# The Production Function

AP Microeconomics | Unit 3 | total, marginal and average product; diminishing marginal returns

*Running example.* A pizza kitchen with one oven (the fixed input) hires cooks (the variable input).

## 1. Total, marginal, average

**Three measures of output**

**Total product (TP)**: all the output the workers make together.

**Marginal product (MP)**: the extra output from one more worker, $MP = \dfrac{\Delta TP}{\Delta L}$.

**Average product (AP)**: output per worker, $AP = \dfrac{TP}{L}$.

| workers | TP | MP | AP | |
|---|---|---|---|---|
| 0 | 0 | – | – | |
| 1 | 10 | 10 | 10 | increasing marginal returns |
| 2 | 25 | 15 | 12.5 | increasing marginal returns |
| 3 | 36 | 11 | 12 | diminishing marginal returns |
| 4 | 44 | 8 | 11 | diminishing marginal returns |
| 5 | 48 | 4 | 9.6 | diminishing marginal returns |
| 6 | 48 | 0 | 8 | TP is at its maximum |
| 7 | 45 | −3 | 6.4 | negative marginal returns |

## 2. Diminishing marginal returns

**Law of diminishing marginal returns**

As more of a **variable** input is added to a **fixed** input, the marginal product of the variable input eventually falls.

- **Increasing returns**: MP rises (workers specialize).
- **Diminishing returns**: MP falls but is positive. Output still *rises*, more and more slowly.
- **Negative returns**: MP is below zero. Total output *falls*.

It is a short-run law (something is fixed), and the cause is the fixed input, not worse workers. TP is at its maximum where $MP = 0$.

## 3. How MP and AP fit together

| | |
|---|---|
| MP above AP | AP is rising |
| MP below AP | AP is falling |
| MP = AP | AP is at its **maximum** |


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Like grades: a new score above your average pulls the average up, and one below pulls it down. The same relationship holds between marginal cost and average cost.

## 4. From product to cost

Every cook is paid \$30 an hour. The cost of one more pizza is the wage divided by the marginal product:

$$\text{2nd cook: } \frac{\$30}{15} = \$2 \text{ per extra pizza} \qquad \text{5th cook: } \frac{\$30}{4} = \$7.50 \text{ per extra pizza}$$

**The link to cost**

When marginal product falls, marginal cost rises. The MC curve is the MP curve turned upside down.

## 5. Mirror images, and a group of new workers

With wage $w$: $MC = \frac{w}{MP}$ and $AVC = \frac{w}{AP}$. While $MP > AP$, AP is rising, AVC is falling and $MC < AVC$ (2nd cook: $MP = 15$, $AP = 12.5$, $MC = \$2 < AVC = \$2.40$). Once $MP < AP$, AP falls, AVC rises and $MC > AVC$ (5th cook: $MP = 4$, $AP = 9.6$, $MC = \$7.50 > AVC \approx \$3.13$).

The average product of a group of added workers is the group's added output divided by its size: 5 workers with $AP = 40$ make 200; with 8 workers output is 260, so the 3 new workers average $\frac{60}{3} = 20$, not the new overall $AP = \frac{260}{8} = 32.5$.

**Where students lose points**

1. Saying diminishing returns means output falls: it means MP falls.
2. Finding where returns start to diminish from TP instead of from MP.
3. Blaming the workers: the cause is the fixed input.
4. Mixing up marginal ($\Delta TP$) and average ($TP \div L$).
5. Forgetting that MP crosses AP at the maximum of AP.

**Now practise it**

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