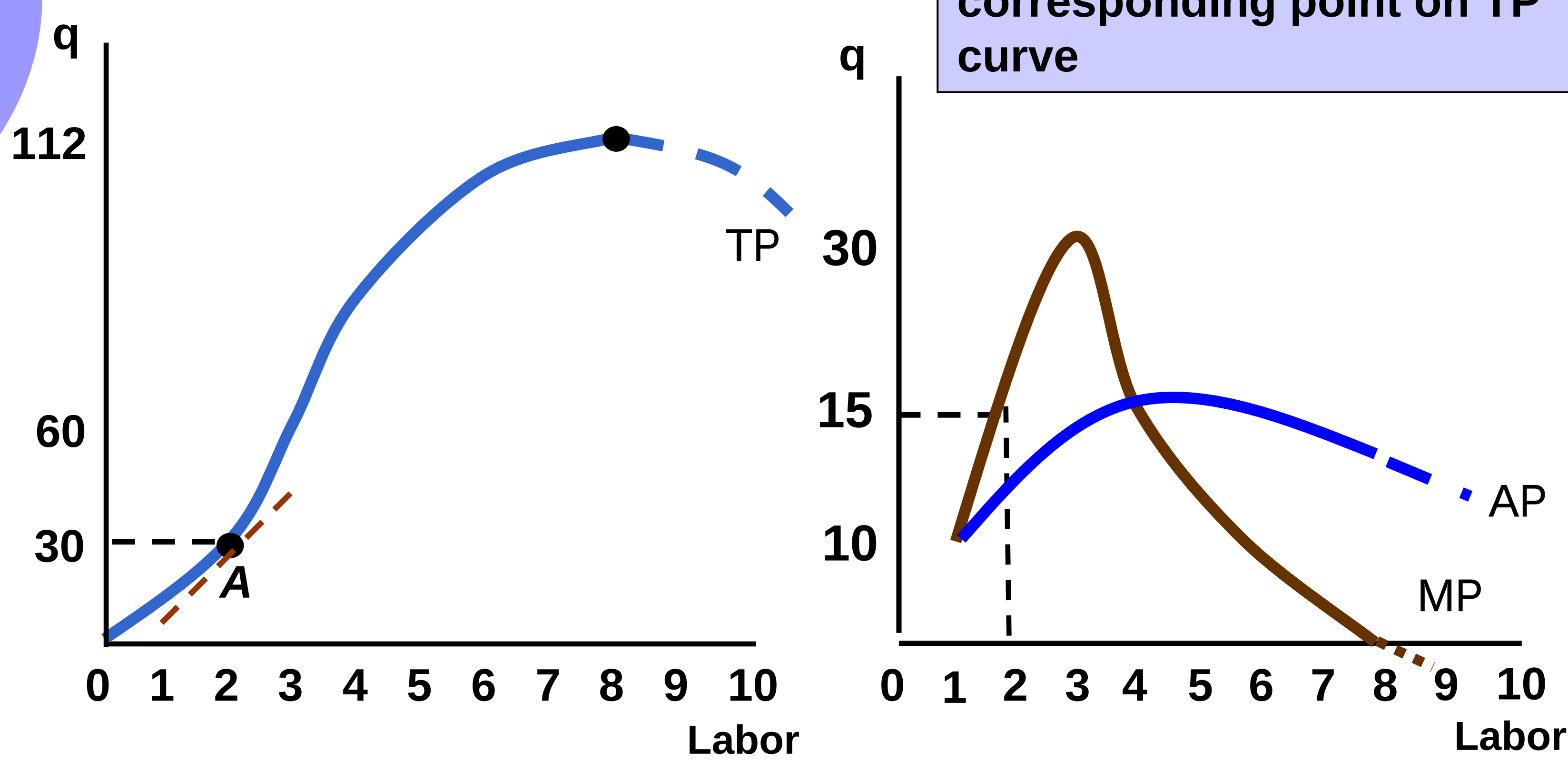
AP is slope of line from origin to point on TP curve





Product Curves

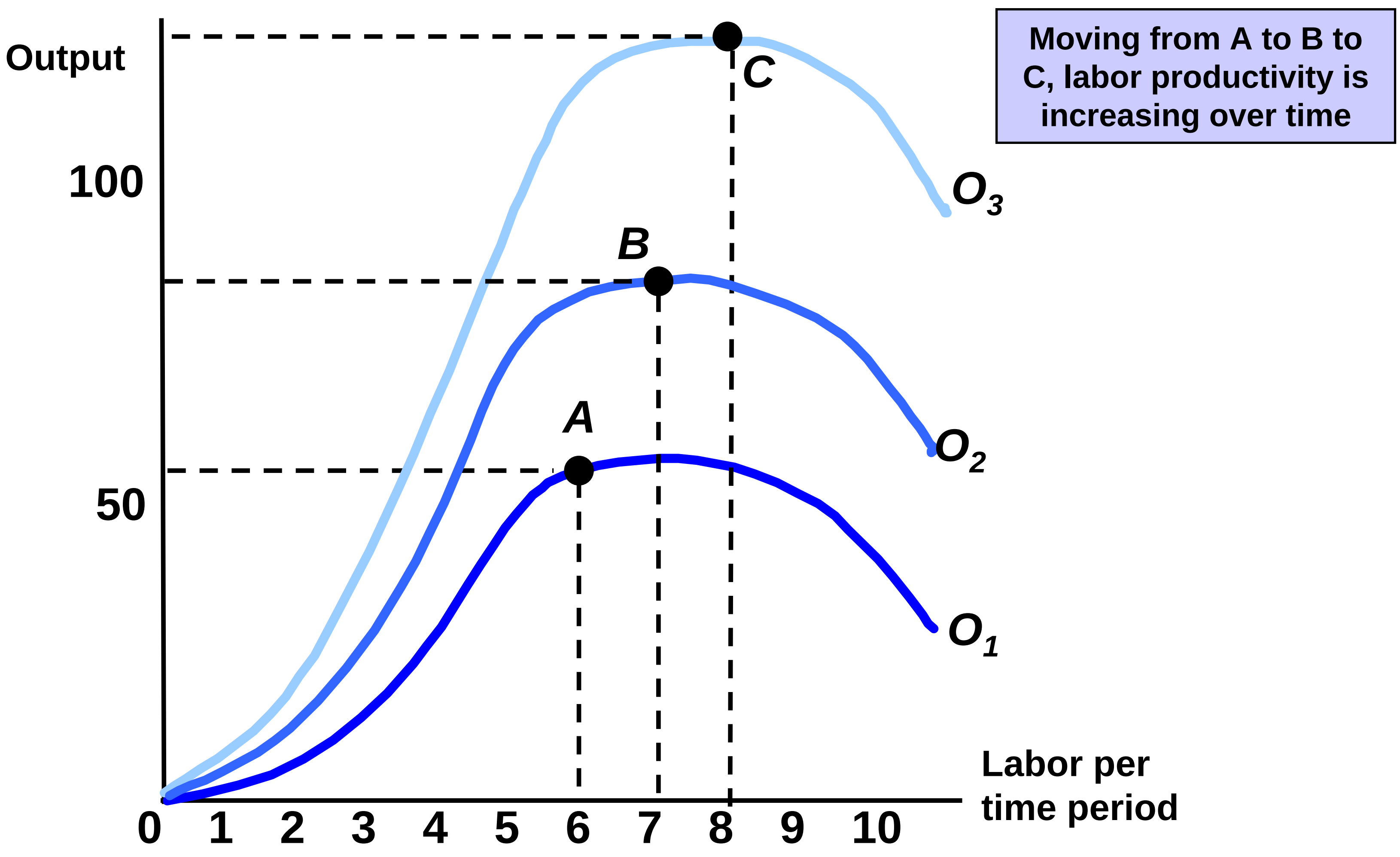
MP is slope of line tangent to corresponding point on TP curve



Law of Diminishing Marginal Returns

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

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 in Developed Countries

	UNITED STATES	JAPAN	FRANCE	GERMANY	UNITED KINGDOM
	Real Output per Employed Person (2001)				
	$75,575	$52,848	$62,461	$66,369	$52,499
Years	Annual Rate of Growth of Labor Productivity (%)				
1960–1973	2.29	7.86	4.70	3.98	2.84
1974–1982	0.22	2.29	1.73	2.28	1.53
1983–1991	1.54	2.64	1.50	2.07	1.57
1992–2001	2.00	1.19	0.86	2.10	1.98

Productivity Growth in US

- Why has productivity growth slowed down?
  1. Growth in the stock of capital is the primary determinant of the growth in productivity
  2. Rate of capital accumulation (US) was slower than other developed countries because they had to rebuild after WWII
  3. Depletion of natural resources
  4. Environmental regulations

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

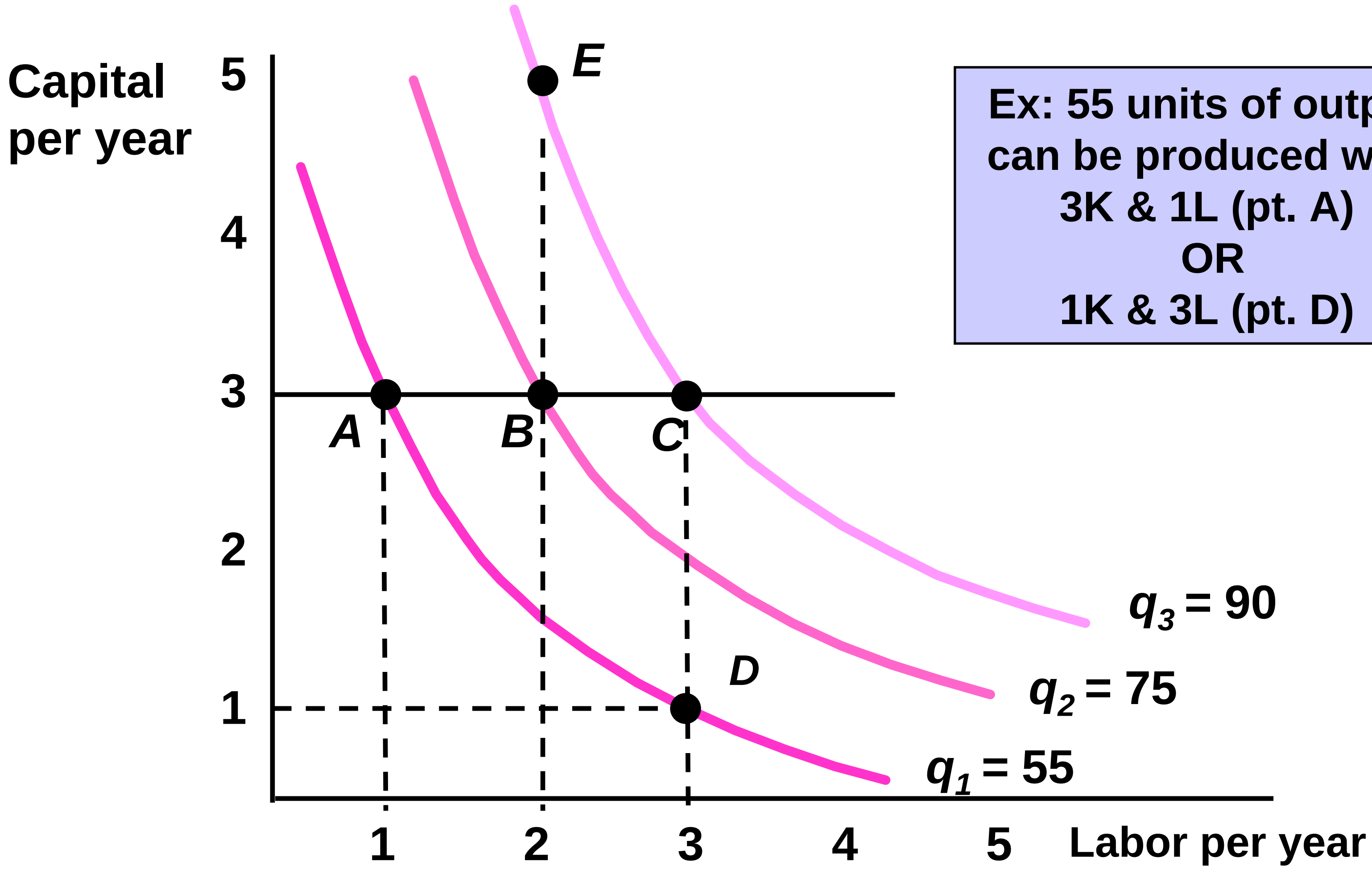
Production: Two Variable Inputs

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

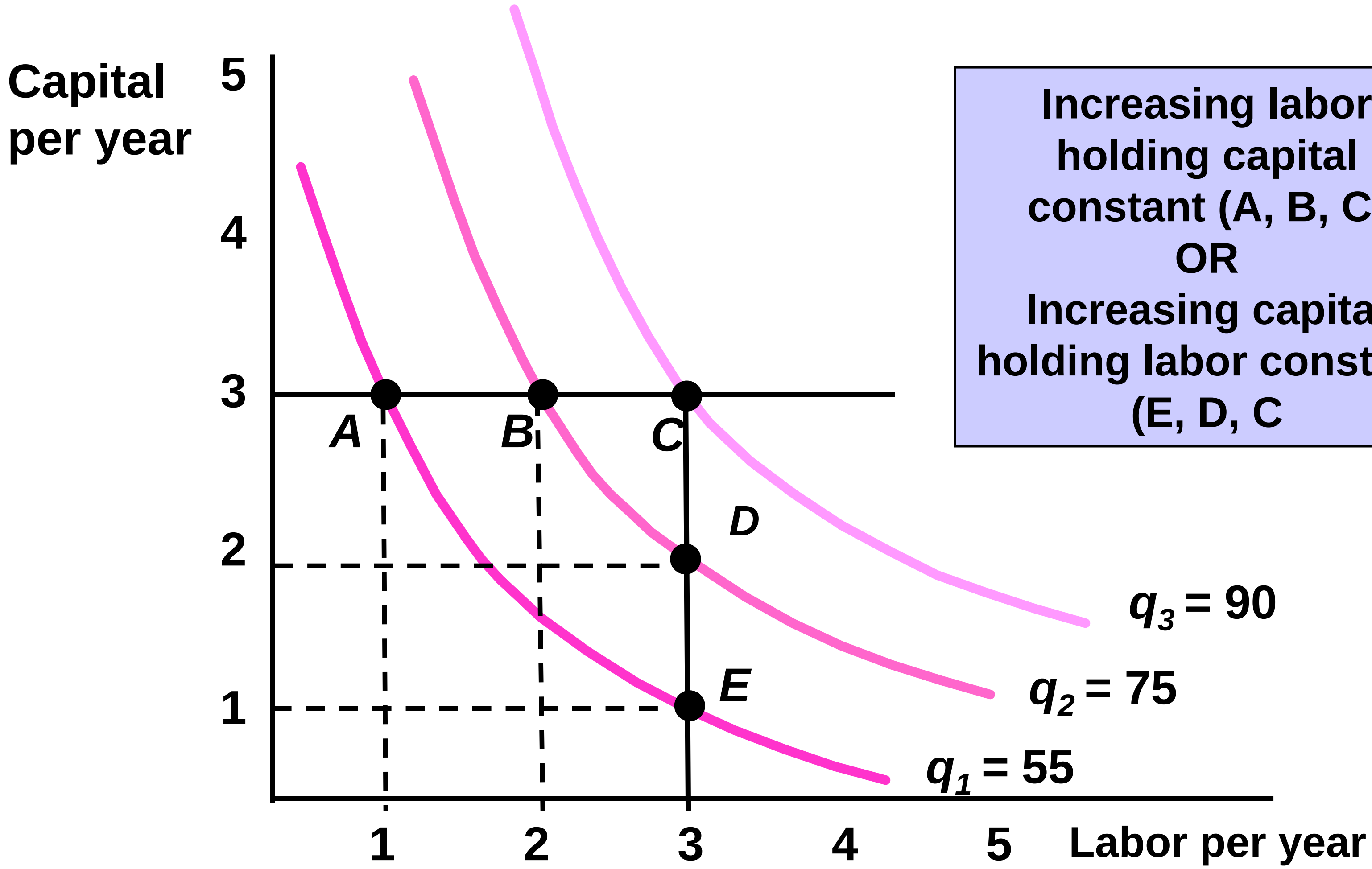
- The information can be represented graphically using **isoquants**
  - Curves showing all possible combinations of inputs that yield the same output
- Curves are smooth to allow for use of fractional inputs
  - Curve 1 shows all possible combinations of labor and capital that will produce 55 units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

Isoquant Map



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

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

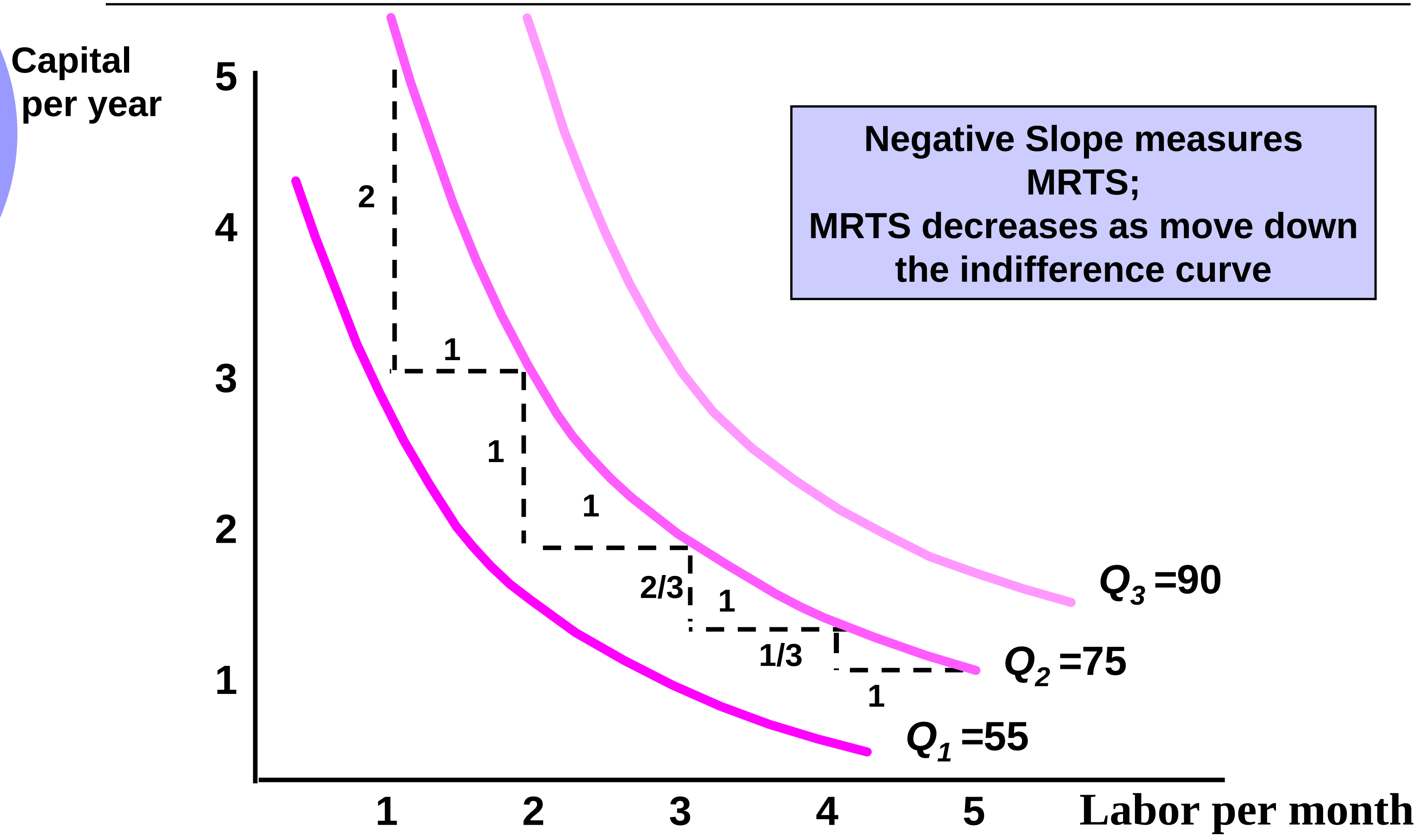
Production: Two Variable Inputs

- The marginal rate of technical substitution equals:

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

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

Marginal Rate of Technical Substitution



MRTS and Marginal Products

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

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

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

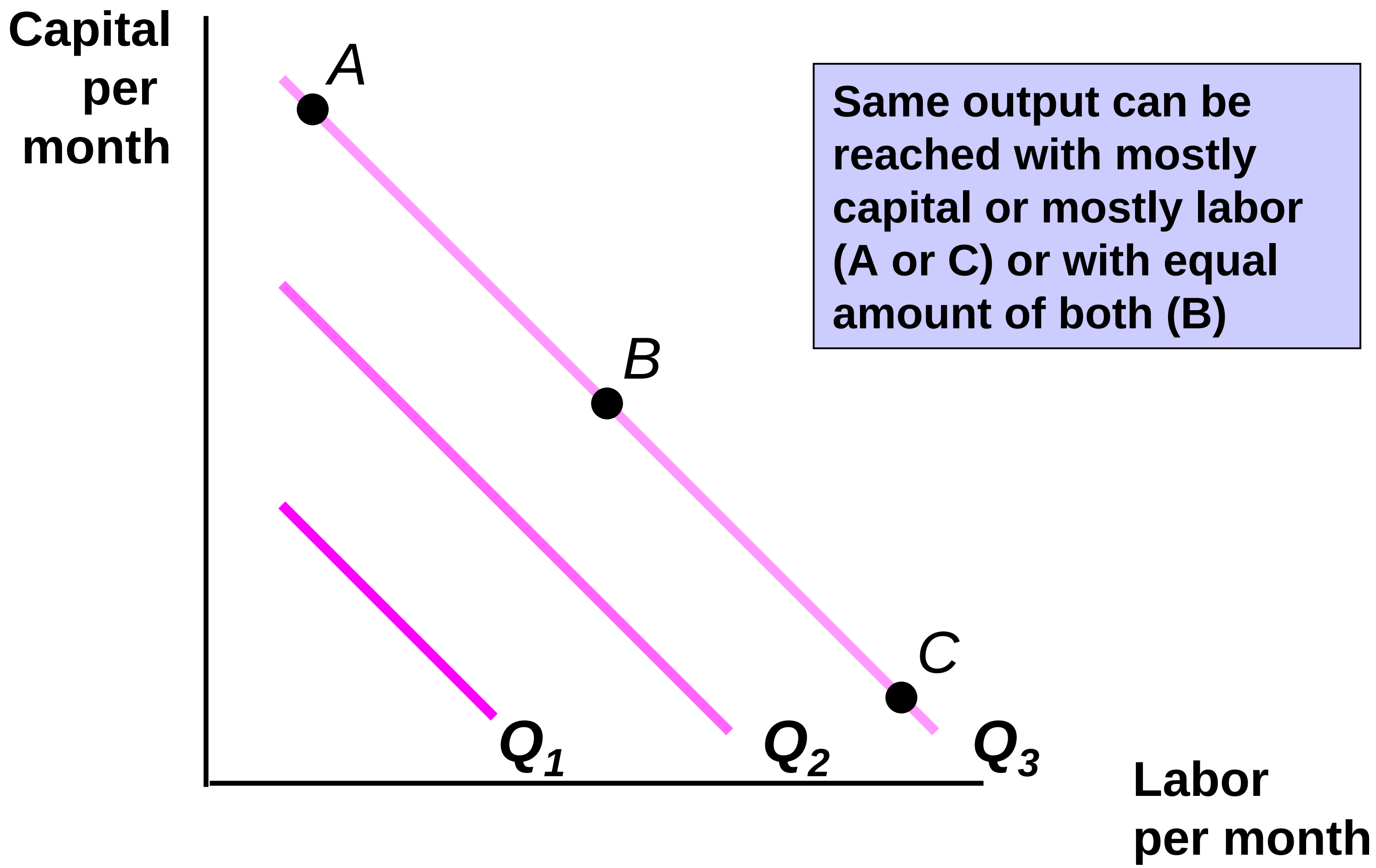
$$\frac{(MP_L)}{(MP_K)} = -\frac{\Delta L}{\Delta K} = MRTS$$

Isoquants: Special Cases

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

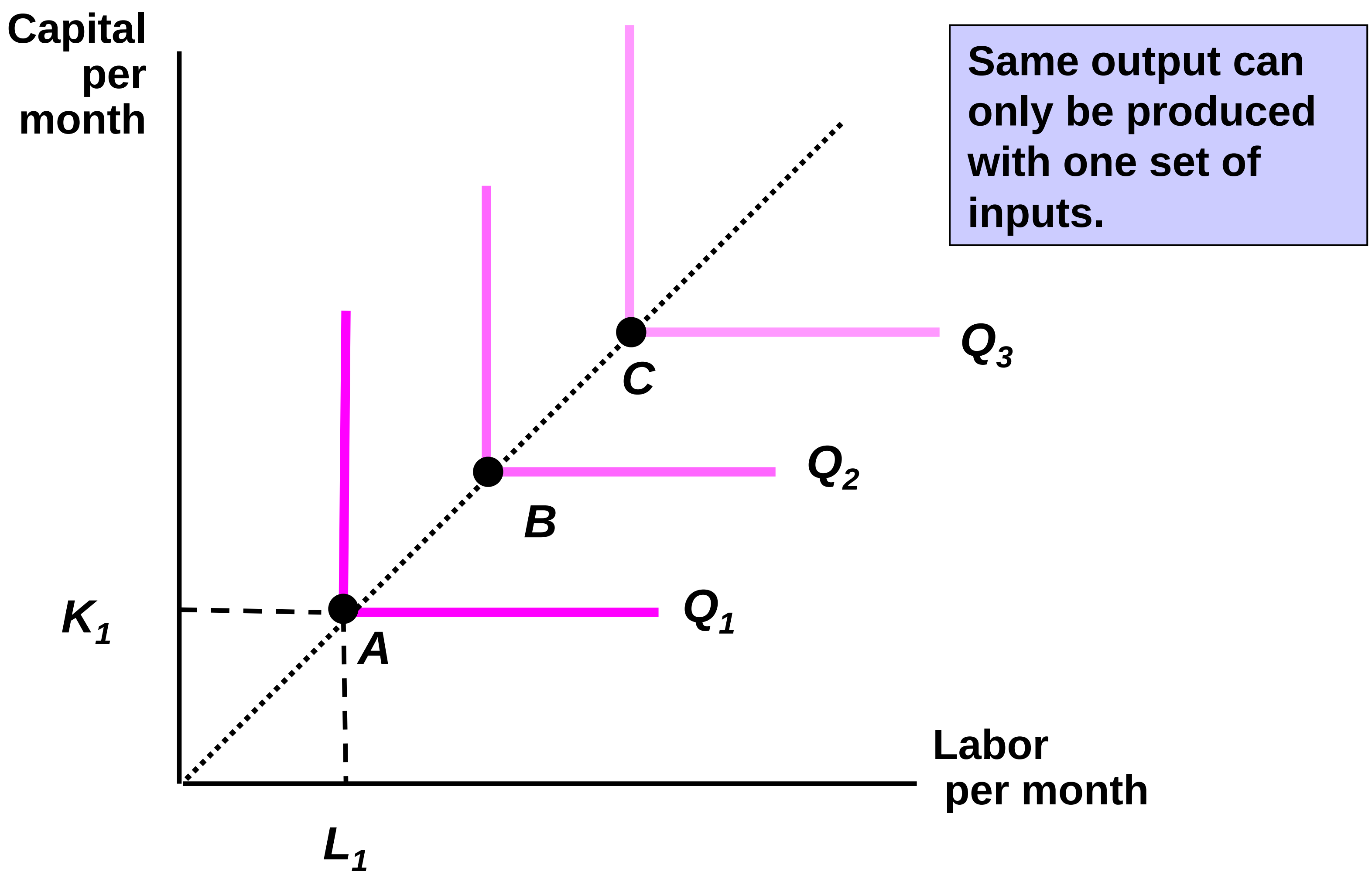
1. Perfect substitutes
   - MRTS is constant at all points on isoquant
   - Same output can be produced with a lot of capital or a lot of labor or a balanced mix
2. Perfect Complements
   - Fixed proportions production function
   - There is no substitution available between inputs

Perfect Substitutes



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

Fixed-Proportions Production Function



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?

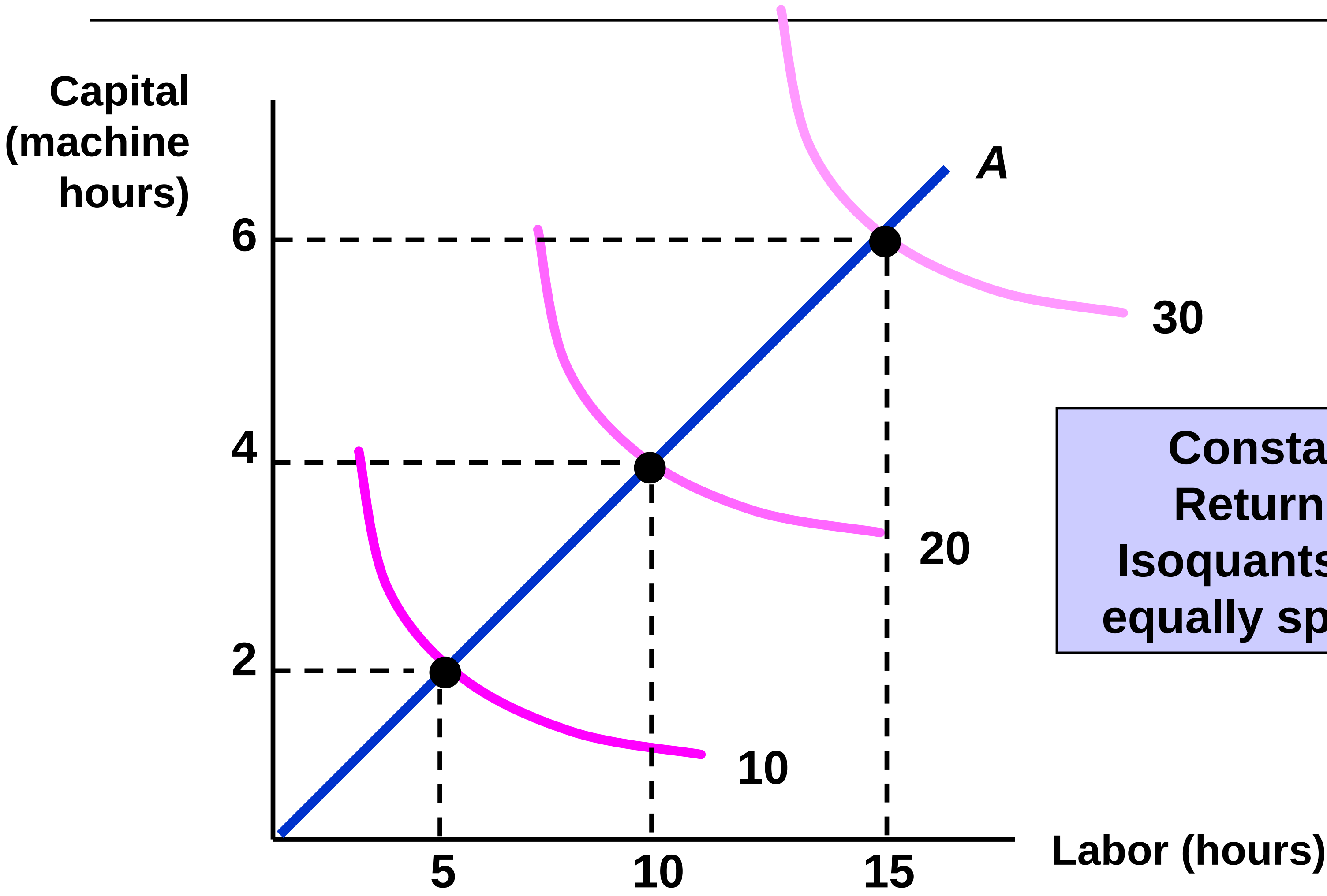
Returns to Scale

- 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

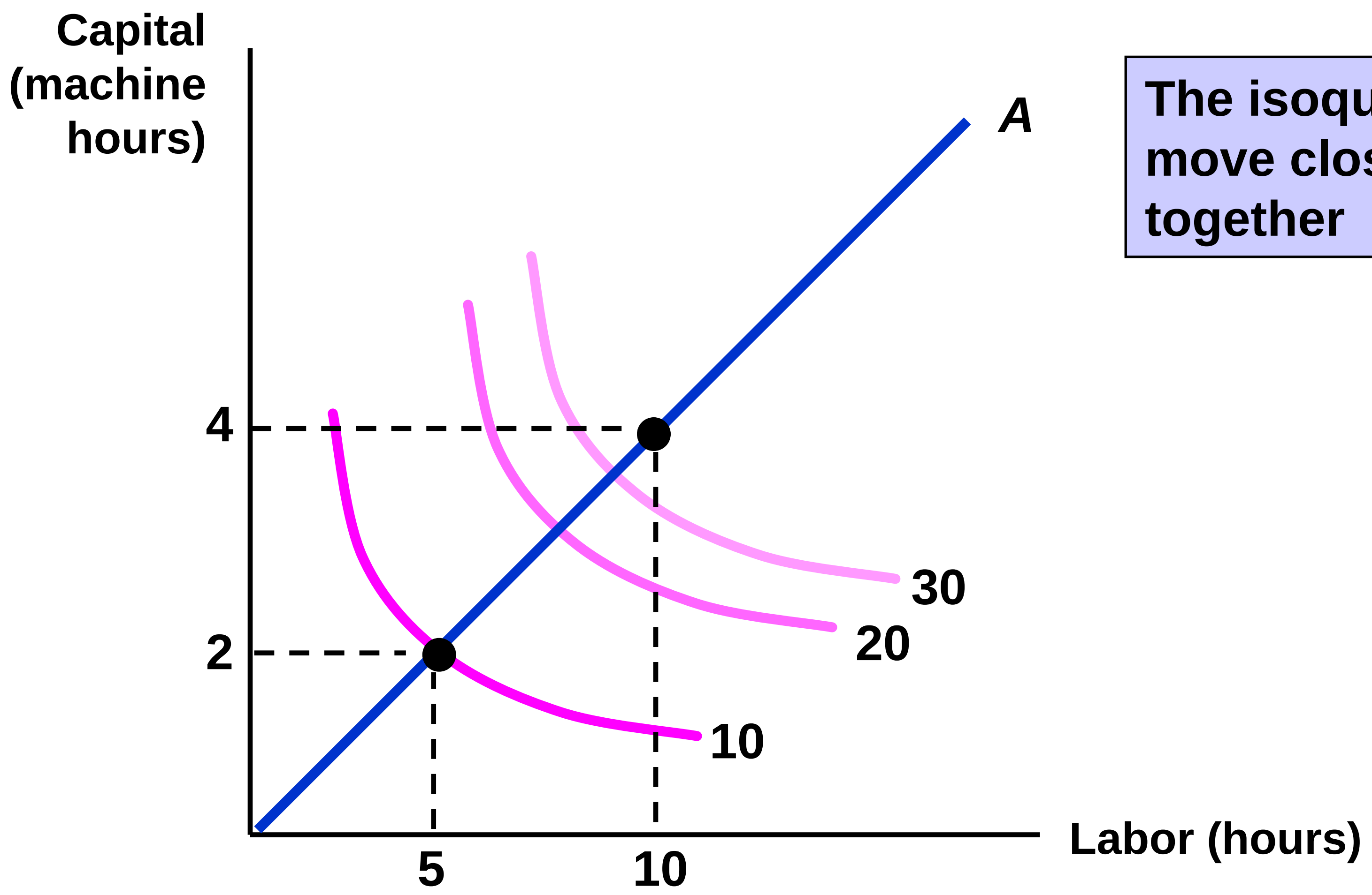
- **Constant returns to scale (CRTS)**: output doubles when all inputs are doubled
- **Increasing returns to scale (IRTS)**: output more than doubles when all inputs are doubled
- **Decreasing returns to scale (DRTS)**: output less than doubles when all inputs are doubled

Constant Returns to Scale



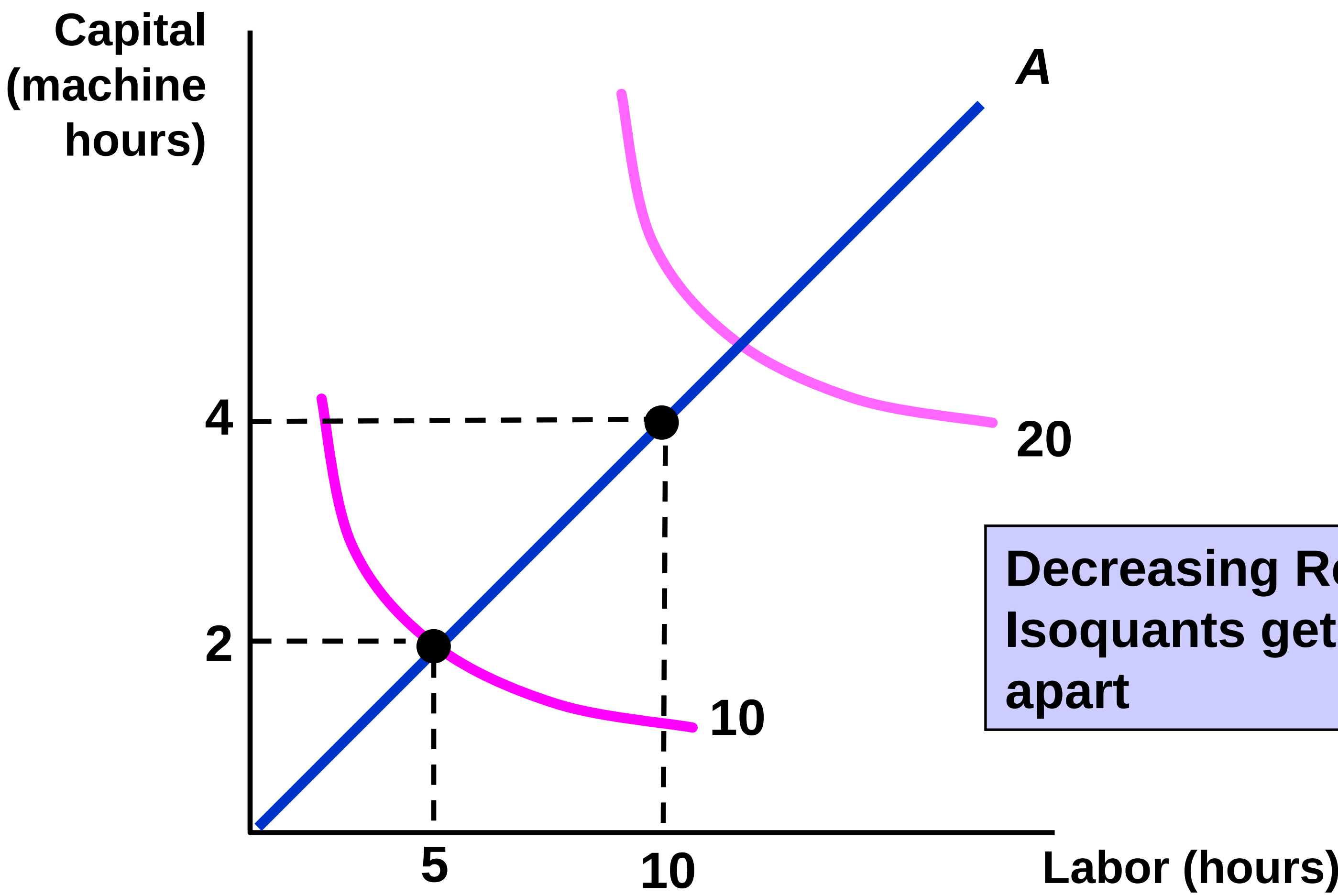
Constant Returns: Isoquants are equally spaced

Increasing Returns to Scale



The isoquants move closer together

Decreasing Returns to Scale



Decreasing Returns: Isoquants get further apart

Numerical Example

- q = f(L, K) = L*K
  - When all inputs are doubled….

  $f(2L, 2K) = (2L)*(2K) = 4*L*K = 4*q$

  Output is quadrupled (IRTS)
- $q = f(L, K) = L^{0.5}*K^{0.5}$
  - When all inputs are doubled….

  $f(2L, 2K) = (2L)^{0.5}*(2K)^{0.5} = 4^{0.5}*L*K = 2*q$

  Output is doubled (CRTS)