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## Production Function

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Production is the process by which inputs are transformed into output. Firms acquire inputs such as labour, capital, land, and raw materials to produce goods or services. The production function represents the relationship between the quantity of inputs used and the maximum quantity of output produced.

For example, a farmer using land ( $K$ ) and labour ( $L$ ) to produce wheat can be described by a production function:

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

where  $q$  is output,  $L$  is labour input, and  $K$  is capital input.

The production function assumes efficient use of inputs and is defined for a given technology. Improvements in technology shift the production function upward, allowing more output from the same inputs.

**Example:** Table 3.1 shows output levels for different combinations of labour and capital. For instance, with 2 units of labour and 3 units of capital, output is 18 units.

**Isoquant:** An isoquant is a curve representing all combinations of two inputs that yield the same level of output. Isoquants are negatively sloped, indicating that an increase in one input can compensate for a decrease in the other to maintain the same output.

#### Practice Set:

- Identify input combinations that lie on the isoquant for output level 50 from Table 3.1.
- Explain how an improvement in technology affects the production function.
- Draw and interpret an isoquant curve for a given output level.

#### Answer Key:

- Input combinations (6L, 3K), (4L, 4K), and (3L, 6K) lie on the isoquant for output 50.
- Technological improvement increases maximum output for given inputs, shifting the production function upward.
- Isoquants are convex to the origin and negatively sloped, showing substitutability between inputs.

**Quick Reference:** Production function:  $q = f(L, K)$ ; Isoquant: curve of constant output.

#### Glossary:

- **Production Function:** Relationship between inputs and maximum output.
- **Isoquant:** Curve showing input combinations producing the same output.
- **Inputs/Factors of Production:** Resources like labour and capital used in production.

## The Short Run and the Long Run

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In production analysis, time periods are classified as short run and long run based on input variability.

**Short Run:** At least one input (e.g., capital) is fixed and cannot be changed. The firm can vary only the other inputs (e.g., labour) to change output.

**Long Run:** All inputs are variable; the firm can adjust all factors of production to change output.

For example, if capital is fixed at 4 units, the firm can vary labour to produce different output levels in the short run. In the long run, both labour and capital can be varied.

#### Practice Set:

- Explain why capital is considered fixed in the short run but variable in the long run.
- Give examples of fixed and variable factors in a manufacturing firm.

#### Answer Key:

- Capital is fixed in the short run because it takes time to adjust (e.g., building a factory), but in the long run, the firm can invest in new capital.
- Fixed factors: factory building, machinery; Variable factors: labour, raw materials.

**Quick Reference:** Short run: some inputs fixed; Long run: all inputs variable.

#### Glossary:

- **Short Run:** Time period with at least one fixed input.
- **Long Run:** Time period where all inputs can be varied.

# Total Product, Average Product and Marginal Product

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When varying one input while keeping others constant, the output changes as follows:

- **Total Product (TP):** Total output produced by a given amount of variable input.
- **Average Product (AP):** Output per unit of variable input, calculated as  $AP = TP / L$ .
- **Marginal Product (MP):** Additional output from one more unit of variable input, calculated as  $MP = \Delta TP / \Delta L$ .

For example, with capital fixed at 4 units, increasing labour from 1 to 2 units increases total product from 10 to 24 units, so marginal product of the second unit of labour is 14.

## Practice Set:

- Calculate AP and MP for labour units 3 and 4 using Table 3.2 data.
- Explain the relationship between AP and MP curves.

## Answer Key:

- AP at 3 units labour =  $TP / L = 40 / 3 \approx 13.33$ ; MP at 3 units labour =  $TP(3) - TP(2) = 40 - 24 = 16$ .
- MP curve cuts AP curve at AP's maximum point; when  $MP > AP$ , AP rises; when  $MP < AP$ , AP falls.

**Quick Reference:** TP: total output; AP: average output per input; MP: additional output per input.

## Glossary:

- **Total Product (TP):** Total output from variable input.
- **Average Product (AP):** Output per unit of variable input.
- **Marginal Product (MP):** Change in output from one additional unit of input.

## Law of Diminishing Marginal Product and Law of Variable Proportions

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The law of variable proportions states that as the quantity of one input increases, keeping other inputs fixed, the marginal product of that input initially rises, reaches a maximum, and then declines.

This happens because initially, increasing the variable input improves factor proportions and efficiency, but after a point, overcrowding occurs, reducing marginal productivity.

**Example:** A farmer with fixed land and increasing labour sees marginal product rise initially, then fall after the fourth worker due to limited land.

### Practice Set:

- Explain why marginal product declines after a certain point.
- Describe the shape of TP, AP, and MP curves based on this law.

### Answer Key:

- Marginal product declines due to overcrowding and limited fixed inputs.
- TP curve rises at a decreasing rate; MP and AP curves are inverse U-shaped; MP curve cuts AP curve at AP's maximum.

**Quick Reference:** Marginal product rises then falls; total product increases at decreasing rate.

## Glossary:

- **Law of Variable Proportions:** Marginal product first rises then falls as variable input increases.
- **Diminishing Marginal Product:** Decline in additional output from extra input after a point.

## Returns to Scale

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Returns to scale describe how output changes when all inputs are increased proportionally in the long run.

- **Constant Returns to Scale (CRS):** Output increases in the same proportion as inputs.
- **Increasing Returns to Scale (IRS):** Output increases by a larger proportion than inputs.
- **Decreasing Returns to Scale (DRS):** Output increases by a smaller proportion than inputs.

Mathematically, for a production function  $q = f(x_1, x_2)$ , increasing inputs by factor  $t$  yields:

- CRS if  $f(tx_1, tx_2) = t f(x_1, x_2)$
- IRS if  $f(tx_1, tx_2) > t f(x_1, x_2)$
- DRS if  $f(tx_1, tx_2) < t f(x_1, x_2)$

## Practice Set:

- Give examples of industries exhibiting IRS, CRS, and DRS.
- Explain the economic significance of returns to scale.

## Answer Key:

- IRS: software industry; CRS: small-scale manufacturing; DRS: agriculture with limited land.
- Returns to scale affect firm size, cost efficiency, and market structure.

**Quick Reference:** Returns to scale measure output response to proportional input changes.

### Glossary:

- **Returns to Scale:** Output change when all inputs change proportionally.
- **CRS, IRS, DRS:** Types of returns to scale.

## Costs

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Costs are payments made by firms to acquire inputs for production. Firms choose input combinations that minimize cost for a given output level.

**Short Run Costs:** In the short run, some inputs are fixed, leading to fixed costs (TFC) and variable costs (TVC). Total cost (TC) is the sum of fixed and variable costs:

$$TC = TFC + TVC$$

Average costs are per unit costs:

- Average Fixed Cost (AFC) =  $TFC / q$
- Average Variable Cost (AVC) =  $TVC / q$
- Short Run Average Cost (SAC) =  $TC / q = AFC + AVC$

Marginal Cost (SMC) is the change in total cost from producing one more unit:

$$SMC = \Delta TC / \Delta q$$

Cost curves are typically U-shaped due to the law of diminishing returns.

**Long Run Costs:** All inputs are variable; no fixed costs. Long Run Average Cost (LRAC) and Long Run Marginal Cost (LRMC) are defined similarly:

$$LRAC = TC / q$$

$$LRMC = \Delta TC / \Delta q$$

LRAC is also U-shaped, reflecting returns to scale.

#### Practice Set:

- Calculate AFC, AVC, SAC, and SMC from given cost data.
- Explain why AFC decreases as output increases.
- Describe the relationship between SMC and SAC curves.

#### Answer Key:

- AFC decreases because fixed costs are spread over more units.
- SMC curve cuts SAC and AVC curves at their minimum points.

**Quick Reference:**  $TC = TFC + TVC$ ;  $SAC = AFC + AVC$ ; Marginal cost is change in total cost per unit output.

#### Glossary:

- **Total Fixed Cost (TFC):** Cost that does not vary with output.
- **Total Variable Cost (TVC):** Cost that varies with output.
- **Total Cost (TC):** Sum of fixed and variable costs.
- **Average Cost (AC):** Cost per unit of output.
- **Marginal Cost (MC):** Cost of producing one additional unit.

## Summary

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- Production function shows maximum output from input combinations.
- Short run has fixed and variable inputs; long run all inputs are variable.
- Total product is output from variable input; average and marginal products measure productivity.
- Law of variable proportions states marginal product rises then falls.
- Returns to scale describe output response to proportional input changes.
- Costs include fixed and variable; average and marginal costs guide production decisions.
- Cost curves are typically U-shaped due to diminishing returns and returns to scale.

## Key Concepts

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- Production function
- Short run and long run
- Total product, average product, marginal product
- Law of diminishing marginal product
- Law of variable proportions
- Returns to scale
- Cost function
- Marginal cost, average cost