

Review Session Handout #7

Chapter 8: Production

Chapter 9: The Costs of Production

Introduction to Microeconomics: Markets, Strategy, and Real-World Cases

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Exercise R7.1. A bakery with one oven produces the following number of loaves of bread per day.

Workers	0	1	2	3	4	5	6
Total product	0	12	28	42	52	58	60

Part (a). Compute the marginal product of each worker.

The marginal product of a worker is the extra output from adding that worker. For example, the third worker raises output from 28 to 42 loaves, so her marginal product is $42 - 28 = 14$ loaves. For every worker:

Worker	First	Second	Third	Fourth	Fifth	Sixth
Calculation	$12 - 0$	$28 - 12$	$42 - 28$	$52 - 42$	$58 - 52$	$60 - 58$
Marginal product	12	16	14	10	6	2

Part (b). Compute the average product with each number of workers.

The average product is total output divided by the number of workers. For example, with three workers it is $\frac{42}{3} = 14$ loaves per worker. Rounding to one decimal place where needed, the complete table is as follows.

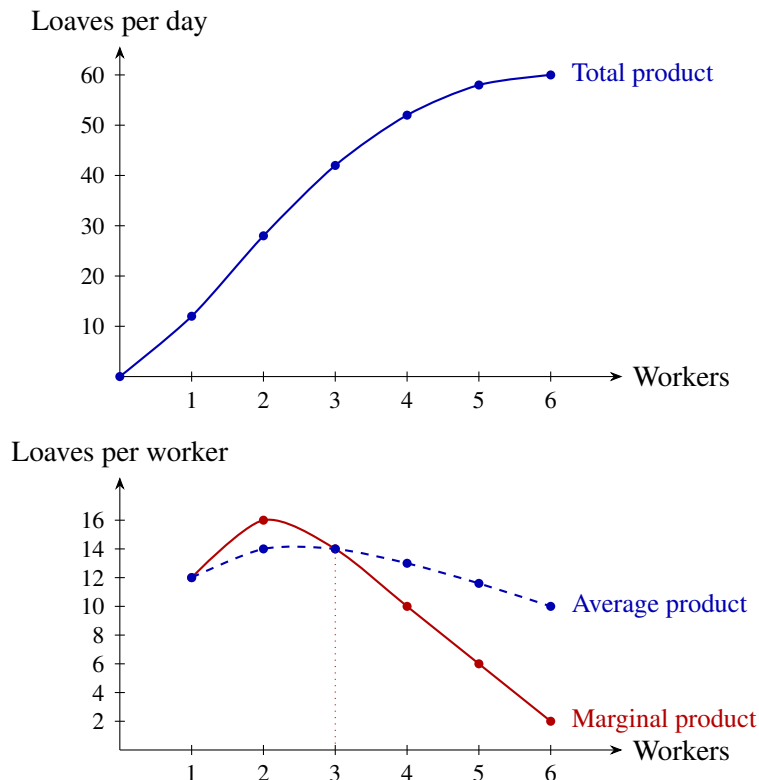
Workers	0	1	2	3	4	5	6
Total product	0	12	28	42	52	58	60
Marginal product	—	12	16	14	10	6	2
Average product	—	12	14	14	13	11.6	10

Part (c). At which worker does diminishing marginal product set in?

Diminishing marginal product sets in at the third worker. The marginal product rises from 12 (first worker) to 16 (second worker), as the first two workers help each other, and then falls to 14 with the third worker. From that point on, each additional worker adds less output than the one before (10, 6, and 2 loaves), as more workers crowd the same oven.

Part (d). Draw total product, marginal product, and average product in a figure with two panels: total product in the top panel, and marginal and average product in the bottom panel.

The following figure shows total product in the top panel and marginal and average product in the bottom panel.



Remark. In the top panel, total product rises at an increasing rate up to the second worker, whose marginal product (16) is the largest, and at a decreasing rate afterward, reflecting diminishing marginal product. In the bottom panel, the marginal product of the second worker (16) is above the average product (12 with one worker), pulling the average up to 14. The third worker's marginal product (14) equals the average product, which is at its highest (14 loaves per worker with two or three workers). From the fourth worker on, the marginal product is below the average product (10 against 13 for the fourth worker), pulling the average down. The marginal product curve thus cuts the average product curve at the latter's highest point.

Exercise R7.2. A firm has a fixed cost of \$200 and the following variable costs.

Output	1	2	3	4	5	6
Variable cost	\$50	\$80	\$120	\$200	\$300	\$420

Part (a). Compute the total cost, average fixed cost, average variable cost, average total cost, and marginal cost at each output. Present your answers in a table.

Total cost is the sum of fixed and variable cost. Marginal cost is the extra cost of producing one more unit. Average fixed cost is fixed cost divided by output, average variable cost is variable cost divided by output, and average total cost is total cost divided by output. At an output of 3, for example:

- Total cost is $\$200 + \$120 = \$320$.
- Marginal cost of the third unit is $\$320 - \$280 = \$40$ (the same as the change in variable cost, $\$120 - \$80$, since fixed cost does not change).

- Average fixed cost is $\frac{\$200}{3} \approx \$66.67$, average variable cost is $\frac{\$120}{3} = \$40$, and average total cost is $\frac{\$320}{3} \approx \$106.67$.

Rounding to the nearest cent, the complete table is as follows (all figures in dollars).

Output	1	2	3	4	5	6
Variable cost	50	80	120	200	300	420
Total cost	250	280	320	400	500	620
Marginal cost	50	30	40	80	100	120
Average fixed cost	200.00	100.00	66.67	50.00	40.00	33.33
Average variable cost	50.00	40.00	40.00	50.00	60.00	70.00
Average total cost	250.00	140.00	106.67	100.00	100.00	103.33

Part (b). At which output is average total cost lowest?

Average total cost reaches its lowest value, \$100, at outputs of 4 and 5.

Part (c). At which output is average variable cost lowest?

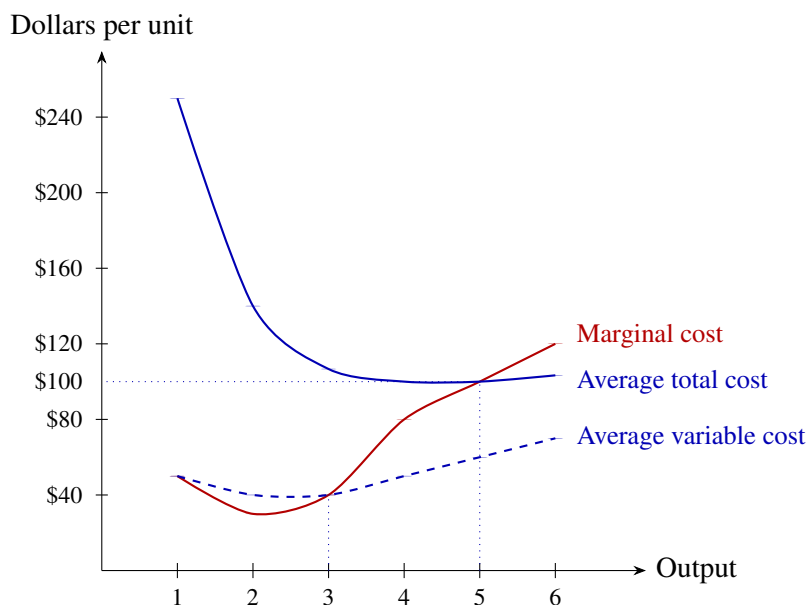
Average variable cost reaches its lowest value, \$40, at outputs of 2 and 3.

Part (d). Verify that marginal cost equals average total cost at the lowest point of average total cost, and that marginal cost equals average variable cost at the lowest point of average variable cost.

At an output of 3, marginal cost is \$40 and average variable cost is \$40, its lowest value. At an output of 5, marginal cost is \$100 and average total cost is \$100, its lowest value. The marginal cost curve therefore cuts the average variable cost and average total cost curves at their lowest points.

Part (e). Draw marginal cost, average variable cost, and average total cost in a figure, showing marginal cost crossing both average cost curves at their lowest points.

The following figure plots the three curves.



Remark. Marginal cost first falls, reaching its lowest value at the second unit (\$30), and then rises. While the cost of the next unit is below an average, it pulls that average down: the second unit's marginal cost of \$30 is below the \$50 average variable cost of one unit, so average variable cost falls to \$40. Once the cost of the next unit is above the average, it pushes the average up: the fourth unit's marginal cost of \$80 is above the \$40 average variable cost of three units, so average variable cost rises to \$50. Marginal cost can therefore equal an average only where that average is at its lowest point.

Exercise R7.3. A print shop fills 120 orders per day with any of the five combinations of workers and printers in the following table, so the five combinations lie on one isoquant. Hiring a worker costs \$120 per day, and renting a printer costs \$40 per day.

Combination	1	2	3	4	5
Workers	1	2	3	4	6
Printers	12	6	4	3	2

Part (a). Moving from combination 1 to combination 5, how many printers does the shop give up for each worker it adds at each step? What does the pattern show?

- From combination 1 to 2: one more worker replaces 6 printers, so 6 printers per worker.
- From combination 2 to 3: one more worker replaces 2 printers.
- From combination 3 to 4: one more worker replaces 1 printer.
- From combination 4 to 5: two more workers replace 1 printer, so $\frac{1}{2}$ printer per worker.

The marginal rate of technical substitution, the rate at which the shop can trade printers for workers while still filling 120 orders, diminishes. When printers are plentiful and workers scarce, one more worker replaces many printers; as workers become plentiful, each additional worker replaces fewer printers. This is why the isoquant bows toward the origin.

Part (b). Compute the total cost of each combination.

Total cost is \$120 times the number of workers plus \$40 times the number of printers:

- Combination 1: $\$120 \times 1 + \$40 \times 12 = \$120 + \$480 = \$600$.
- Combination 2: $\$120 \times 2 + \$40 \times 6 = \$240 + \$240 = \$480$.
- Combination 3: $\$120 \times 3 + \$40 \times 4 = \$360 + \$160 = \$520$.
- Combination 4: $\$120 \times 4 + \$40 \times 3 = \$480 + \$120 = \$600$.
- Combination 5: $\$120 \times 6 + \$40 \times 2 = \$720 + \$80 = \$800$.

Part (c). Which of the five combinations has the lowest total cost?

Combination 2 (2 workers and 6 printers) has the lowest total cost of the five combinations listed, \$480. The two ends of the isoquant are expensive: combination 1 rents 12 printers, and combination 5 hires 6 workers at \$120 each.

Part (d). The daily rent of a printer falls to \$15, while a worker still costs \$120 per day. Which combination now has the lowest total cost? Explain.

The new total costs are:

- Combination 1: $\$120 + \$15 \times 12 = \$120 + \$180 = \$300$.
- Combination 2: $\$240 + \$15 \times 6 = \$240 + \$90 = \$330$.
- Combination 3: $\$360 + \$15 \times 4 = \$360 + \$60 = \$420$.
- Combination 4: $\$480 + \$15 \times 3 = \$480 + \$45 = \$525$.
- Combination 5: $\$720 + \$15 \times 2 = \$720 + \$30 = \$750$.

Combination 1 (1 worker and 12 printers) now has the lowest total cost, \$300. When printers become less expensive relative to workers, the shop substitutes printers for workers, moving along the same isoquant toward the end that uses much capital and little labor. It fills the same 120 orders with one worker instead of two.