Production

This module introduces you to:

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

- **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**

- **<u>Production Decisions of a Firm</u>**

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**
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.**
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**
   - **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.**

- **<u>The Technology of Production</u>**
- **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 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 improves, more output can be produced for a given level of inputs.**
- **<u>Short Run versus Long Run</u>**
    - **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**
  - **<u>Short Run</u>**
    - **Period of time in which quantities of one or more production factors cannot be changed**
    - **These inputs are called fixed inputs**
  - **<u>Long Run</u>**

- time needed to make all production inputs variable

- **In the long run, all inputs to a firm's production function may be changed → because there are no fixed costs.**

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**

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

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 early in the production process**
   - **After a point, more labor is not useful and can be counterproductive**

- **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 from an incremental unit of an input?**

- **Sometimes useful to make comparison on an average basis**

<u>Short-run cost function</u>

- **Standard variables in the short-run cost function:**
  - **Quantity (Q) is the amount of output that a firm can produce in the short run**
  - **Total fixed cost (TFC) is the total cost of using the fixed input, capital (K)**
  - **Total variable cost (TVC) is the total cost of using the variable input, labor (L)**
  - **Total cost (TC) is the total cost of using all the firm's inputs,**

TC = TFC + TVC

  - **Average fixed cost (AFC) is the average per-unit cost of using the fixed input K**

    AFC = TFC/Q

  - **Average variable cost (AVC) is the average per-unit cost of using the variable input L**

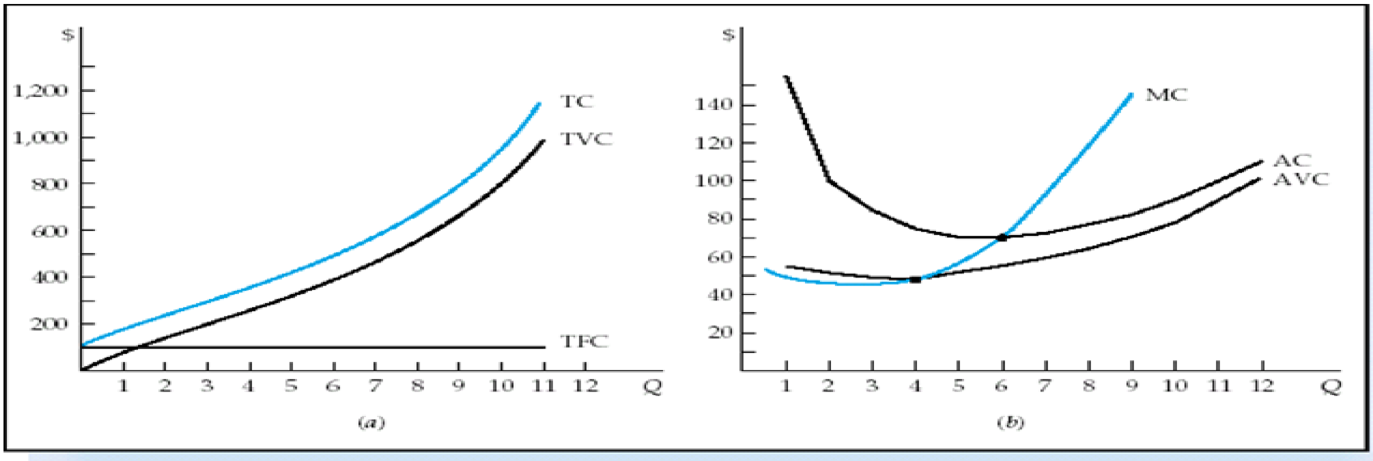
    AVC = TVC/Q

  - **Average total cost (AC) is the average per-unit cost of all the firm's inputs**

    AC = AFC + AVC = TC/Q

  - **Marginal cost (MC) is the change in a firm's total cost (or total variable cost) resulting from a unit change in output**

    MC = DTC/DQ = DTVC/DQ



Total Cost, Total Variable Cost, Total Fixed Cost, Average Cost, Average Variable Cost, and Marginal Cost

observations

- **AFC declines steadily**
- **when MC = AVC, AVC is at a minimum**
- **when MC < AVC, AVC is falling**
- **when MC > AVC, AVC is rising**

The same three rules apply for average cost (AC) as for AVC

- **A reduction in the firm's fixed cost would cause the average cost line to shift downward**

A reduction in the firm's variable cost would cause all three cost lines (AC, AVC, MC) to shift

- **Profit Total revenue minus total cost**
- **Profit = TR – TC**

<u>Production: One Variable Input</u>

- **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.**

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

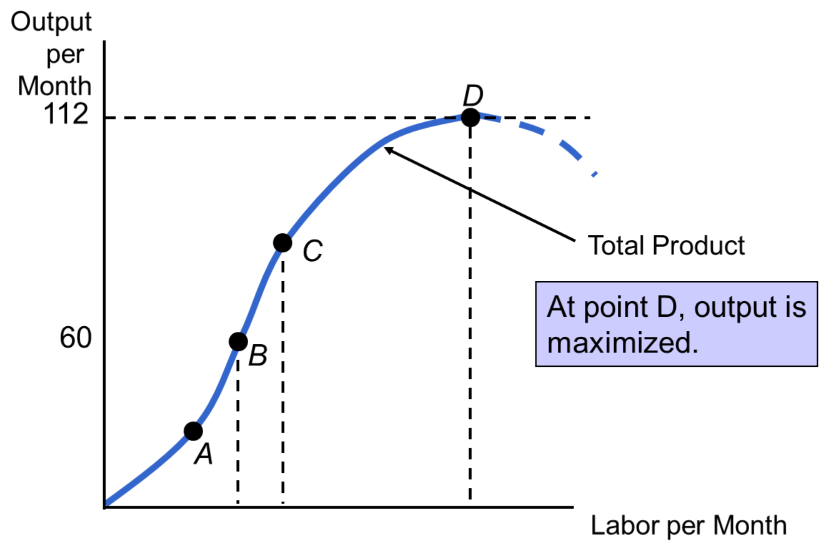
- **Marginal Product of Labor – additional output produced when labor increases by one unit**
- **Change in output divided by the change in labor**

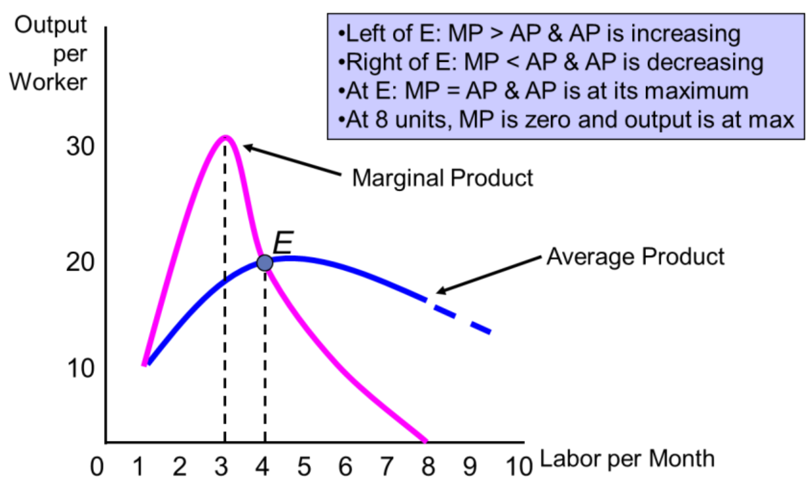
$$MP_L = \frac{\Delta Output}{\Delta Labor\ Input} = \frac{\Delta q}{\Delta L}$$

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

<u>Production: One Variable Input</u>

- **We can graph the information 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**





Marginal and Average Product

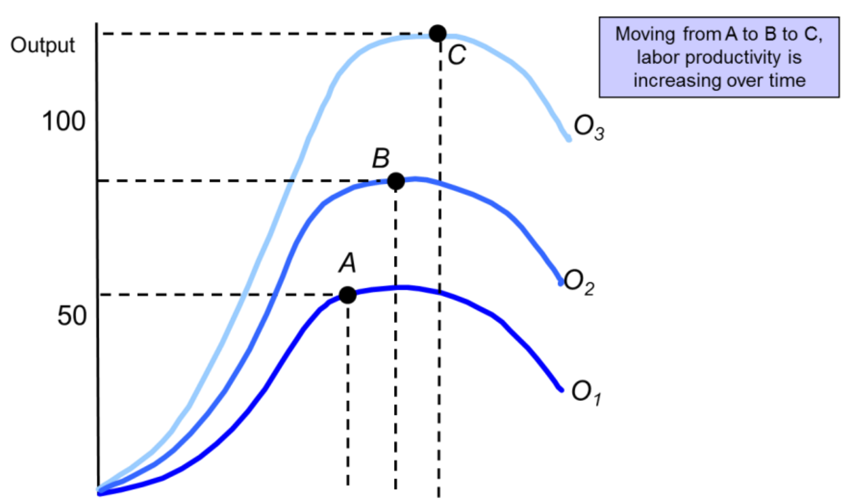
- **When marginal product is greater than the average product, the average product is increasing**
- **When marginal product is less than the average product, the average product is decreasing**
- **When marginal product is zero, total product (output) is at its maximum**
- **Marginal product crosses average product at its maximum**
- **From the previous example, we can see that as we increase labor the additional output produced declines**

- **Law of Diminishing Marginal Returns: At some point in the production process, the additional output achieved from adding a variable input to a fixed input, will decline and eventually become negative**

Law of Diminishing Marginal Returns

- **Typically applies only for the short run when one variable input, such as labor, 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**
- **Explains a declining marginal product, not necessarily a negative one**
    - **Additional output can be declining while total output is increasing**
- **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:



<u>Production: Two Variable Inputs</u>

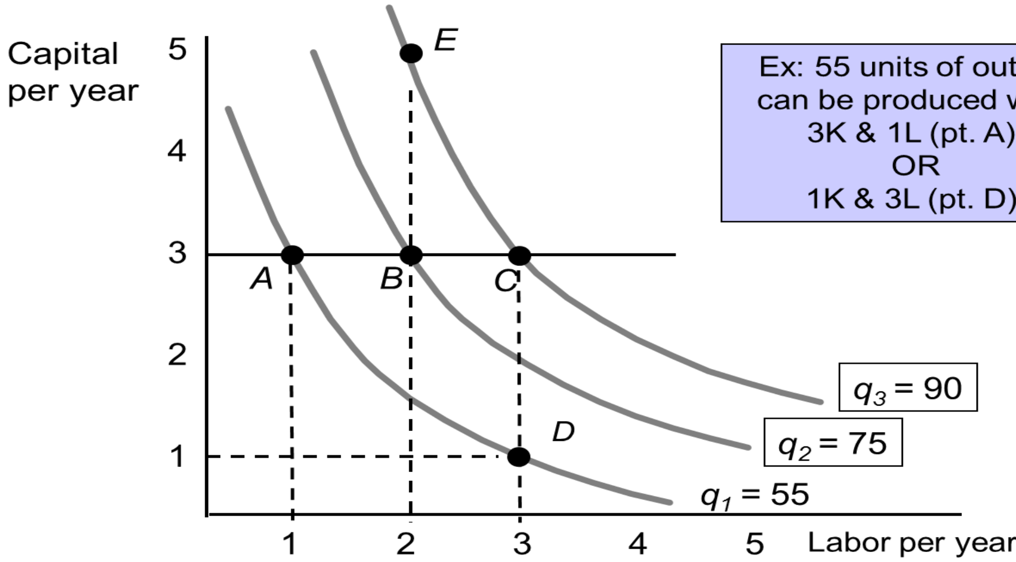
- **Firm can produce output by combining different amounts of labor and capital**
- **In the long run, capital and labor are both variable**

We can look at the output we can achieve with different combinations of capital and labor

	Labor Input				
Capital 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

- **The information can be represented graphically using isoquants**
- **Iso' means equal and 'quant' means quantity. Therefore,**
  an isoquant represents a constant quantity of output
  - **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**
- **What are the differences between an Isoquant and an indifference curve?**
- **An isoquant is equivalent to an indifference curve in more than one way. In it, two factors (capital and labour) replace two commodities of consumption. An isoquant shows equal level of product while an indifference curve shows equal level of satisfaction at all points.**

Isoquant Map:



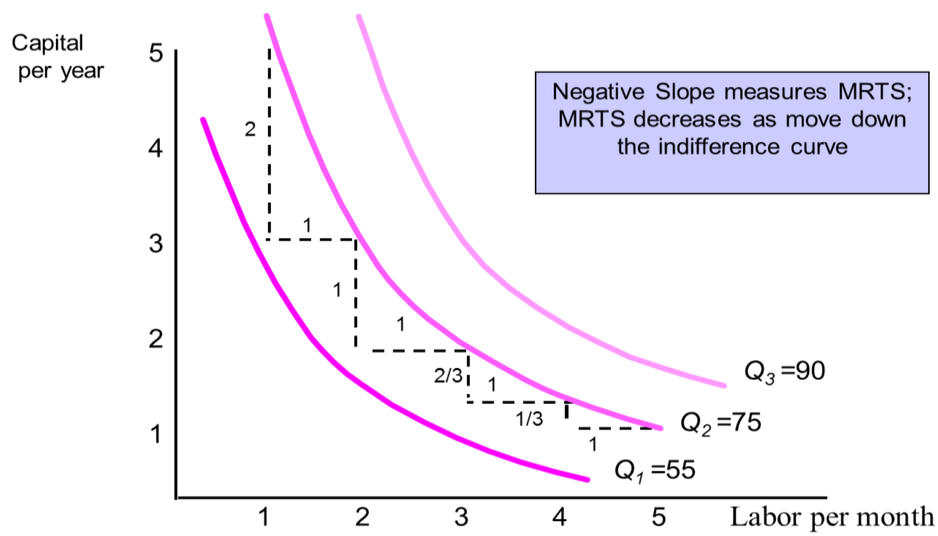
- **Diminishing Returns to Labor with Isoquants**
- **Holding capital at 3 and increasing labor from 0 to 1 to 2 to 3**
    - **Output increases at a decreasing rate (0, 55, 20, 15) illustrating diminishing marginal returns from labor in the short run and long run**
- **Diminishing Returns to Capital 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**
- **<u>Substituting Among Inputs</u>**
    - **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**

- **<u>The marginal rate of technical substitution equals:</u>**

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

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

- **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**



- **<u>MRTS and Isoquants</u>**
- **We assume there is diminishing MRTS**
    - **Increasing labor in one unit raises 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**
- **If we increase labor and decrease capital while keeping output constant:**
- **We can see that there will be a decrease in output due to decreased capital usage, but an equally offsetting increase in output due to the increased labor usage**
    - **The change in output attributable to an increase in labor usage can be written:**

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

- **Similarly, the decrease in output from the decrease in capital usage can be calculated:**

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

- **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**

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