Robots and Taxes

EC 350: Labor Economics

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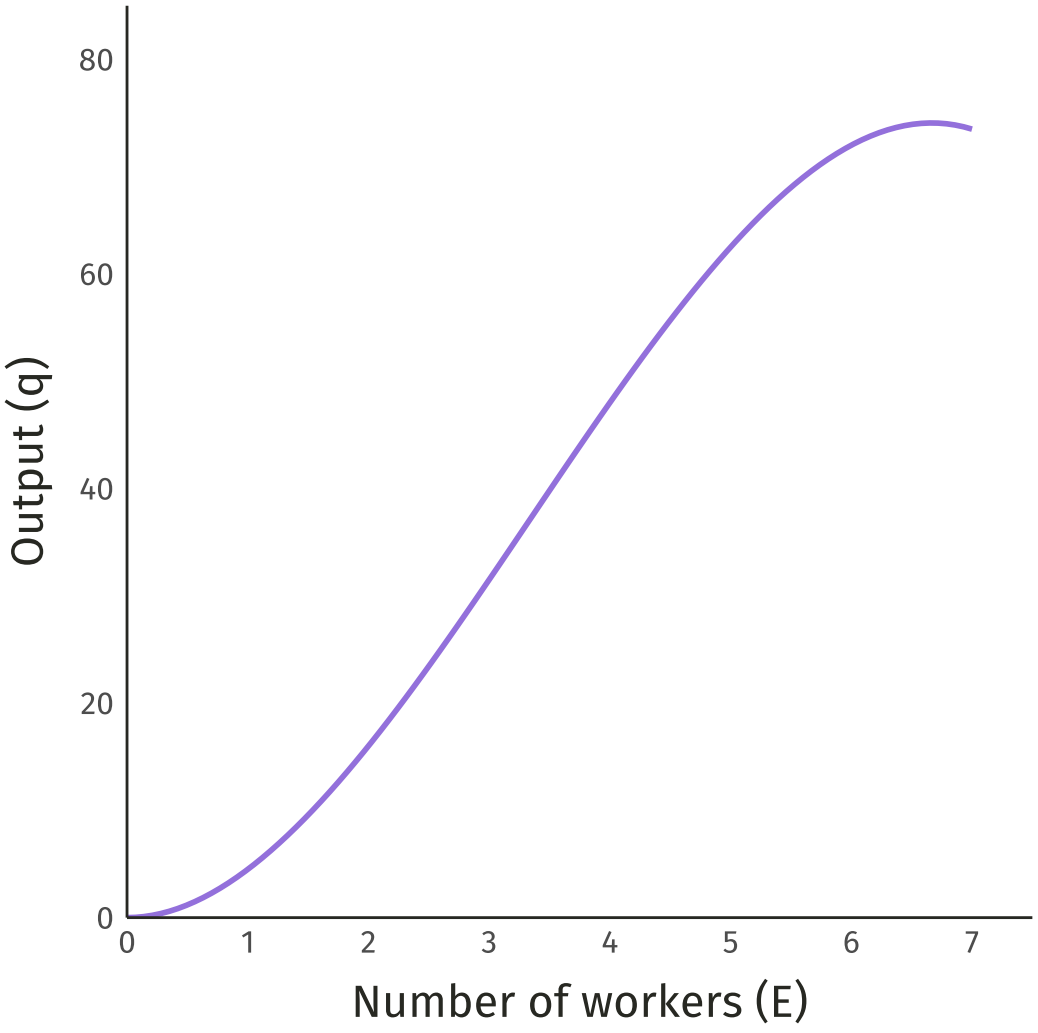
Spring 2021

Agenda

1. Production technology
    - Review
    - Valuing production
2. Factor demand
    - Hiring in the short run
    - Hiring in the long run
    - Labor demand curve
3. Robot tax, featuring Bill Gates

Production technology

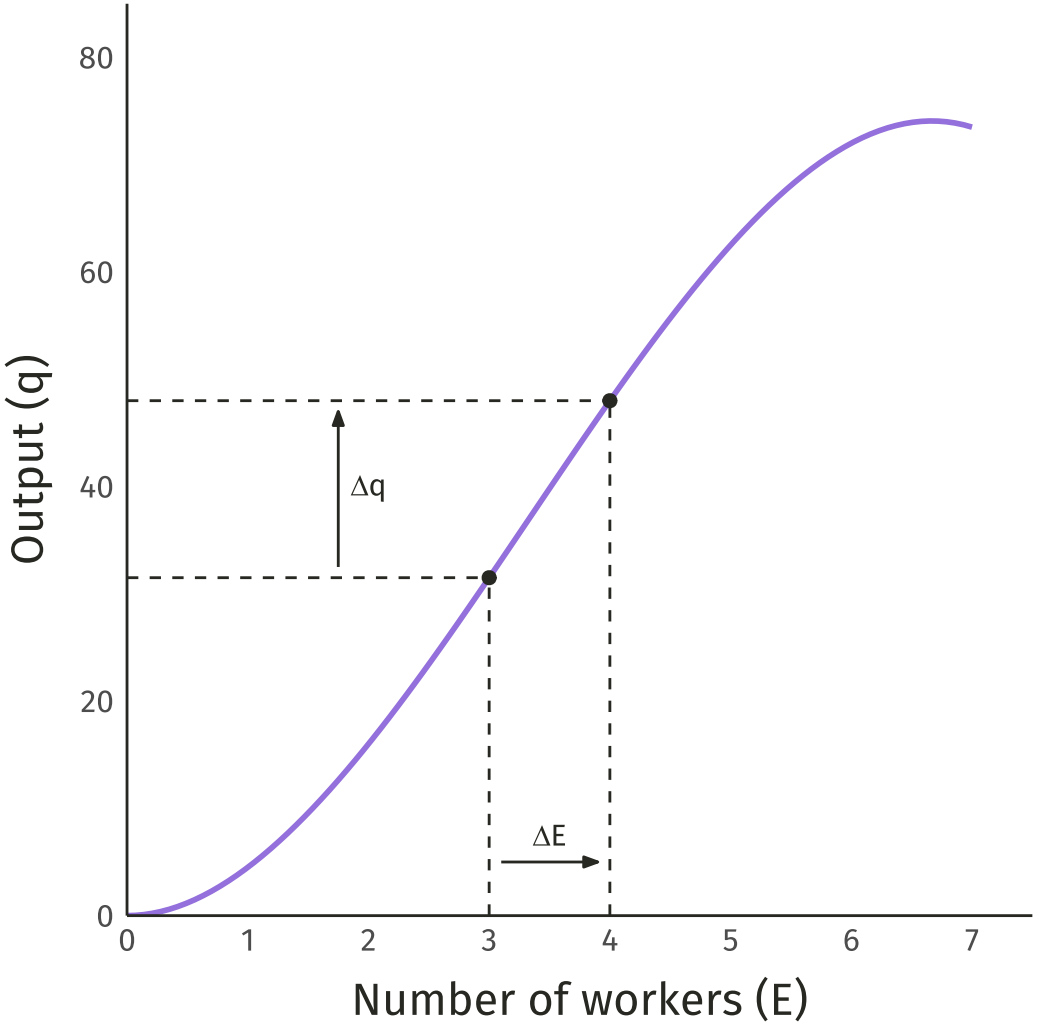
Production technology



Total product of labor

> The amount of output from a given quantity of labor, *holding the amount of capital and other inputs constant.*

Production technology

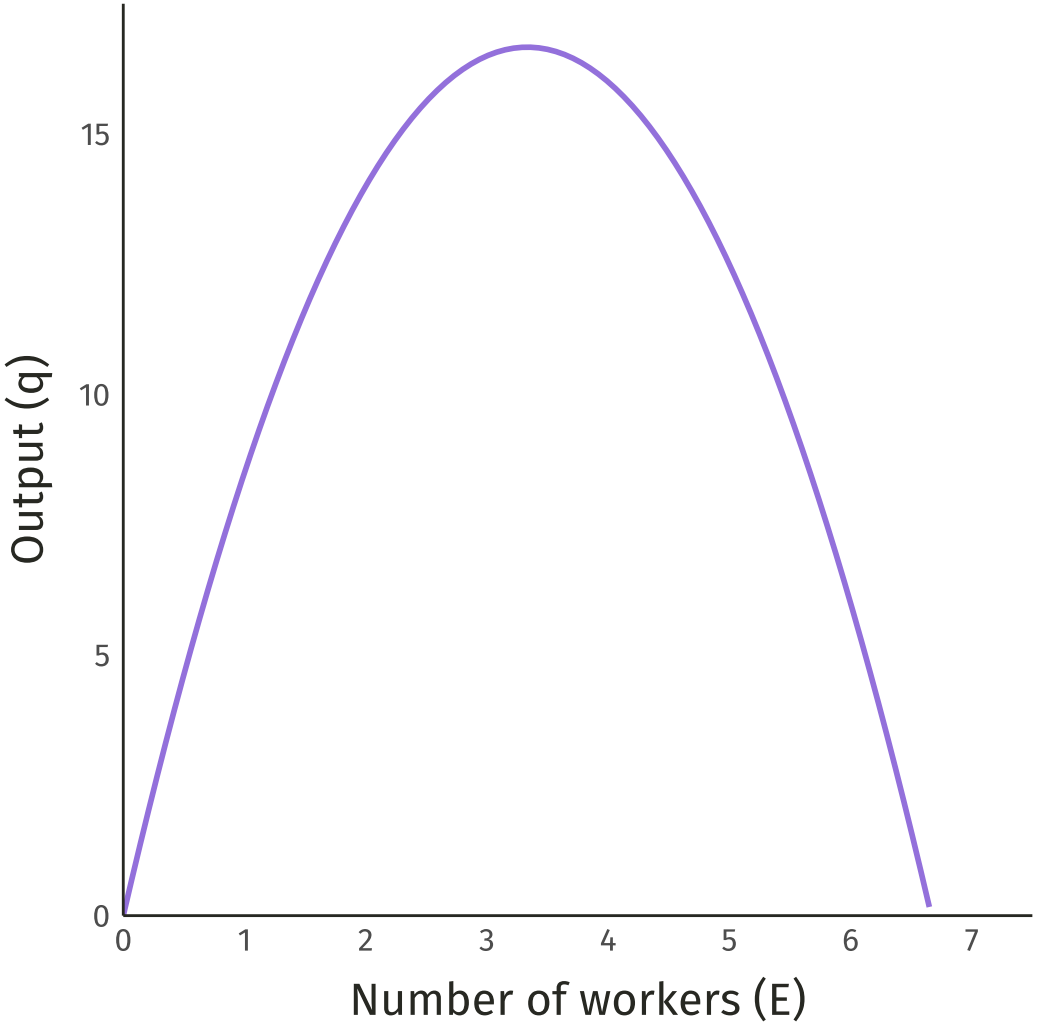


Marginal product of labor

> The change in output from a one-unit increase in labor, *holding the amount of capital and other inputs constant.*

$$\text{MP}_E = \frac{\Delta q}{\Delta E}$$

Production technology



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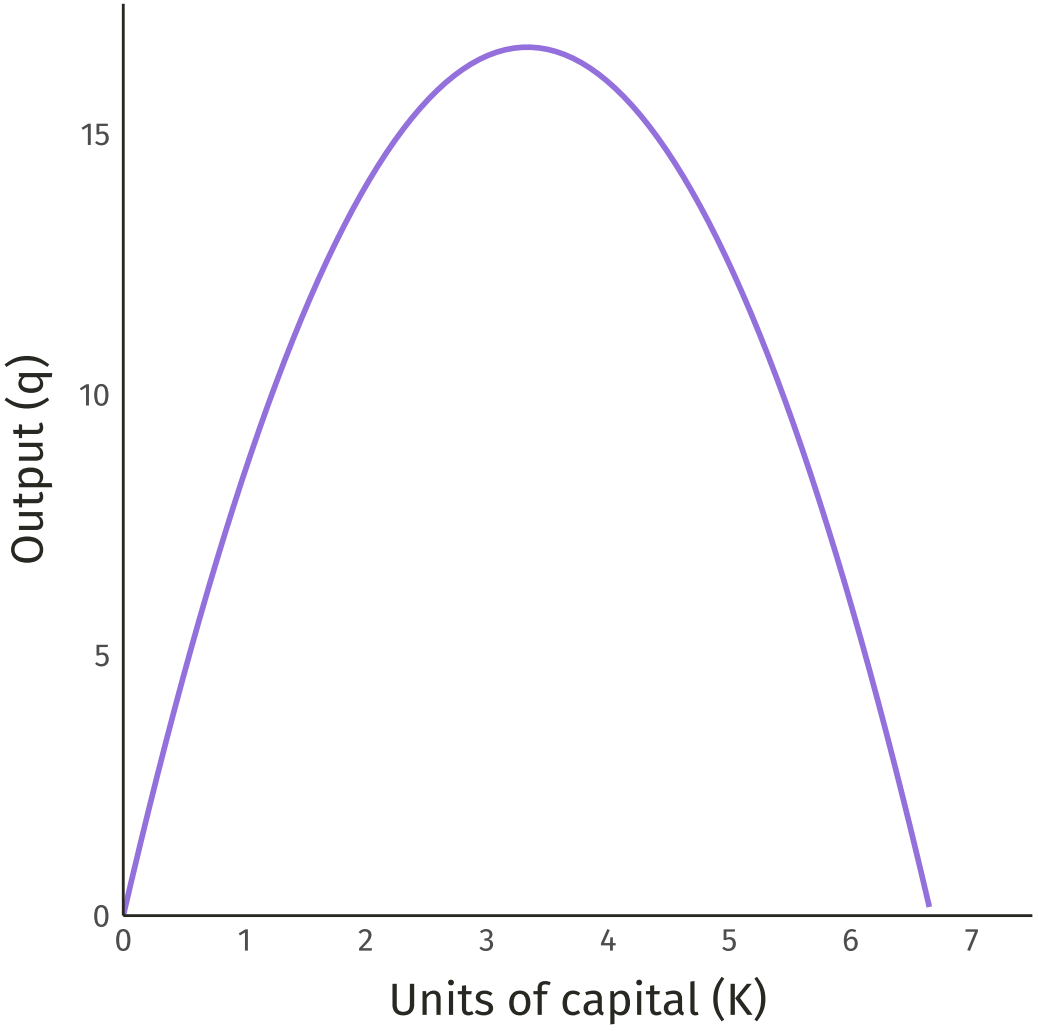
> The change in output from a one-unit increase in labor, *holding the amount of capital and other inputs constant.*

$$\text{MP}_E = \frac{\Delta q}{\Delta E}$$

Production technology



Marginal product of capital

> The change in output from a one-unit increase in capital, *holding the amount of labor and other inputs constant*.

$$\text{MP}_K = \frac{\Delta q}{\Delta K}$$

Production technology

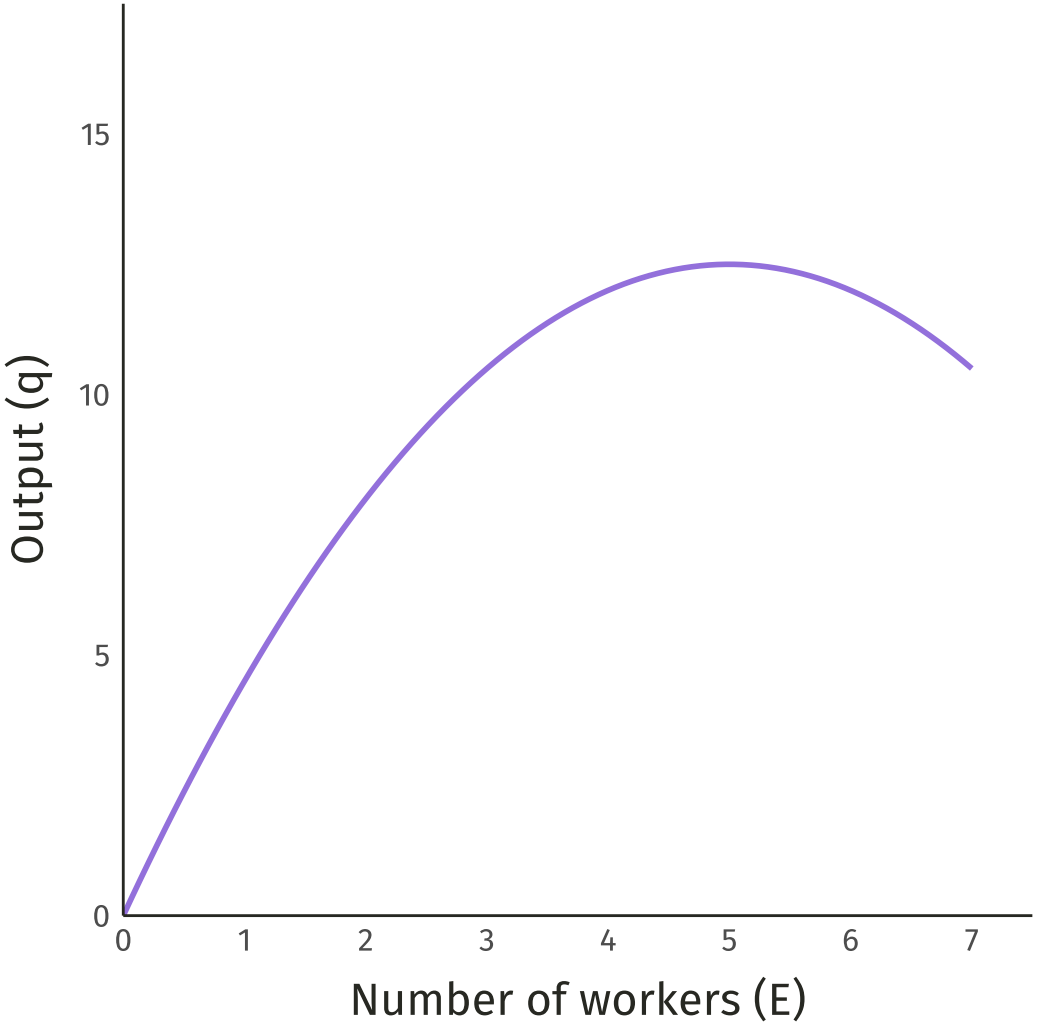
"Law" of diminishing returns†

> For a fixed amount of capital, the **marginal product** of labor **eventually declines** as employment increases.

Early gains from specialization give way to crowded capital inputs.

† Also known as "diminishing marginal productivity."

Production technology

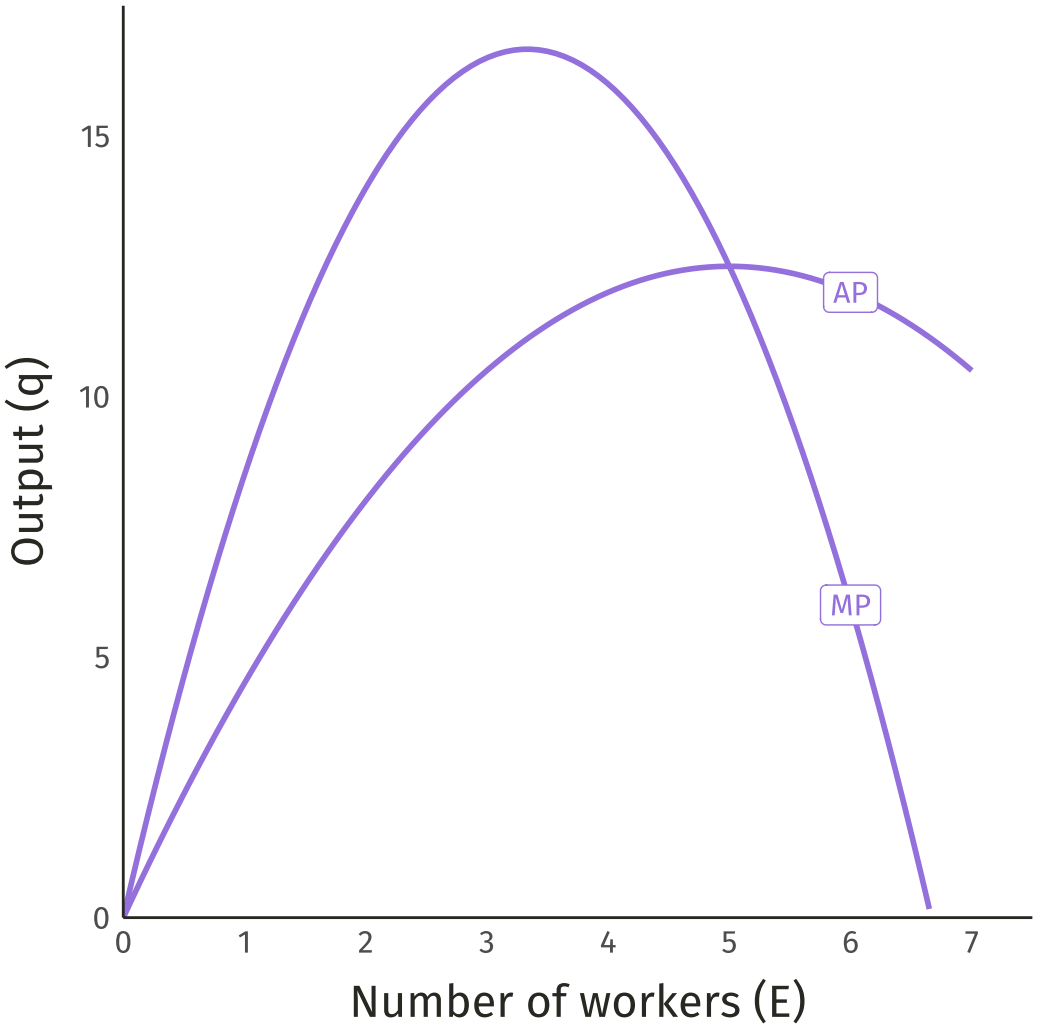


Average product of labor

> The amount of output produced by the typical worker, *holding the amount of capital and other inputs constant.*

$$\text{AP}_E = \frac{q}{E}$$

Production technology



Average product of labor

The marginal product curve intersects the average product curve where average product is maximized.

- When the average product curve is **increasing**, marginal product **is greater than** average product.
- When the average product curve is **decreasing**, marginal product **is less than** average product.

Production technology

Q: What is the marginal product of each worker?

Workers (E)	Output (q)	Marginal product (MP)	Average product (AP)
0	0	—	—
1	1000	1000	
2	1800	800	
3	2400	600	
4	2800	400	
5	3000	200	
6	3000	0	
7	2800	-200	

Production technology

Q: What is the average product for each level of employment?

Workers (E)	Output (q)	Marginal product (MP)	Average product (AP)
0	0	—	—
1	1000	1000	1000
2	1800	800	900
3	2400	600	800
4	2800	400	700
5	3000	200	600
6	3000	0	500
7	2800	-200	400

Valuing production

Marginal revenue product of labor

> The change in total revenue from a one-unit increase in labor, *holding capital and other inputs constant*.

$$\begin{aligned}\text{MRP}_E &= \frac{\Delta \text{TR}}{\Delta q} \times \frac{\Delta q}{\Delta E} \\ &= \text{MR} \times \text{MP}_E\end{aligned}$$

In a **perfectly competitive market** for the output good, price does not depend on a firm's level of output (*i.e.*, $\text{MR} = p$).

- **Implication?** Marginal revenue product is the same as the **value of marginal product of labor**:

$$\text{VMP}_E = \text{MRP}_E = p \times \text{MP}_E$$

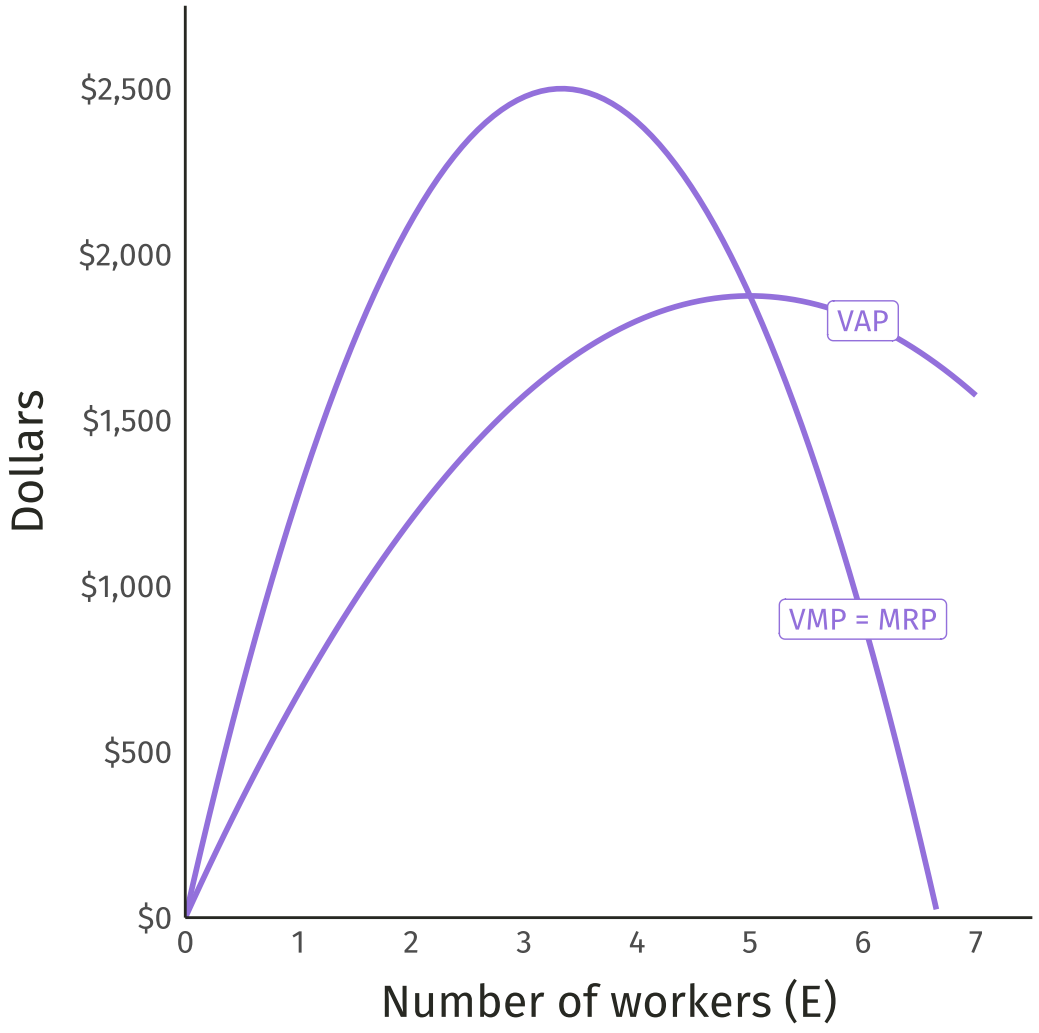
Valuing production

Value of average product of labor

> The amount of revenue the typical worker produces for the firm.

$$\text{VAP}_E = p \times \text{AP}_E$$

Valuing production



The relationship between the value of average product and the value of marginal product is the same as the relationship between average product and marginal product.

The difference? The average product and marginal product curves are now "scaled up" by the price of the output good.

- Vertical axis is now in dollars instead of units of output.
- In this example, p = \$150.

Valuing production

Q: If the price of the output good is $2, what is the marginal revenue product of each worker?

Workers (E)	Output (q)	MP	AP	Marginal revenue product (MRP)	Value of MP (VAP)
0	0	—	—	—	—
1	1000	1000	1000	$2000	
2	1800	800	900	$1600	
3	2400	600	800	$1200	
4	2800	400	700	$800	
5	3000	200	600	$400	
6	3000	0	500	$0	
7	2800	-200	400	-$400	

Valuing production

Q: If the price of the output good is $2, what is the value of average product?

Workers (E)	Output (q)	MP	AP	Marginal revenue product (MRP)	Value of MP (VAP)
0	0	—	—	—	—
1	1000	1000	1000	$2000	$2000
2	1800	800	900	$1600	$1800
3	2400	600	800	$1200	$1600
4	2800	400	700	$800	$1400
5	3000	200	600	$400	$1200
6	3000	0	500	$0	$1000
7	2800	-200	400	-$400	$800

Factor demand

Short run *vs.* long run

Short run

> The time span over which a business can adjust some inputs (*e.g.*, labor), but cannot adjust others (*e.g.*, capital).

In the short run, we will assume that the level of employment **E** can vary, but capital **K** is fixed at an initial level $\mathbf{K_0}$.

- **Example:** A shop foreman can hire or fire workers or adjust hours, but they are unable to expand the factory by adding assembly lines, heavy machinery, or a new building.

Short run *vs.* long run

Long run

> The time span over which a business can adjust all inputs.

In the long-run, we will assume that both the level of employment **E** and capital **K** can vary.

- **Example:** An office manager can hire or fire workers, adjust hours, buy or sell desks and computers, or lease new office space.

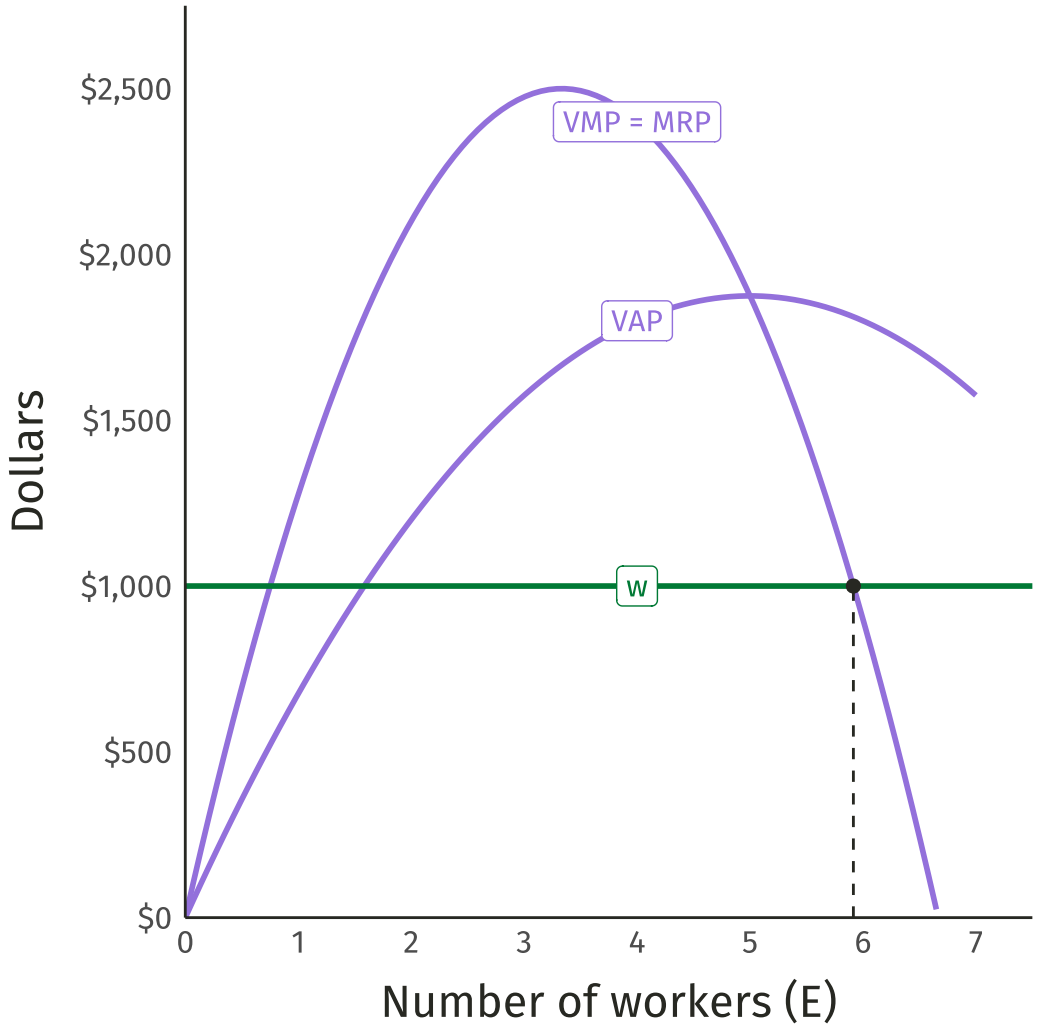
Q: If the price of the output good is $2 and the market wage is $500 per week, how many workers should the employer hire?

Workers (E)	Output (q)	MP	AP	MRP	VAP	Wage (w)
0	0	—	—	—	—	$500
1	1000	1000	1000	$2000	$2000	$500
2	1800	800	900	$1600	$1800	$500
3	2400	600	800	$1200	$1600	$500
4	2800	400	700	$800	$1400	$500
5	3000	200	600	$400	$1200	$500
6	3000	0	500	$0	$1000	$500
7	2800	-200	400	-$400	$800	$500

The employer should **think at the margin** and keep hiring as long as **MRP** $\geq$ **w**.

A: The employer should hire 4 workers.

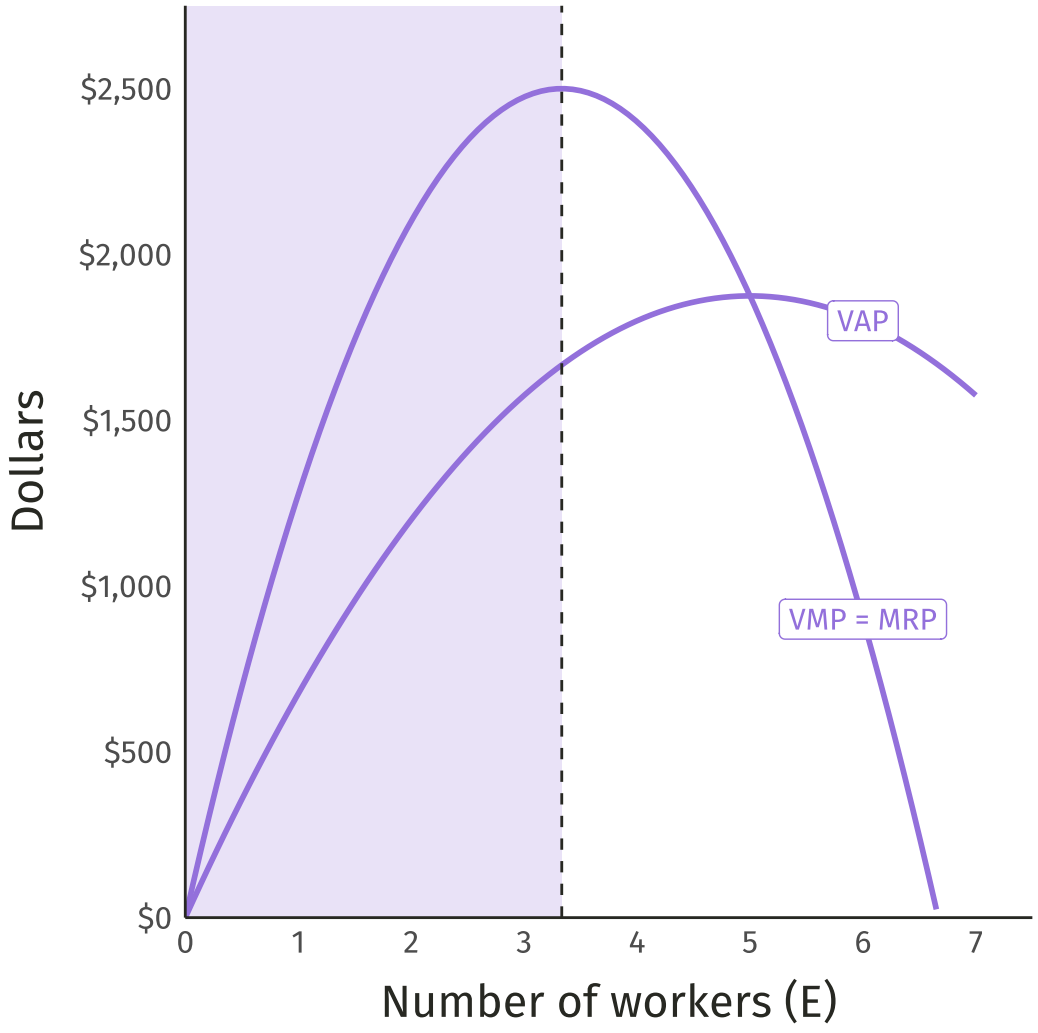
Hiring in the short run



Profit maximization

An employer maximizes profit by hiring E^* workers where $w = \text{MRP}_E$ and MRP_E is decreasing.

Hiring in the short run



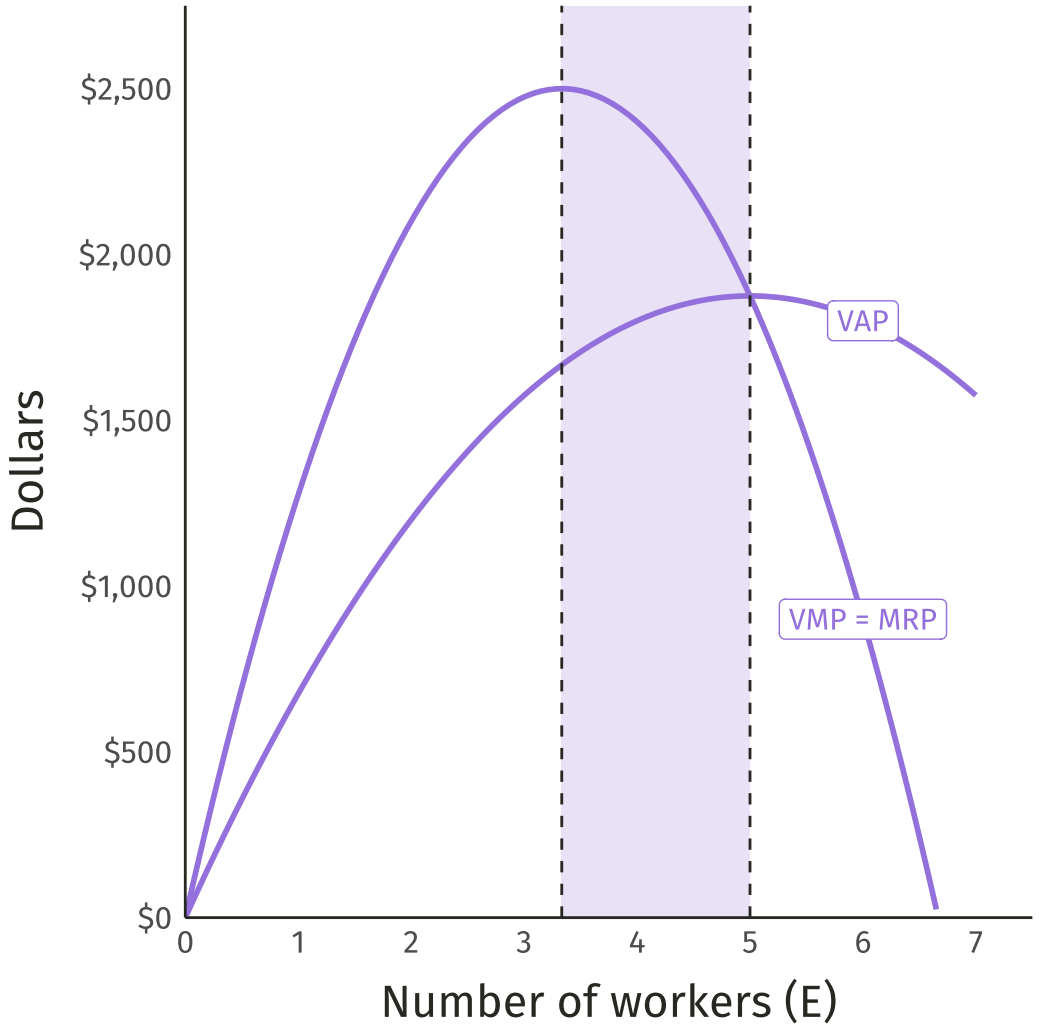
Profit maximization

Q: Why wouldn't an employer stop hiring while marginal revenue product is increasing?

A: Because the employer would be "leaving money on the table."

- The employer could increase profit at the margin by hiring an additional worker.

Hiring in the short run



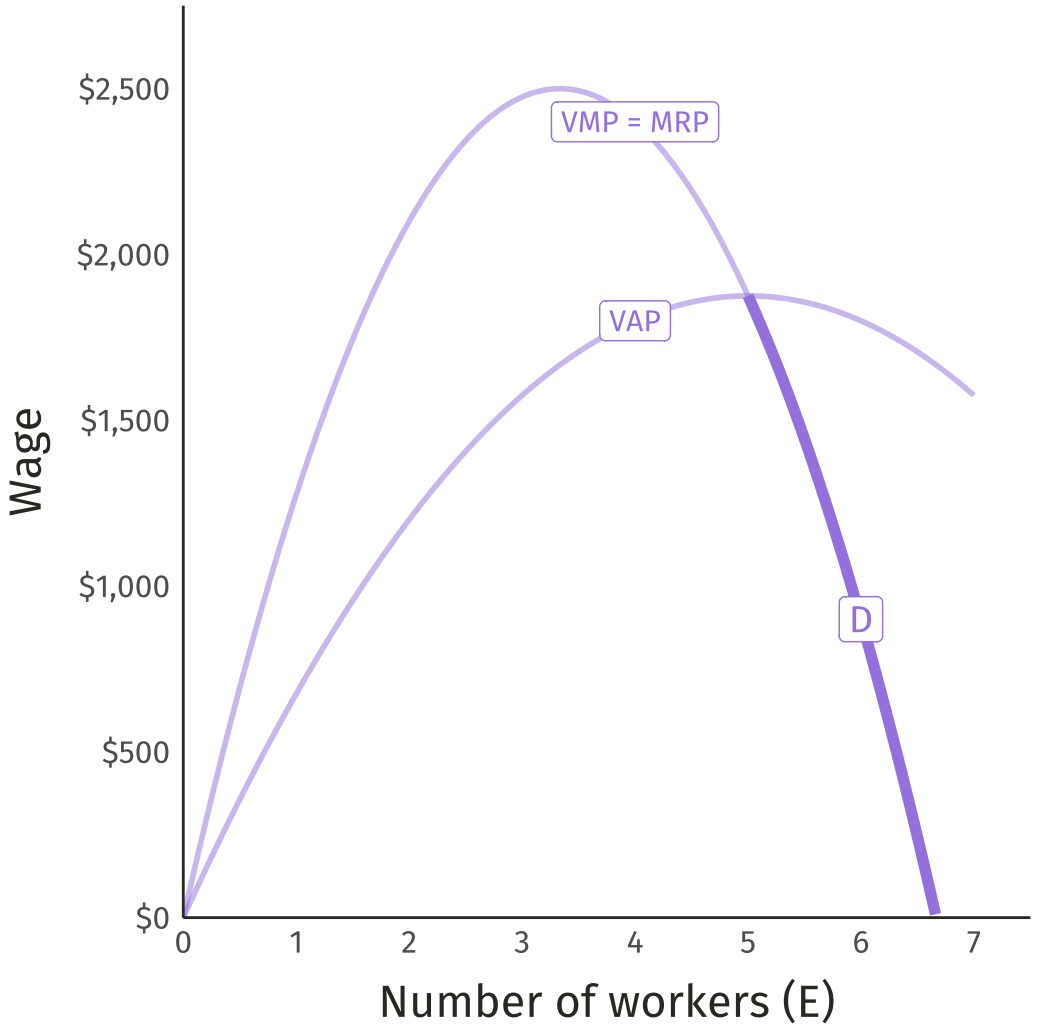
Profit maximization

Q: What happens when marginal revenue product exceeds the value of average product?

A: The employer will shut down the business.

- Any wage that intersects MRP in this region will exceed VAP $\longrightarrow$ business would operate at a loss!

Hiring in the short run



Labor demand

The portion of the MRP curve below the VAP curve traces out the **short-run labor demand** curve.

- Describes how an employer adjusts employment as the market wage changes, holding other inputs constant.
- **Downward sloping:** An employer wants to reduce staffing as the wage increases, *all else equal*.

Hiring in the long run

Profit maximization

In the long run, employers have the flexibility to adjust both labor and capital.

Q: How does the intuition for long-run factor demand compare to the intuition for the short run?

A: Employers will still make decisions ***at the margin*!**

- The underlying model is more elaborate and **our time is scarce**, so we will forgo a full derivation of the long-run profit maximization conditions.

Hiring in the long run

Profit maximization

As in the short run, an employer will choose the profit-maximizing level of employment E^* such that

$$\begin{aligned} w &= \text{MRP}_E \\ &= p \times \text{MP}_E \end{aligned}$$

- The employer will keep hiring until the **marginal cost** of the last worker **equals** the **marginal benefit** of the last worker.

Likewise, an employer will choose the profit-maximizing quantity of capital K^* such that

$$\begin{aligned} r &= \text{MRP}_K \\ &= p \times \text{MP}_K \end{aligned}$$

- The employer will keep purchasing capital until the **marginal cost** of the last unit of capital **equals** the **marginal benefit** of the last unit of capital.

Hiring in the long run

Intuition?

At the optimal, profit-maximizing bundle of labor and capital, we have

$$w = p \times \text{MP}_E \qquad r = p \times \text{MP}_K$$

Dividing by marginal product, we obtain

$$p = \frac{w}{\text{MP}_E} \qquad p = \frac{r}{\text{MP}_K}$$

Now we can equate both conditions to obtain the **long-run profit maximization condition**

$$\frac{w}{\text{MP}_E} = \frac{r}{\text{MP}_K}$$

Hiring in the long run

Intuition?

Q: What can we learn from the long-run profit maximization condition?

$$\frac{w}{\text{MP}_E} = \frac{r}{\text{MP}_K}$$

- $\frac{w}{\text{MP}_E}$ represents the cost of producing one more unit of output using labor.
- $\frac{r}{\text{MP}_K}$ represents the cost of producing one more unit of output using capital.

A: At the profit-maximizing bundle, it would **not** be **cheaper to switch** from one input to the other.

- If it were cheaper to switch from labor to capital, then a **profit-maximizing employer would have already made the switch** (in the long run).

Hiring in the long run

Intuition?

Suppose that $w = 10$, $\text{MP}_E = 15$, $r = 5$, and $\text{MP}_K = 10$. Then

$$\frac{w}{\text{MP}_E} = \frac{r}{\text{MP}_K} \implies \frac{10}{15} = \frac{5}{10} \implies \frac{2}{3} \neq \frac{1}{2}$$

This employer is not profit maximizing!

- The cost of producing one more unit of output using labor exceeds the cost of producing one more unit using capital.
- It would be **more profitable to switch**, at the margin, from labor to capital!

Hiring in the long run

Q: How does an employer respond to an increase in the market wage?

- **A_1:** The employer will respond by hiring fewer workers.
- **A_2:** The employer will adjust the level of capital, but the direction is theoretically ambiguous.
  - When the number of workers decreases, there are fewer people on each machine, which can reduce MP_K.
  - The direction of the response will depends on the **scale** and **substitution** effects.

Hiring in the long run

Scale effect

Other things being equal, a **decrease** in the **price** of an input will **increase** the **quantity demanded** of that input.

- If the cost of production decreases, the employer will want to "scale up" production of the output good.
- Conversely, if the cost of production increases, the employer will "scale back" production.
- Analogous to the wealth effect for a worker.[†]

[†] We assume that labor and capital are "normal" inputs—production increases as the amount of labor and capital increase.

Hiring in the long run

Substitution effect

Other things being equal, if the price of an input increases, **demand for the other input increases.**

- If labor becomes **relatively more expensive** than capital, then the employer will want to **substitute away** from labor and toward capital.
- If labor becomes **relatively cheaper** than capital, then the employer will want to **substitute toward** labor and away from capital.
- Analogous to the substitution effect for the worker.

Hiring in the long run

Scale and substitution effects

Q: How would a employer respond to an increase in the market wage?

	Scale effect	Substitution effect
Δ in labor	$-$	$-$
Δ in capital	$-$	$+$

A_K: For capital, it depends.

- If the scale effect dominates the substitution effect, then capital will eventually decrease.

A_E: For labor, the effect is unambiguous.

- The scale effect and substitution effect will move in the same direction for the input that undergoes a change in price.

Hiring in the long run

Scale and substitution effects

Q: What determines whether the scale or substitution effect dominates?

A: Whether labor and capital are **substitutes** or **complements**.

- **Substitutes:** Inputs used in place of one another.
  - Self-checkout kiosk *vs.* cashier
  - Tax prep software *vs.* accountant
  - Robot *vs.* low-skill worker?
- **Complements:** Inputs used together.
  - Carpenter and hammer
  - Mail carrier and mail truck
  - Robot and high-skill worker?

Hiring in the long run

Substitutes

> Inputs used in place of one another.

Two inputs are said to be substitutes if the price of one input changes the demand of the other input **in the same direction.**

- Substitution effect outweighs the scale effect.

Complements

> Inputs used together.

Two inputs are said to be complements if the price of one input changes the demand of the other input **in the opposite direction.**

- Scale effect outweighs the substitution effect.

Hiring in the long run

Cross-elasticity of factor demand

> A unit-free measure of the responsiveness of demand for one input to a change in the price of the other.

Labor responsiveness to a change in the price of capital:

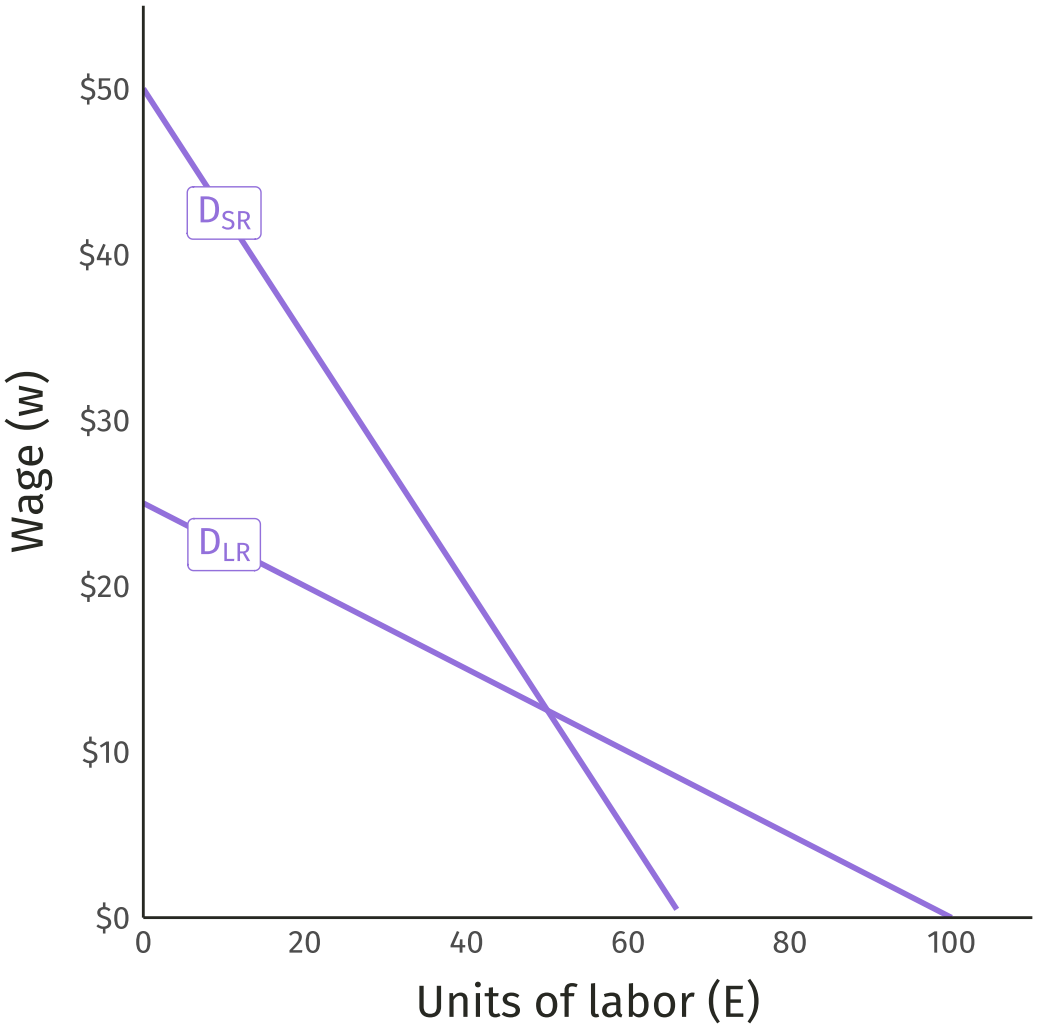
$$\eta = \frac{\%\Delta E}{\%\Delta r} = \frac{(E_2 - E_1)/E_1}{(r_2 - r_1)/r_1}$$

Capital responsiveness to a change in the price of labor:

$$\eta = \frac{\%\Delta K}{\%\Delta w} = \frac{(K_2 - K_1)/K_1}{(w_2 - w_1)/w_1}$$

$\eta > 0 \longrightarrow$ substitutes $\longrightarrow$ substitution effect dominates.
$\eta < 0 \longrightarrow$ complements $\longrightarrow$ scale effect dominates.

Market labor demand curve



Q: Why is the short-run labor demand curve ($\mathbf{D_{SR}}$) steeper than the short-run labor demand curve ($\mathbf{D_{LR}}$)?

A: Firms have fewer alternatives to labor in the short run $\longrightarrow$ less responsive to changes in the wage.

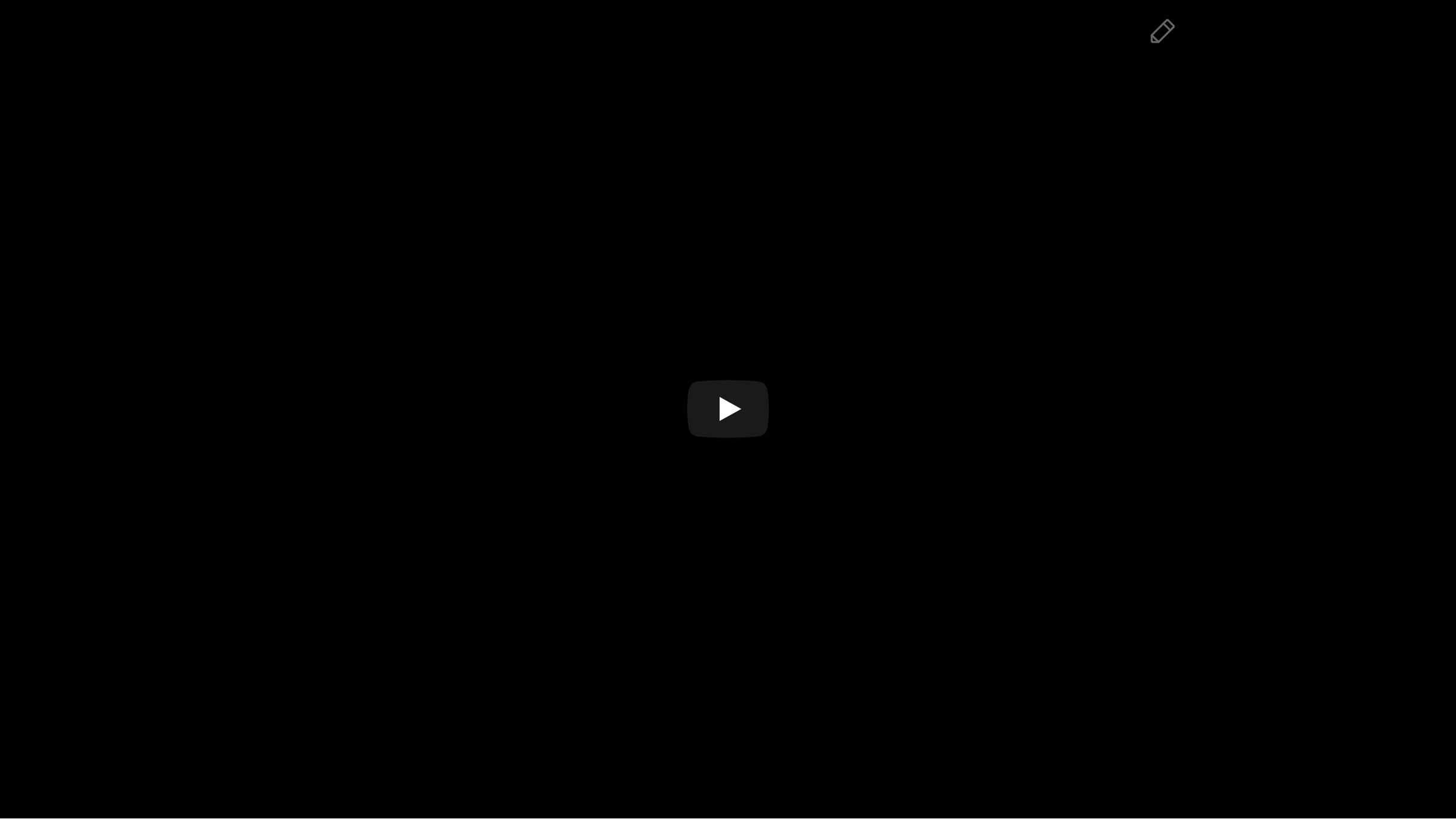
Responsiveness

Labor demand elasticity

> A unit-free measure of the responsiveness of the quantity of labor demanded to changes in the wage.

$$\epsilon_d = \frac{\%\Delta E}{\%\Delta w} = \frac{(E_2 - E_1)/E_1}{(w_2 - w_1)/w_1} \leq 0$$

Robot tax, featuring Bill Gates



Robot tax, featuring Bill Gates

Discussion

Q: How would a robot tax affect...

- The price of capital?
- The employment of capital in the long run?
- The employment of labor in the long run?
  - Low-skill labor?
  - High-skill labor?
- Tax revenue?

Q: Should we do it?

Housekeeping

Midterm exam scheduled for Wednesday, April 28th during class time.

Midterm review session during class on Monday, April 26th.

Problem Set 2 due Monday, April 26th by 4:00pm PDT.