Chapter 6
Production

Topics to be Discussed

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

Introduction

- Our focus is the *supply side*.
- **The theory of the firm** will address:
  - How a firm makes cost-minimizing production decisions
  - How cost varies with output
  - Characteristics of market supply
  - Issues of business regulation

The Technology of Production

- The Production Process
  - Combining inputs or factors of production to achieve an output
- Categories of Inputs (factors of production)
  - Labor
  - Materials
  - Capital

The Technology of Production

- Production Function:
  - Indicates the highest output that a firm can produce for every specified combination of inputs given the state of technology.
  - Shows what is *technically feasible* when the firm operates *efficiently*.

The Technology of Production

- The production function for two inputs:

  $Q = F(K,L)$

  Q = Output, K = Capital, L = Labor
- For a given technology

Isoquants

- Assumptions
  - Food producer has two inputs
    - Labor (*L*) & Capital (*K*)

Isoquants

- Observations:
  1) For any level of K, output increases with more L.
  2) For any level of L, output increases with more K.
  3) Various combinations of inputs produce the same output.

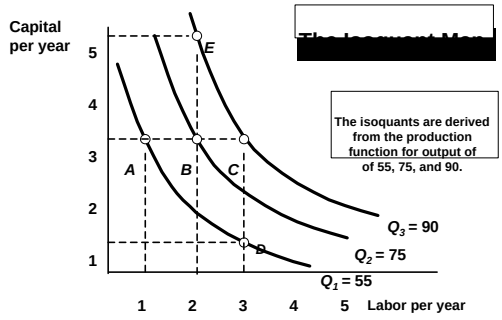
Isoquants

- Isoquants
  - Curves showing all possible combinations of inputs that yield the same output

Production Function for Food

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 with Two Variable Inputs (*L*,*K*)



The isoquants are derived from the production function for output of of 55, 75, and 90.

Isoquants

- The isoquants emphasize how different input combinations can be used to produce the same output.
- This information allows the producer to respond efficiently to changes in the markets for inputs.

Isoquants

The Short Run versus the Long Run

- Short-run:
  - Period of time in which quantities of one or more production factors cannot be changed.
  - These inputs are called fixed inputs.

Isoquants

The Short Run versus the Long Run

- Long-run
  - Amount of time needed to make all production inputs variable.

Production with One Variable Input (Labor)

Amount of Labor (*L*)	Amount of Capital (*K*)	Total Output (*Q*)	Average Product	Marginal Product
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 with One Variable Input (Labor)

- Observations:

  1) With additional workers, output (*Q*) increases, reaches a maximum, and then decreases.

Production with One Variable Input (Labor)

- Observations:

  2) The average product of labor (*AP*), or output per worker, increases and then decreases.

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

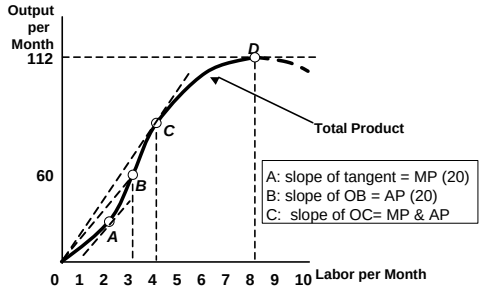
Production with One Variable Input (Labor)

- Observations:

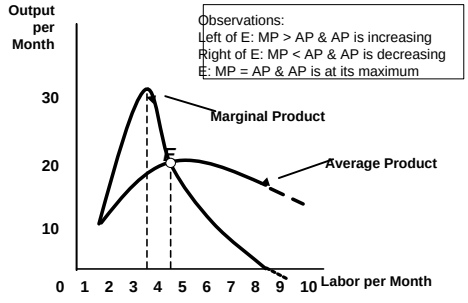
  3) The marginal product of labor (M*P*), or output of the additional worker, increases rapidly initially and then decreases and becomes negative..

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

Production with One Variable Input (Labor)



Production with One Variable Input (Labor)

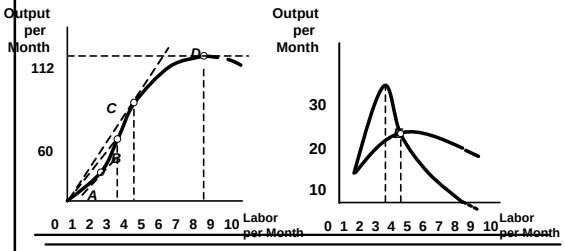


Production with One Variable Input (Labor)

- Observations:
  - When *MP* = 0, *TP* is at its maximum
  - When *MP* > *AP, AP* is increasing
  - When *MP* < *AP, AP* is decreasing
  - When *MP* = *AP, AP* is at its maximum

Production with One Variable Input (Labor)

AP* = slope of line from origin to a point on *TP*, lines *b, & c.
***MP* = slope of a tangent to any point on the *TP* line, lines a & c.**



Production with One Variable Input (Labor)

The Law of Diminishing Marginal Returns

- As the use of an input increases in equal increments, a point will be reached at which the resulting additions to output decreases (i.e. *MP* declines).

Production with One Variable Input (Labor)

The Law of Diminishing Marginal Returns

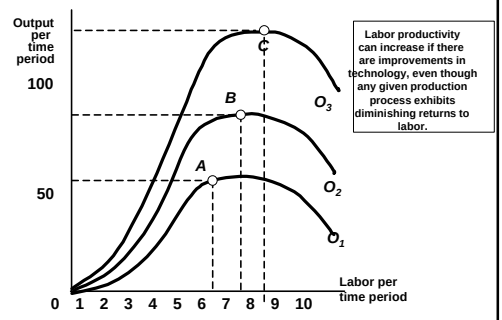
- Can be used for long-run decisions to evaluate the trade-offs of different plant configurations
- Assumes the quality of the variable input is constant

Production with One Variable Input (Labor)

The Law of Diminishing Marginal Returns

- Explains a declining *MP*, not necessarily a negative one
- Assumes a constant technology

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?

Index of World Food Consumption Per Capita

Year	Index
1948-1952	100
1960	115
1970	123
1980	128
1990	137
1995	135
1998	140

Malthus and the Food Crisis

- The data show that production increases have exceeded population growth.
- Malthus did not take into consideration the potential impact of technology which has allowed the supply of food to grow faster than demand.
- Technology has created surpluses and driven the price down.

Production with One Variable Input (Labor)

- Labor Productivity

$$\text{Average Productivity} = \frac{\text{Total Output}}{\text{Total Labor Input}}$$

Production with One Variable Input (Labor)

- Labor Productivity and the Standard of Living
  - Consumption can increase only if productivity increases.
  - Determinants of Productivity
    - Stock of capital
    - Technological change

Labor Productivity in Developed Countries

	France	Germany	Japan	United Kingdom	United States
	Output per Employed Person (1997)				
	$54,507	$55,644	$46,048	$42,630	$60,915
	Annual Rate of Growth of Labor Productivity (%)				
1960-1973	4.75	4.04	8.30	2.89	2.36
1974-1986	2.10	1.85	2.50	1.69	0.71
1987-1997	1.48	2.00	1.94	1.02	1.09

Production with One Variable Input (Labor)

- Trends in Productivity
  1) U.S. productivity is growing at a slower rate than other countries.
  2) Productivity growth in developed countries has been decreasing.

Production with One Variable Input (Labor)

- Explanations for Productivity Growth Slowdown
  1) Growth in the stock of capital is the primary determinant of the growth in productivity.

Production with One Variable Input (Labor)

- Explanations for Productivity Growth Slowdown
  2) Rate of capital accumulation in the U.S. was slower than other developed countries because the others were rebuilding after WWII.

Production with One Variable Input (Labor)

- Explanations for Productivity Growth Slowdown
  3) Depletion of natural resources
  4) Environment regulations

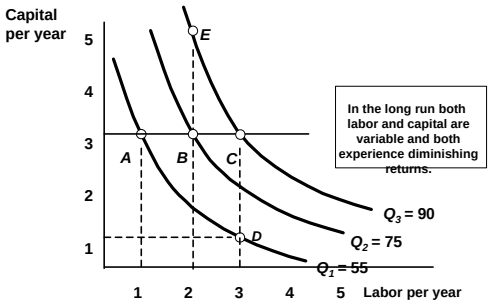
Production with One Variable Input (Labor)

- Observation
  - U.S. productivity has increased in recent years

Production with Two Variable Inputs

- There is a relationship between production and productivity.
- Long-run production *K& L* are variable.
- Isoquants analyze and compare the different combinations of *K & L* and output

The Shape of Isoquants



Production with Two Variable Inputs

Diminishing Marginal Rate of Substitution

- Reading the Isoquant Model
  1) Assume capital is 3 and labor increases from 0 to 1 to 2 to 3.
     - ◆Notice output increases at a decreasing rate (55, 20, 15) illustrating diminishing returns from labor in the short-run and long-run.

Production with Two Variable Inputs

Diminishing Marginal Rate of Substitution

- Reading the Isoquant Model
  2) Assume labor is 3 and capital increases from 0 to 1 to 2 to 3.
     - ◆Output also increases at a decreasing rate (55, 20, 15) due to diminishing returns from capital.

Production with Two Variable Inputs

- Substituting Among Inputs
  - Managers want to determine what combination of inputs to use.
  - They must deal with the trade-off between inputs.

Production with Two Variable Inputs

- Substituting Among Inputs
  - The slope of each isoquant gives the trade-off between two inputs while keeping output constant.

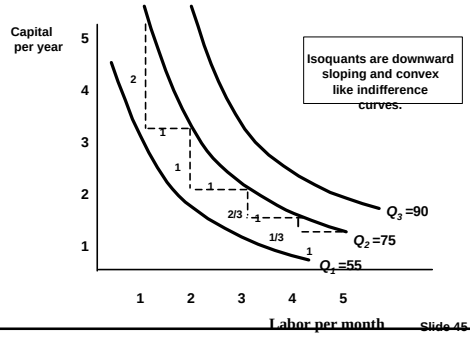
Production with Two Variable Inputs

- Substituting Among Inputs
  - The marginal rate of technical substitution equals:

$$MRTS = -\text{Change in capital}/\text{Change in labor input}$$

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

Marginal Rate of Technical Substitution



Production with Two Variable Inputs

- Observations:
  1) Increasing labor in one unit increments from 1 to 5 results in a decreasing *MRTS* from 2 to 1/3.
  2) Diminishing *MRTS* occurs because of diminishing returns and implies isoquants are convex.

Production with Two Variable Inputs

- Observations:
  3) *MRTS* and Marginal Productivity
     - The change in output from a change in labor equals:

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

Production with Two Variable Inputs

- Observations:
  3) *MRTS* and Marginal Productivity
     - The change in output from a change in capital equals:

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

Production with Two Variable Inputs

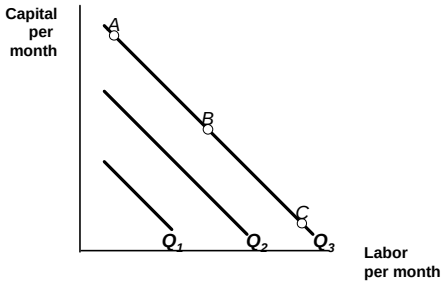
- Observations:

  3) *MRTS* and Marginal Productivity

  - If output is constant and labor is increased, then:

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

Isoquants When Inputs are Perfectly Substitutable



Production with Two Variable Inputs

Perfect Substitutes

- Observations when inputs are perfectly substitutable:

  1) The MRTS is constant at all points on the isoquant.

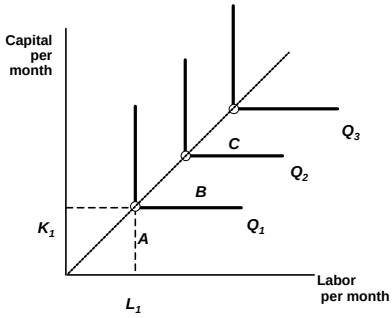
Production with Two Variable Inputs

Perfect Substitutes

- Observations when inputs are perfectly substitutable:

  2) For a given output, any combination of inputs can be chosen (*A, B, or C)* to generate the same level of output (e.g. toll booths & musical instruments)

Fixed-Proportions Production Function



Production with Two Variable Inputs

Fixed-Proportions Production Function

- Observations when inputs must be in a fixed-proportion:

  1) No substitution is possible.Each output requires a specific amount of each input (e.g. labor and jackhammers).

Production with Two Variable Inputs

Fixed-Proportions Production Function

- Observations when inputs must be in a fixed-proportion:

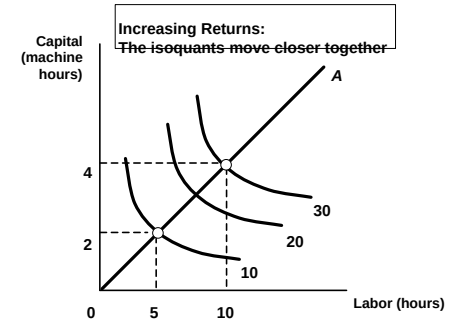
  2) To increase output requires more labor and capital (i.e. moving from *A* to *B* to *C* which is technically efficient).

Returns to Scale

- Measuring the relationship between the scale (size) of a firm and output

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

Returns to Scale

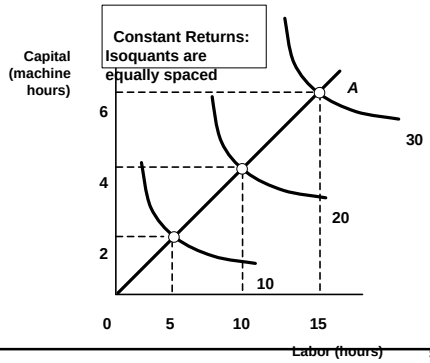


Returns to Scale

- Measuring the relationship between the scale (size) of a firm and output

  2) 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

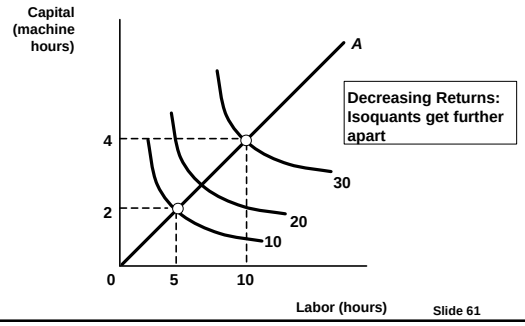


Returns to Scale

- Measuring the relationship between the scale (size) of a firm and output

  3) 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



Slide 61

Summary

- A *production function* describes the maximum output a firm can produce for each specified combination of inputs.
- An *isoquant* is a curve that shows all combinations of inputs that yield a given level of output.

Slide 62

Summary

- *Average product of labor* measures the productivity of the average worker, whereas *marginal product of labor* measures the productivity of the last worker added.

Slide 63

Summary

- The *law of diminishing returns* explains that the marginal product of an input eventually diminishes as its quantity is increased.

Slide 64

Summary

- Isoquants always slope downward because the marginal product of all inputs is positive.
- The standard of living that a country can attain for its citizens is closely related to its level of productivity.

Slide 65

Summary

- In long-run analysis, we tend to focus on the firm's choice of its scale or size of operation.

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