

Productivity: the key relationships

Formula sheet · Session 1 · Heizer, Render & Munson, Chapter 1 · Sustainable Supply Chain Management, TH Köln

Allowed during the bonus exercises and the Session 1 practice problems

The generic example: Corner Bakery, one day, before and after a new dough mixer

Before	Amount	After (same 3 bakers, same 8 h)	Amount
Output	1,200 rolls	Output	1,380 rolls
Labor: 3 bakers × 8 h × 20 €/h	480 €	Labor: 3 bakers × 8 h × 20 €/h	480 €
Material (flour, yeast, seeds)	180 €	Material (rises with output)	207 €
Energy	60 €	Energy (mixer runs longer)	75 €
Capital (ovens, rent share)	90 €	Capital (mixer added)	105 €
All inputs	810 €	All inputs	867 €

Seven relationships, in words and as formulas

	In words	As a formula	In the example
1 Productivity	How much comes out for each unit that goes in. Always name the input.	$\text{Productivity} = \frac{\text{output}}{\text{input}}$	Output = what was <i>made</i> (1,200 rolls), not what the ovens <i>could</i> make.
2 Single-factor productivity	Output divided by <i>one</i> input, in that input's own unit (hours, kg, kWh).	$\text{Labor productivity} = \frac{\text{output}}{\text{labor-hours}}$ labor-hours = workers × hours each	$\frac{1,200 \text{ rolls}}{3 \times 8 \text{ h}} = \mathbf{50 \text{ rolls per labor-hour}}$
3 Inputs in euros	Hours, kg and kWh cannot be added. Turn each input into euros first.	input € = quantity × price per unit labor € = labor-hours × wage per hour	24 h × 20 €/h = 480 € 480 + 180 + 60 + 90 = 810 €
4 Multifactor productivity	Output divided by <i>all</i> inputs together, each in euros.	$\text{MFP} = \frac{\text{output}}{\text{all inputs in €}}$ all inputs = labor + material + energy + capital + other	$\frac{1,200 \text{ rolls}}{810 \text{ €}} = \mathbf{1.48 \text{ rolls per €}}$
5 Cost per unit	Multifactor turned upside down: what one unit costs in inputs.	$\text{cost per unit} = \frac{\text{all inputs €}}{\text{output}} = \frac{1}{\text{MFP}}$	$\frac{810 \text{ €}}{1,200 \text{ rolls}} = \mathbf{0.675 \text{ € per roll}}$
6 Rearranged	Know the productivity, find the input you need or the output you get.	input needed = $\frac{\text{output wanted}}{\text{productivity}}$ output = productivity × input	1,500 rolls at 50 rolls per labor-hour: $\frac{1,500}{50} = \mathbf{30 \text{ labor-hours}}$
7 Productivity change	How much better or worse the new period is, measured against the <i>old</i> one.	$\text{change \%} = \frac{\text{new} - \text{old}}{\text{old}} \times 100$	Labor: $1,380 \div 24 \text{ h} = 57.5 \text{ per h}$ $\frac{57.5 - 50}{50} \times 100 = \mathbf{+15.0 \%}$ MFP: $1,380 \div 867 \text{ €} = 1.5917 \text{ per €}$ $\frac{1.5917 - 1.4815}{1.4815} \times 100 = \mathbf{+7.4 \%}$

What the example shows

- **One ratio can mislead.** Labor productivity rose by 15 %, but part of the gain was bought with more energy and capital, so multifactor productivity rose by only 7.4 %.
- **More input without more output lowers productivity.** A fourth baker for the same 1,380 rolls: $1,380 \div 32 \text{ h} = 43.1 \text{ rolls per labor-hour}$, a change of -25 %.
- **Three productivity variables** drive improvement: *labor* (skills, motivation), *capital* (machines, tools), *management* (how labor and capital are organised and used).

Five checks before you hand in

- Every result carries its unit: rolls *per labor-hour*, rolls *per €*.
- Labor-hours, not workers: multiply workers by hours each.
- Multifactor: convert every input to € *before* you add.
- Change: divide by the *old* value, not the new one.
- Keep full decimals while you calculate; round only the final answer (2 decimals).

Source: Heizer, J., Render, B., & Munson, C. (2023). *Operations management: Sustainability and supply chain management* (14th ed., Global ed.). Pearson. ISBN 9781292444895. Chapter 1, sections on productivity and productivity measurement. The Corner Bakery example is invented for this sheet (own compilation, R. Bartnik 2026).

Transparency note: Claude (Anthropic) was used to draft the example, check the arithmetic in Python and lay out this sheet. All content was reviewed, revised and is the responsibility of Roman Bartnik.