

Lecture 7: Producer Behavior

October 6, 2026

Course Administration

- ① Problem set 7 posted – due next week
- ② No class next week
- ③ Midterm
 - Oct. 20: Lecture 8
 - You can bring a 3x5 card, written on both sides, for the midterm
 - Full class period
 - Bring a dumb calculator
 - Review: Thursday October 15, MPA 305, 6 to 8 pm
- ④ Final exam times confirmed: Tuesday December 15
 - Afternoon: PHIL 108, 3:00 to 5:00
 - Evening: MON 250, 5:20 to 7:20
 - If you want to come to the other section, let me know so I can ensure we have enough space
- ⑤ Anything else?

Next Week: Ripped from the Headlines

Afternoon

Finder	Presenter
Tom	Sydney
Elizabeth	Kordiea

Evening

Finder	Presenter
Nicole-Antoinette	Zoey
choose from afternoon	Karolina
Zoey	Olivia

This Week: Ripped from the Headlines

Afternoon

Finder	Presenter
Lily	Alex
Nash	Saniya

Evening

Finder	Presenter
Katy	Sarah J.
choose from afternoon	Kubra
choose from afternoon	Sarah T.

The Logic of the Next Couple Weeks: Production

Why firms make the decisions they do

- Today
 - We take how much the firm wants to produce as given
 - Explore how the firm can make it as cheaply as possible
- Then – Lecture 9
 - Costs – what goes into how much things cost to firms
 - Economies of scope and scale
- And then – Lectures 10 and 11
 - How firms choose how much to produce
 - Maximizing profit
- Concluding with – Lectures 11 and 12
 - market power: where competition fails

Today's Production Lecture

- Basics and assumptions
- Short run
- Long run
- Cost minimization
- Total cost

Today's Production Lecture

- Basics and assumptions
- Short run
- Long run
- Cost minimization
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Today: assume that the firm knows how much to produce and wants to do it as cheaply as possible.

Basics of Production

What is Production?

- Production $\equiv$ process of producing a good or service
- Final good $\equiv$ good bought by consumer
- Intermediate good $\equiv$ good bought by a firm to produce another good
- Production function $\equiv$ mathematical relationship between inputs and outputs

Simplifying Assumptions, 1 of 2

Why do we assume things? To make the problem manageable and look carefully at a limited number of factors.

Simplifying Assumptions, 1 of 2

Why do we assume things? To make the problem manageable and look carefully at a limited number of factors.

- ① Firm produces a single good
- ② Firm has already chosen what product it will produce
- ③ Firm's goal is to minimize cost
- ④ Firm uses only two inputs: capital and labor
- ⑤ In the short run, the firm can change only labor. In the long run the firm can change labor and capital

Simplifying Assumptions, 2 of 2

- ⑥ More inputs $\rightarrow$ more outputs
- ⑦ Production has diminishing marginal returns to capital and labor
- ⑧ An infinite amount of inputs sells at fixed prices
- ⑨ The firm has no budget constraint $\rightarrow$ very well-functioning capital market

Simplifying Assumptions, 2 of 2

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Reminder: Today we assume that the firm knows how much to produce and wants to do it as cheaply as possible.

The Production Function

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

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- K is capital
- L is labor
- $f()$ is a general function

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For example, $Q = K^{0.5}L^{0.5}$

The Production Function

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

- Q is output
- K is capital
- L is labor
- $f()$ is a general function

For example, $Q = K^{0.5}L^{0.5} = \sqrt{KL}$

Parallels: Consumer and Producer Problems

What is the producer parallel of the utility function?

Consumer

Diminishing marginal utility

max U s.t. budget constraint

Utility function

Indifference curves

$MRS_{X,Y}$

Price of consumption goods

Budget Constraint

Slope of budget constraint = $-\frac{P_X}{P_Y}$

Optimality at $MRS_{XY} = \frac{P_X}{P_Y}$

Income expansion path

Producer

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Producer

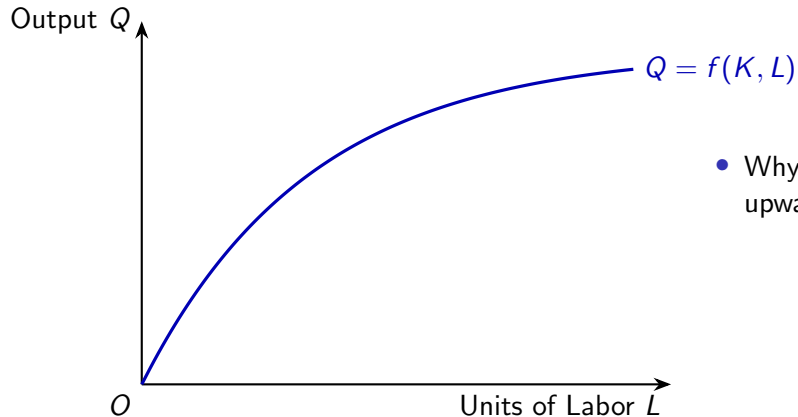
production function

Production in the Short Run

What Do We Mean by Short Run?

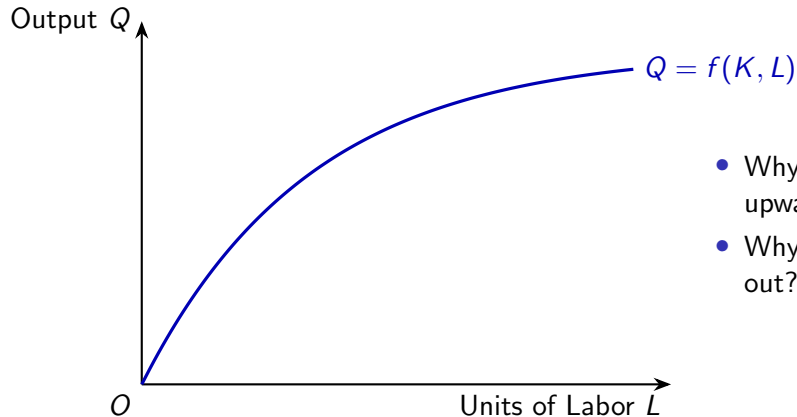
Short run = Capital K is fixed, but labor L can vary

Generic Short Run Production Function



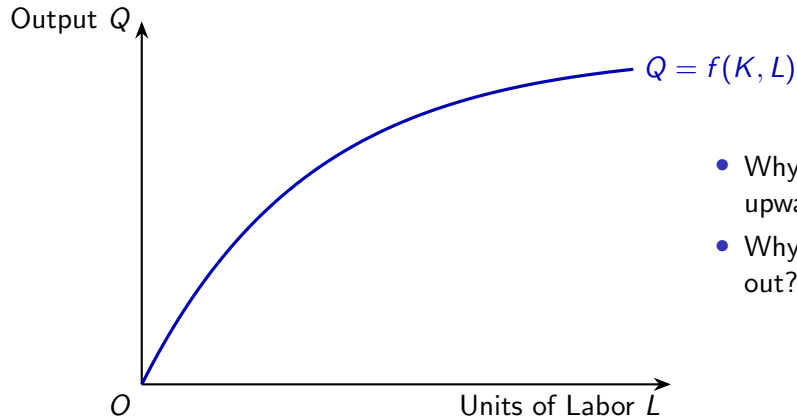
- Why does the line slope upward for a while?

Generic Short Run Production Function



- Why does the line slope upward for a while?
- Why might the line flatten out?

Generic Short Run Production Function



- Why does the line slope upward for a while?
- Why might the line flatten out?

Two Key Concepts for Measuring Changes in Production

Marginal Product

Average Product

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Marginal Product

- Additional output from adding one unit of input, holding all other inputs constant.

Average Product

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- Additional output from adding one unit of input, holding all other inputs constant.

Average Product

- Average output per input, holding all other inputs constant.

Two Key Concepts for Measuring Changes in Production

Marginal Product

- Additional output from adding one unit of input, holding all other inputs constant.

Average Product

- Average output per input, holding all other inputs constant.

$$AP_X = \frac{Q}{X}$$

- where X is capital K or labor L

Marginal Product of Labor or Capital

How does adding an additional unit of labor or capital – holding the other fixed – change output?

- Let X be the input – either capital K or labor L
- **Hold all other inputs fixed**

$$MP_X = \frac{\Delta Q}{\Delta X} = \left(\frac{\partial Q}{\partial X} \right)$$

Marginal Product of Labor or Capital

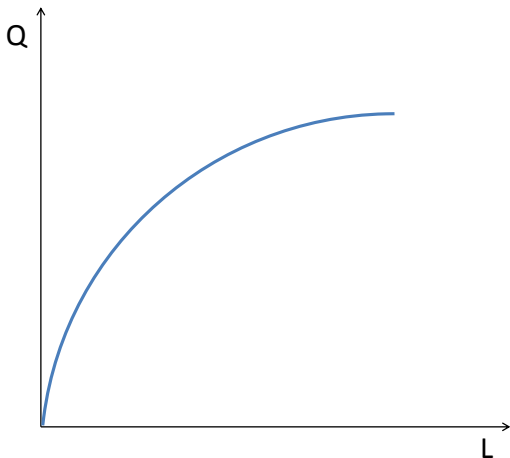
How does adding an additional unit of labor or capital – holding the other fixed – change output?

- Let X be the input – either capital K or labor L
- **Hold all other inputs fixed**

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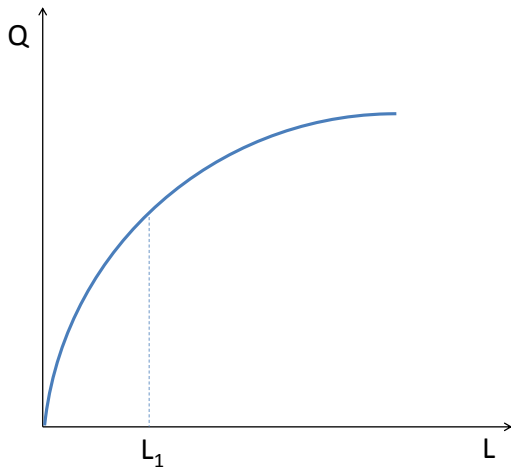
- We assume that at some point, MP_X declines

Finding the Marginal Product of Labor from the Short Run Production Function



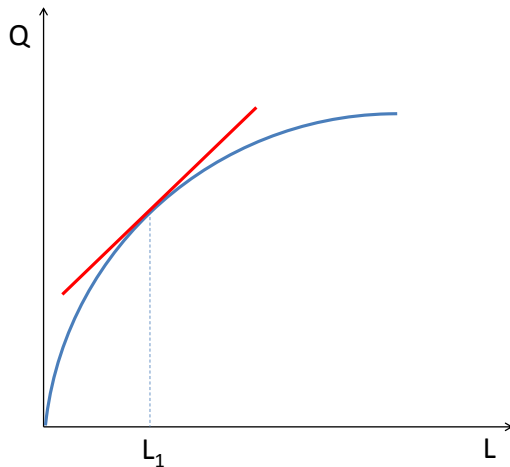
Output Q as a function
of labor inputs L

Finding the Marginal Product of Labor from the Short Run Production Function



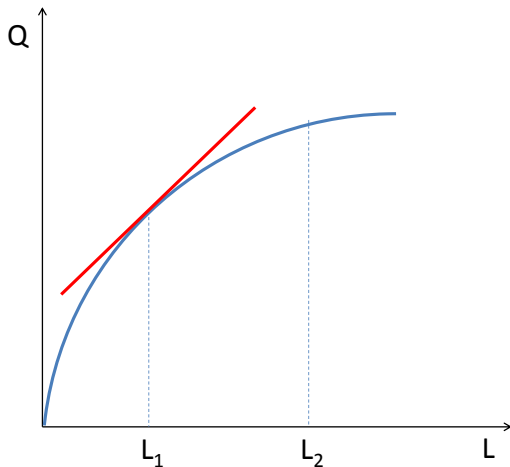
What is the marginal product of labor here?

Finding the Marginal Product of Labor from the Short Run Production Function



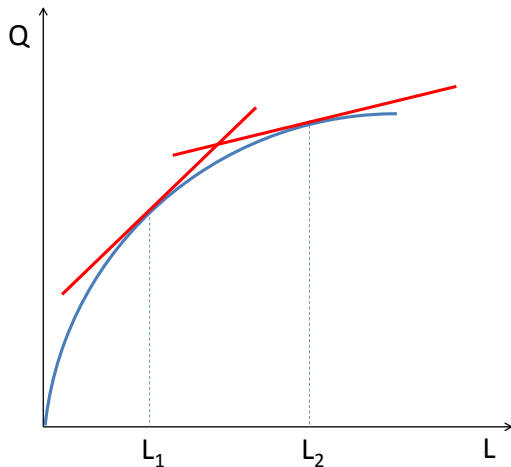
Red line is the slope of the curve at L_1 . This slope is the change in output due to a tiny change in labor = MP_L

Finding the Marginal Product of Labor from the Short Run Production Function



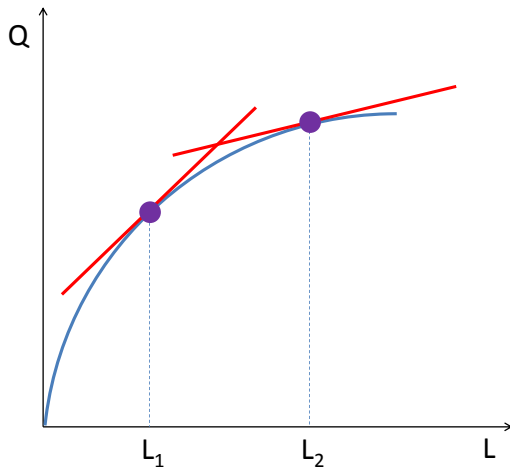
What is the marginal product of labor at L_2 ?

Finding the Marginal Product of Labor from the Short Run Production Function



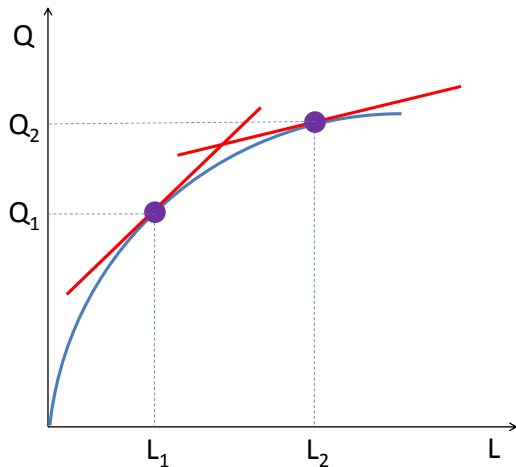
Red line is the slope of the curve at L_2 . This slope is the change in output due to a tiny change in labor = MP_L

Finding the Marginal Product of Labor from the Short Run Production Function



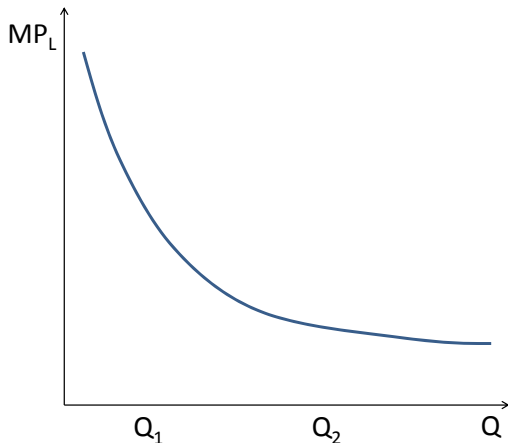
Two different
marginal products of
labor at different L s

Finding the Marginal Product of Labor from the Short Run Production Function



What does a graph of MP_L as a function of Q look like?

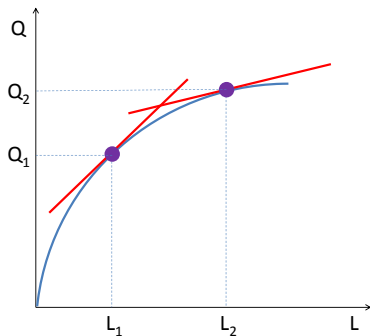
Finding the Marginal Product of Labor from the Short Run Production Function



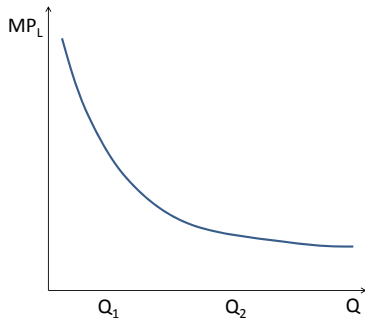
Marginal product of labor diminishes as some point as Q increases. Remember that K is fixed.

Production Function and Marginal Product Side-by-Side

Short Run Production Function



Marginal Product of Labor



Calculating Average vs Marginal Products of Labor

Find average and marginal products of labor

Q	L	$K = 3$	AP_L	MP_L
0	0	3		

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0	0	3	.	.

Calculating Average vs Marginal Products of Labor

Find average and marginal products of labor

Q	L	$K = 3$	AP_L	MP_L
0	0	3	.	.
1	1	3		

Calculating Average vs Marginal Products of Labor

Find average and marginal products of labor

Q	L	$K = 3$	AP_L	MP_L
0	0	3	.	.
1	1	3	$Q/L = 1/1$	

Calculating Average vs Marginal Products of Labor

Find average and marginal products of labor

Q	L	$K = 3$	AP_L	MP_L
0	0	3	.	.
1	1	3	$Q/L = 1/1$	1

Calculating Average vs Marginal Products of Labor

Find average and marginal products of labor

Q	L	$K = 3$	AP_L	MP_L
0	0	3	.	.
1	1	3	$Q/L = 1/1$	1
5	2	3		

Calculating Average vs Marginal Products of Labor

Find average and marginal products of labor

Q	L	$K = 3$	AP_L	MP_L
0	0	3	.	.
1	1	3	$Q/L = 1/1$	1
5	2	3	$\frac{5}{2} = 2.5$	

Calculating Average vs Marginal Products of Labor

Find average and marginal products of labor

Q	L	$K = 3$	AP_L	MP_L
0	0	3	.	.
1	1	3	$Q/L = 1/1$	1
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Calculating Average vs Marginal Products of Labor

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8	3	3		

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8	3	3	$\frac{8}{3} \approx 2.7$	

Calculating Average vs Marginal Products of Labor

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Calculating Average vs Marginal Products of Labor

Find average and marginal products of labor

Q	L	$K = 3$	AP_L	MP_L
0	0	3	.	.
1	1	3	$Q/L = 1/1$	1
5	2	3	$\frac{5}{2} = 2.5$	4
8	3	3	$\frac{8}{3} \approx 2.7$	3
10	4	3		

Calculating Average vs Marginal Products of Labor

Find average and marginal products of labor

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5	2	3	$\frac{5}{2} = 2.5$	4
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Calculating Average vs Marginal Products of Labor

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Q	L	$K = 3$	AP_L	MP_L
0	0	3	.	.
1	1	3	$Q/L = 1/1$	1
5	2	3	$\frac{5}{2} = 2.5$	4
8	3	3	$\frac{8}{3} \approx 2.7$	3
10	4	3	$\frac{10}{4} \approx 2.5$	2

Average vs Marginal Products of Labor

Restaurant example

- Imagine a server at closing: which is greater, average or marginal product?

Average vs Marginal Products of Labor

Restaurant example

- Imagine a server at closing: which is greater, average or marginal product?
- Imagine at server at prime time: which might be greater, average or marginal product?

Parallels: Consumer and Producer Problems

What is the producer parallel of diminishing marginal utility?

Consumer

Diminishing marginal utility

max U s.t. budget constraint

Utility function

Indifference curves

$MRS_{X,Y}$

Price of consumption goods

Budget Constraint

Slope of budget constraint = $-\frac{P_X}{P_Y}$

Optimality at $MRS_{XY} = \frac{P_X}{P_Y}$

Income expansion path

Producer

production function

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Income expansion path

Producer

diminishing marginal product

production function

Production in the Long Run

Production in the Long Run

- In the long run, everything can change
- Diminishing returns are less of a problem, since you can add both capital and labor

Minimizing Costs

Framework for Minimizing Costs

- ① Outline the problem
- ② Combinations of K and L that allow firm to produce the same amount: **isoquants**
- ③ Trade-off between inputs to produce the same output: **marginal rate of technical substitution**
- ④ Cost of producing: **isocost curves**
- ⑤ Constrained minimization problem solution

Firm's Problem

- Firm wants to minimize costs
- Subject to producing a given amount of output

Firm's Problem

- Firm wants to minimize costs
- Subject to producing a given amount of output
- It could always minimize costs by shutting down, but then no one is making any money

Parallels: Consumer and Producer Problems

What is the producer parallel of maximizing utility subject to a budget constraint?

Consumer	Producer
Diminishing marginal utility	diminishing marginal product
$\max U$ s.t. budget constraint	
Utility function	production function
Indifference curves	
$MRS_{X,Y}$	
Price of consumption goods	
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Income expansion path

Producer

diminishing marginal product

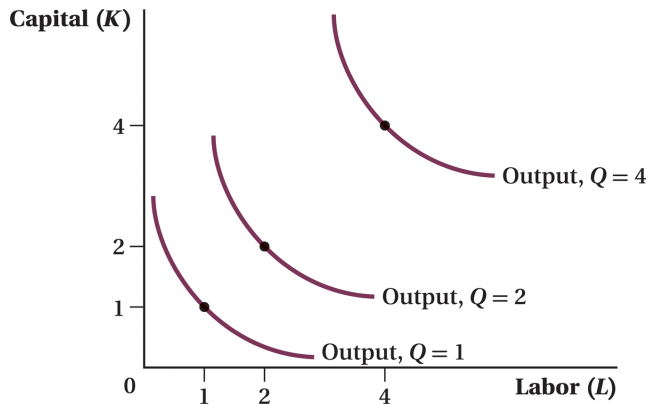
$\min C$ s.t. producing $Q = a$

production function

Isoquants

- “iso” $\equiv$ same
- “quant” for quantity
- All combinations of K and L that produce some level of Q
- Properties of isoquants, for a given production function
 - Further from the origin $\rightarrow$ more production
 - Cannot intersect
 - Convex to the origin

Production Function Isoquants for Different Output Levels



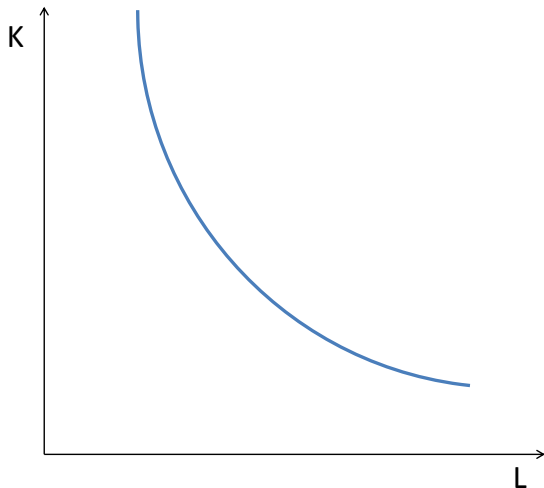
Marginal Rate of Technical Substitution

- $MRTS_{LK} \equiv$ slope of the isoquant

$$MRTS_{LK} = -\frac{MP_L}{MP_K}$$

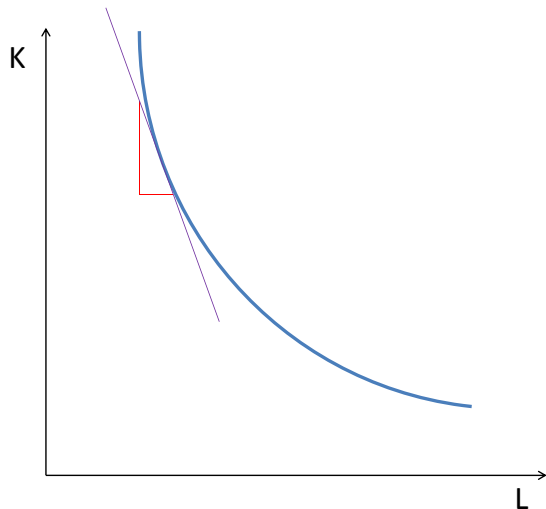
- Or, the rate at which firm can trade input L for input K , holding output constant

Marginal Rate of Technical Substitution Along an Isoquant



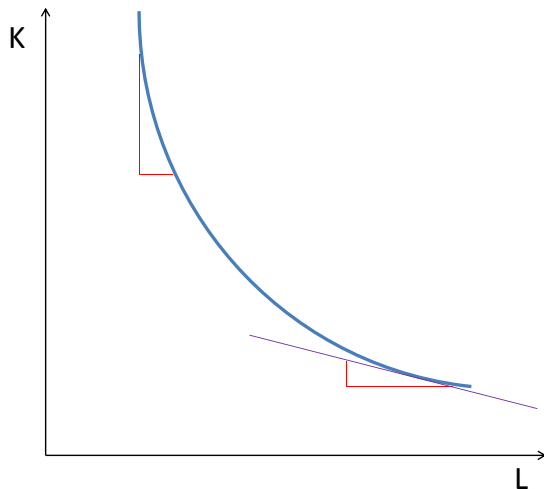
What does the shape of the isoquant tell us about the trade-off between capital and labor?

Marginal Rate of Technical Substitution Along an Isoquant



Here you trade off a lot of capital to get a little more labor. What about at the other end?

Marginal Rate of Technical Substitution Along an Isoquant



When you have more of capital or labor, you are willing to give up more to get the other.

Parallels: Consumer and Producer Problems

What is the producer parallel of indifference curve?

Consumer

Diminishing marginal utility

max U s.t. budget constraint

Utility function

Indifference curves

$MRS_{X,Y}$

Price of consumption goods

Budget Constraint

Slope of budget constraint = $-\frac{P_X}{P_Y}$

Optimality at $MRS_{XY} = \frac{P_X}{P_Y}$

Income expansion path

Producer

diminishing marginal product

min C s.t. producing $Q = a$

production function

Parallels: Consumer and Producer Problems

What is the producer parallel of the marginal rate of substitution?

Consumer

Diminishing marginal utility

max U s.t. budget constraint

Utility function

Indifference curves

$MRS_{X,Y}$

Price of consumption goods

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Isoquants

Parallels: Consumer and Producer Problems

Isoquants and $MRTS$

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Diminishing marginal utility

max U s.t. budget constraint

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Isoquants

$MRTS_{LK}$

Input Substitutability and Complementarity

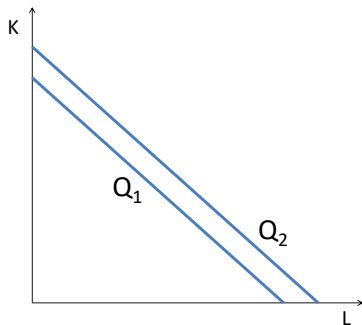
What Does it Mean for the Production Function?

Isoquants if inputs are perfect substitutes?

Input Substitutability and Complementarity

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Isoquants if inputs are perfect substitutes?

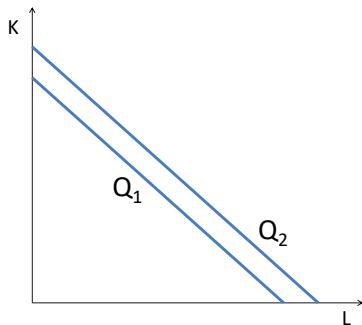


Input Substitutability and Complementarity

What Does it Mean for the Production Function?

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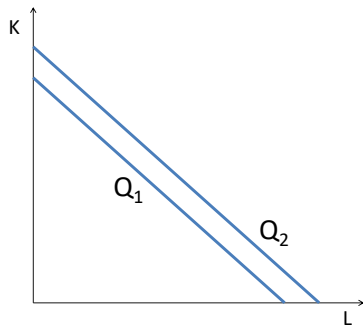
if inputs are perfect complements?



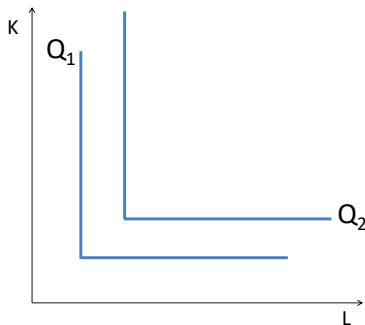
Input Substitutability and Complementarity

What Does it Mean for the Production Function?

Isoquants if inputs are perfect substitutes?



if inputs are perfect complements?



Isocost Lines

- Cost of capital is R : rental rate per period
- Cost of labor is W : wage rate per period
- Total cost: C
- Isocost curve is therefore

$$C = RK + WL$$

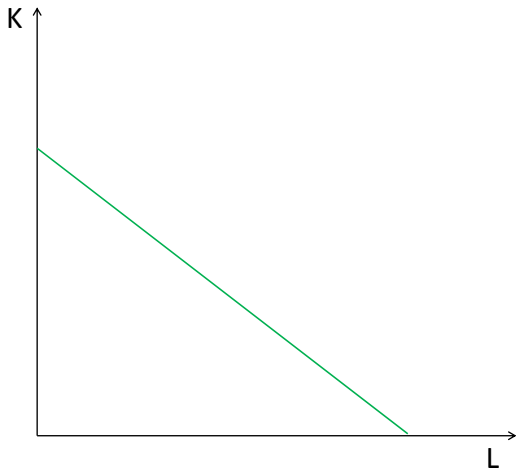
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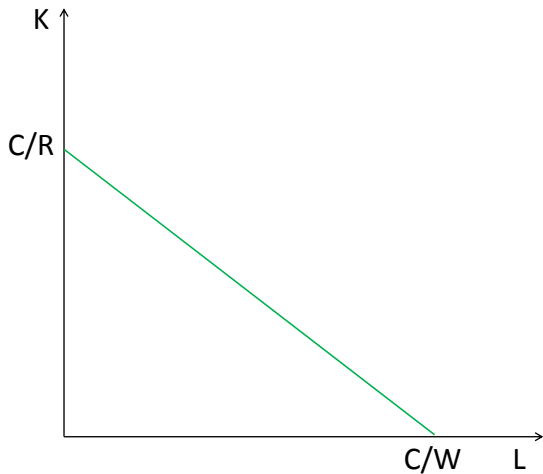
- Now think about the shape of the isocost line

Drawing the Isocost Curve



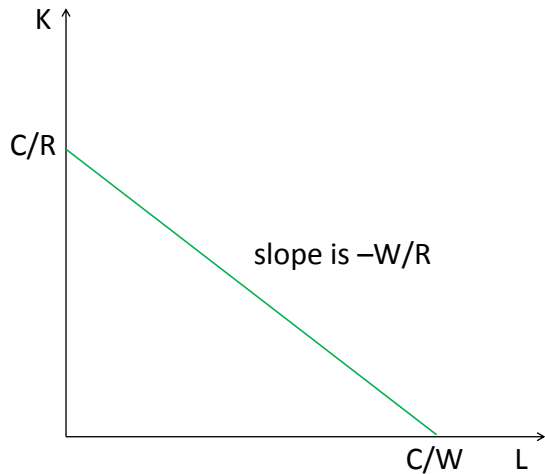
What are the endpoints of the isocost curve?

Drawing the Isocost Curve



Endpoints of the isocost curve. Can you find the slope?

Drawing the Isocost Curve

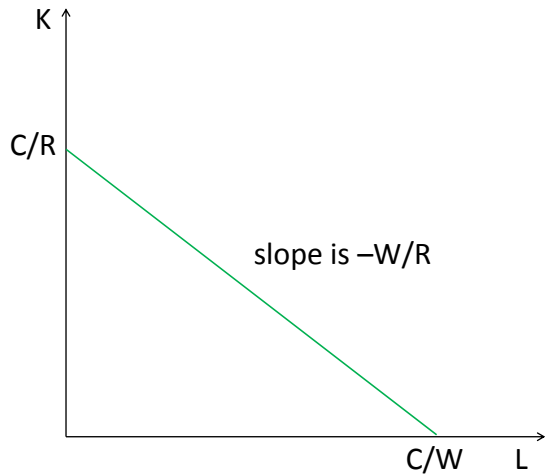


Slope of the isocost
curve

Implications of Isocost Line

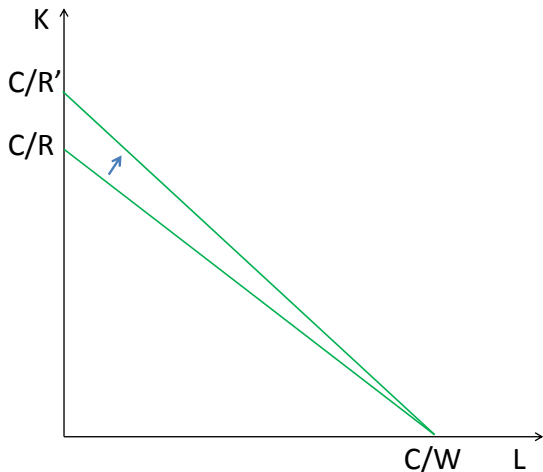
- Slope of isocost line is the cost consequences of trading off one unit of K for L
- What if the price of K decreases?

Changes to the Isocost Curve



What if the price of capital declines?

Changes to the Isocost Curve



The isocost curve twists.
Use these tools to think
about an increase in R or
changes in W .

Parallels: Consumer and Producer Problems

What are the relevant producer prices?

Consumer

Diminishing marginal utility

max U s.t. budget constraint

Utility function

Indifference curves

$MRS_{X,Y}$

Price of consumption goods

Budget Constraint

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Optimality at $MRS_{XY} = \frac{P_X}{P_Y}$

Income expansion path

Producer

diminishing marginal product

min C s.t. producing $Q = a$

production function

Isoquants

$MRTS_{LK}$

Parallels: Consumer and Producer Problems

What is the producer parallel of the budget constraint?

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Utility function

Indifference curves

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Price of consumption goods

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Income expansion path

Producer

diminishing marginal product

min C s.t. producing $Q = a$

production function

Isoquants

$MRTS_{LK}$

$P_L = W, P_K = R$

Parallels: Consumer and Producer Problems

What is the producer parallel of the slope of the budget constraint?

Consumer	Producer
Diminishing marginal utility	diminishing marginal product
$\max U$ s.t. budget constraint	$\min C$ s.t. producing $Q = a$
Utility function	production function
Indifference curves	Isoquants
$MRS_{X,Y}$	$MRTS_{LK}$
Price of consumption goods	$P_L = W, P_K = R$
Budget Constraint	Isocost line
Slope of budget constraint $= -\frac{P_X}{P_Y}$	
Optimality at $MRS_{XY} = \frac{P_X}{P_Y}$	
Income expansion path	

Parallels: Consumer and Producer Problems

Budget constraint $\approx$ Isocost

Consumer

Diminishing marginal utility

max U s.t. budget constraint

Utility function

Indifference curves

$MRS_{X,Y}$

Price of consumption goods

Budget Constraint

Slope of budget constraint $= -\frac{P_X}{P_Y}$

Optimality at $MRS_{XY} = \frac{P_X}{P_Y}$

Income expansion path

Producer

diminishing marginal product

min C s.t. producing $Q = a$

production function

Isoquants

$MRTS_{LK}$

$P_L = W, P_K = R$

Isocost line

Slope of isocost $= -\frac{W}{R}$

Finding Minimum Cost

- Firm wants to produce a given output at minimum cost
- A constrained minimization problem
- Constraint is that firm produces some level of output Q
 - Think of this as a given: $Q = a$
 - Consumer problem: income is given, we find maximum happiness
 - Producer problem: Q is given, and we find minimum cost

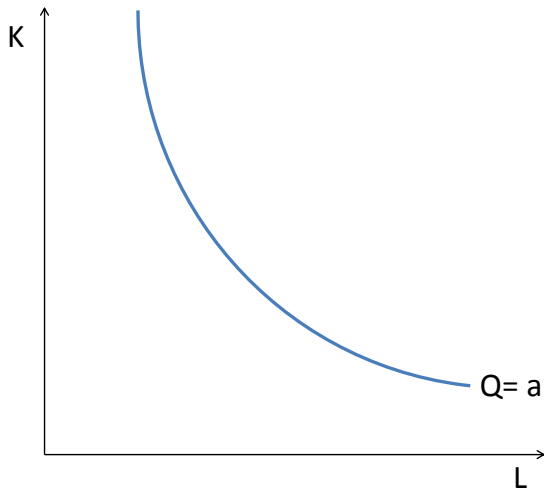
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Finding Minimum Cost

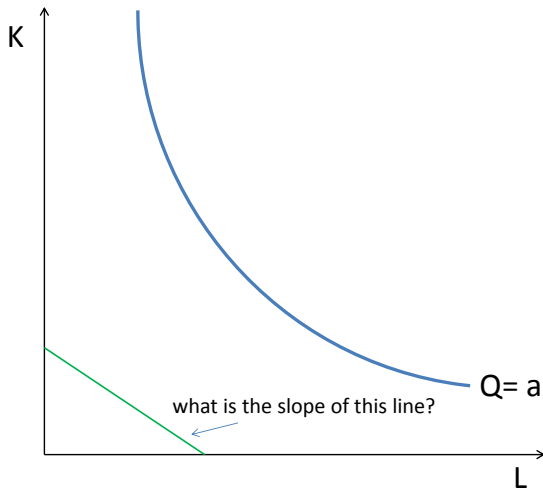
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- Goal: what is the lowest cost at which it can produce output $Q = a$?
- Cost minimization is necessary but not sufficient for profit maximization – more on this later

Cost Minimization in Pictures



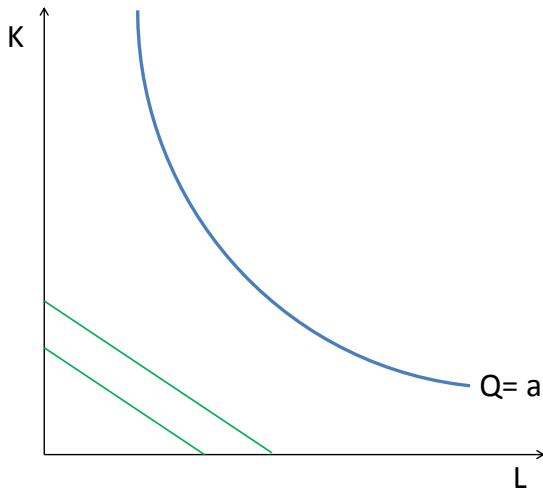
How can you produce
 $Q = a$ at minimum cost?

Cost Minimization in Pictures



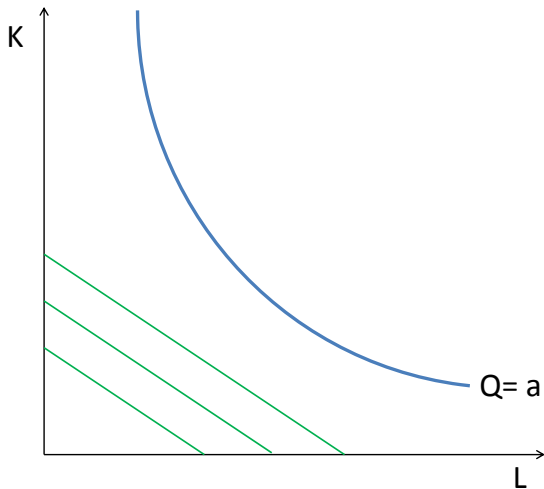
Find the slope of the
isocost line

Cost Minimization in Pictures



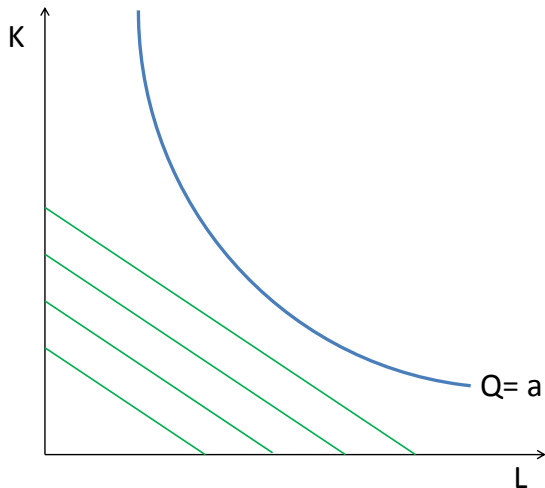
Not enough inputs to
make a

Cost Minimization in Pictures



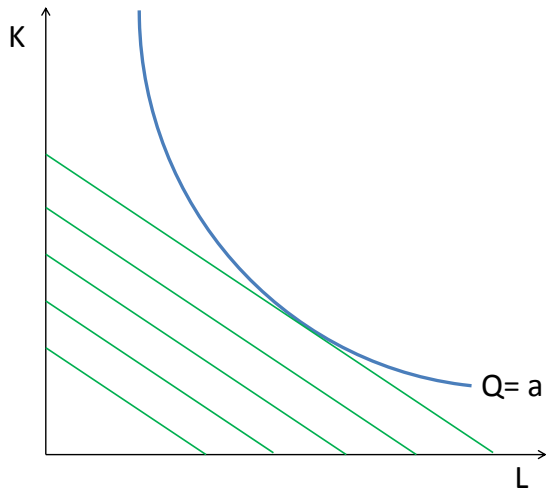
Still not enough

Cost Minimization in Pictures



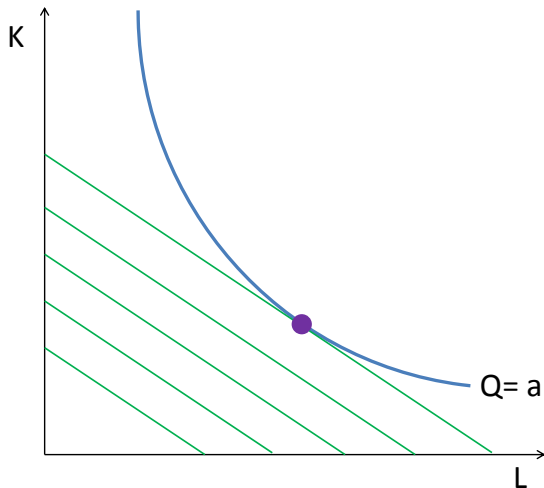
Still not enough

Cost Minimization in Pictures



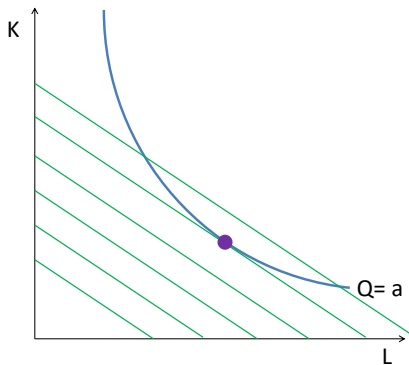
Enough?

Cost Minimization in Pictures



The optimal
combination of K and L .
Occurs when $MRTS = \frac{W}{R}$

Cost Minimization in Pictures



Can you produce
 $Q = a$ with this
spending?

Conditions for Cost Minimization

- Occurs where isocost is tangent to isoquant
- Occurs when

$$-MRTS_{LK} = -\frac{P_L}{P_K}$$

$$-\frac{MP_L}{MP_K} = -\frac{W}{R}$$

Conditions for Cost Minimization

- Occurs where isocost is tangent to isoquant
- Occurs when

$$-MRTS_{LK} = -\frac{P_L}{P_K}$$

$$-\frac{MP_L}{MP_K} = -\frac{W}{R}$$

- More intuitively,

$$\frac{MP_L}{W} = \frac{MP_K}{R}$$

- Marginal product per dollar is equal

Parallels: Consumer and Producer Problems

What is the producer optimality condition?

Consumer	Producer
Diminishing marginal utility	diminishing marginal product
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Optimality at $MRS_{XY} = \frac{P_X}{P_Y}$	
Income expansion path	

Parallels: Consumer and Producer Problems

Think tangency!

Consumer

Diminishing marginal utility

max U s.t. budget constraint

Utility function

Indifference curves

$MRS_{X,Y}$

Price of consumption goods

Budget Constraint

Slope of budget constraint = $-\frac{P_X}{P_Y}$

Optimality at $MRS_{XY} = \frac{P_X}{P_Y}$

Income expansion path

Producer

diminishing marginal product

min C s.t. producing $Q = a$

production function

Isoquants

$MRTS_{LK}$

$P_L = W, P_K = R$

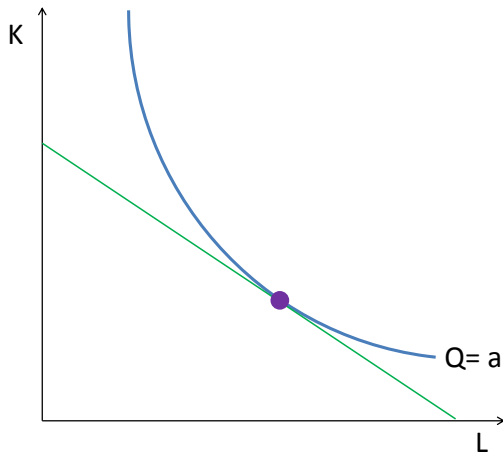
Isocost line

Slope of isocost = $-\frac{W}{R}$

$MRTS_{LK} = \frac{W}{R}$

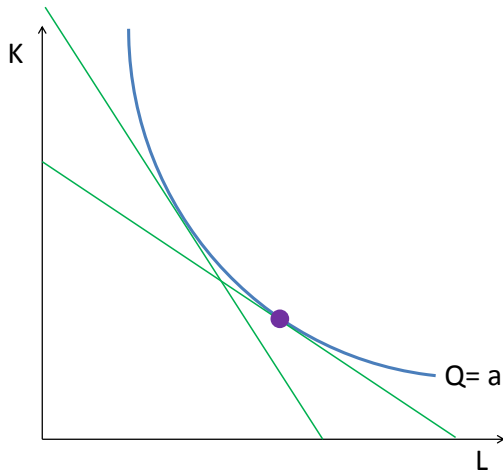
What if Input Prices Change?

- Price of labor increases, and price of capital decreases



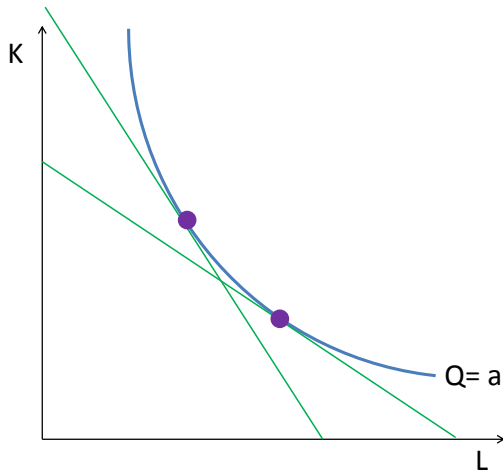
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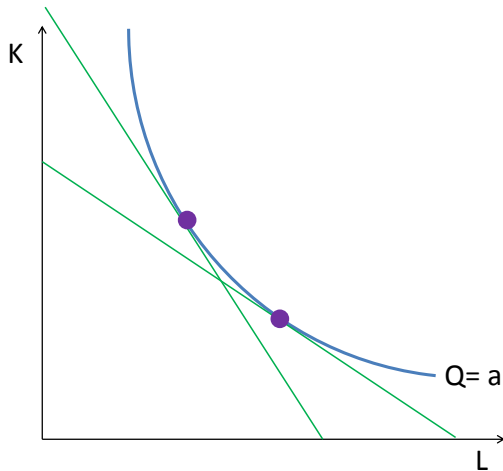
What if Input Prices Change?

- Price of labor increases, and price of capital decreases
- Firms adjust to use more of the less costly input



What if Input Prices Change?

- Price of labor increases, and price of capital decreases
- In both cases
 - the firm is producing optimally
 - $MRTS = \frac{W}{R}$



Minimize Costs on Your Own

Set-Up

- A firm employs 25 workers
- Wage, $W = \$10/\text{hour}$
- Firm uses 5 units of capital
- Rental rate, $R = \$20/\text{hour}$
- At these levels of K and L
 - marginal product of labor is 25
 - marginal product of capital is 30

Questions

- ① Is this firm minimizing costs?
- ② If not, what changes should it make?
- ③ How does the answer to question 2 depend on the time frame of analysis?

In-Class Problem Answer

① Is the firm minimizing costs?

- Firm minimizes costs when $MRTS_{LK} = \frac{P_L}{P_K}$
- Plugging in, this implies $\frac{25}{30} = \frac{10}{20}$
- But $\frac{25}{30} \neq \frac{10}{20}$
- Therefore, the firm cannot be minimizing costs

② What changes should it make?

- To minimize costs, firm should set $\frac{MP_L}{W} = \frac{MP_K}{R}$
- At the moment, the first term is $25/10 = 2.5$, and the second term is $30/20 = 1.5$
- If the firm added more labor, MP_L would decline and the terms would become more equal. To do this, the firm needs to decrease its consumption of capital.

③ How does the answer to question 2 depend on the time frame of analysis?

- In the short run, the firm can change labor, but not capital.

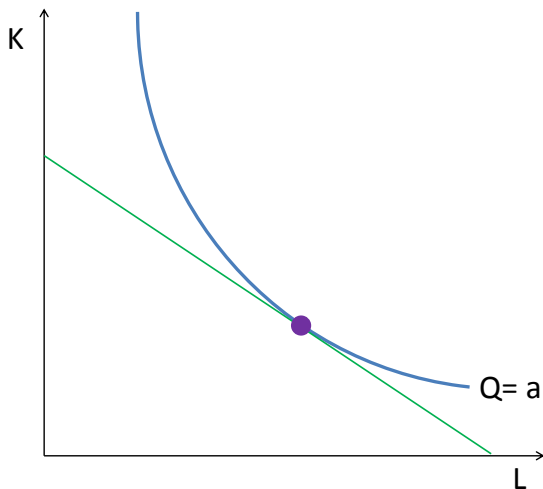
Expansion Path

How Do Production Inputs Change for Different Levels of Q ?

- We know how to find the firm's ideal inputs given Q
- Now we repeat this exercise for a variety of different Q s
 - Each optimal K and L will be where an isoquant is tangent to an isocost line
 - $MRTS_{LK}$ will be the same at each point
- Call this optimal (L, K) for each Q the expansion path
- And we can draw a total cost curve – with different axes

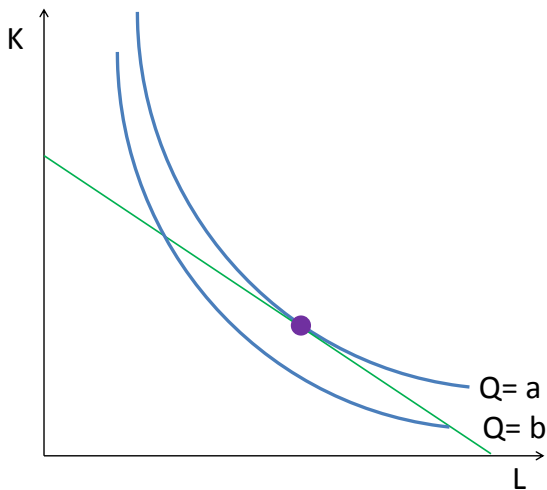
Drawing a Total Cost Curve

Recall Our Previous Optimum. What if the firm wants to produce $b < a$?



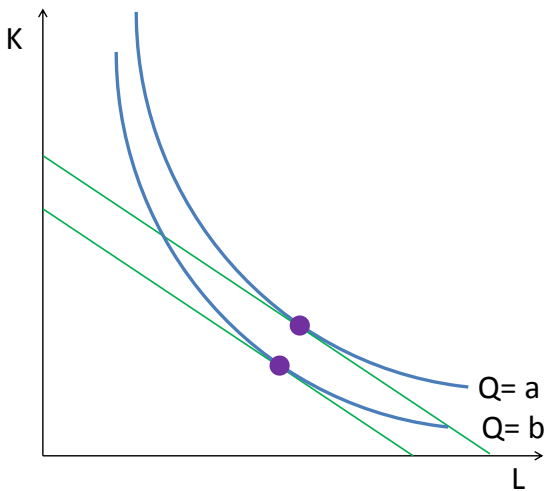
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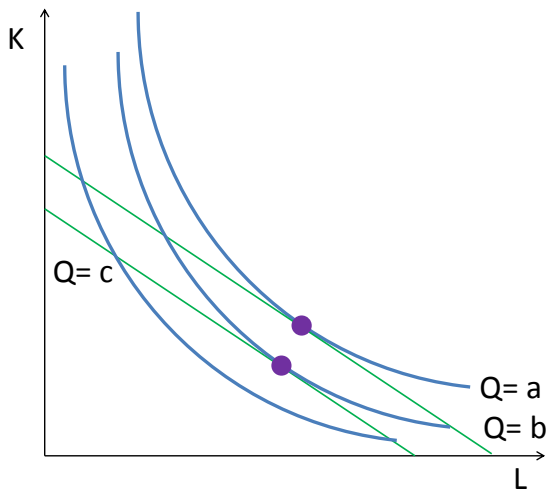
Drawing a Total Cost Curve

What is optimum (L, K) if it wants to make $c < b$?



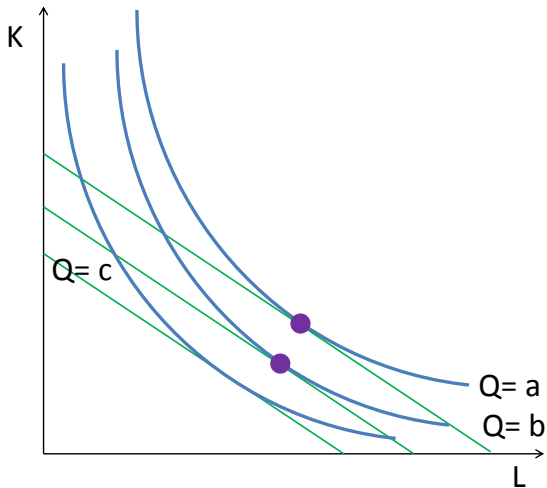
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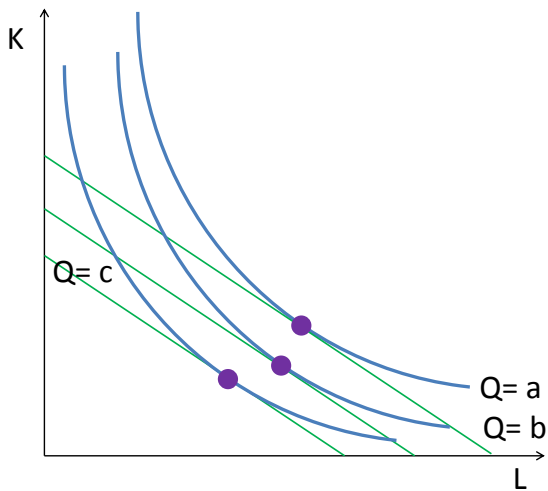
Drawing a Total Cost Curve

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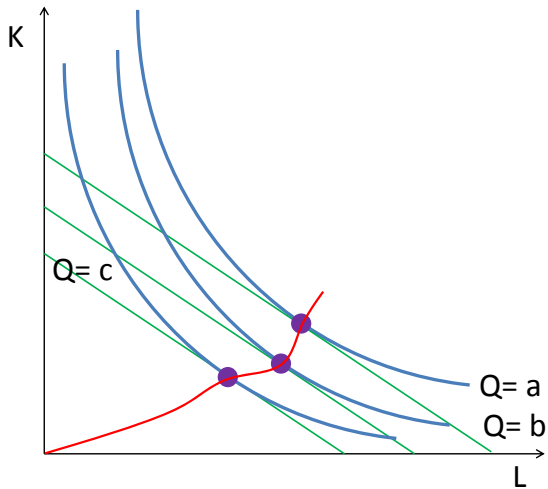
Drawing a Total Cost Curve

Optimum!



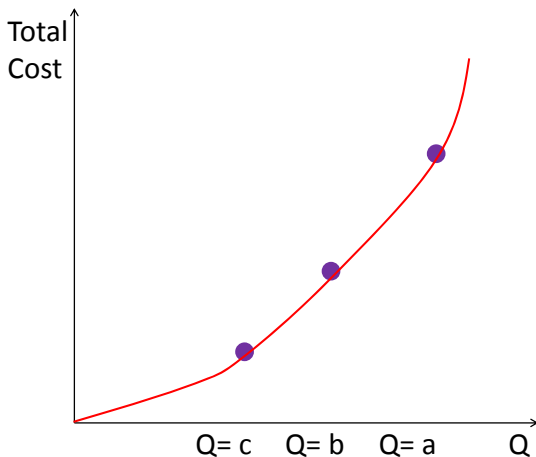
Drawing a Total Cost Curve

Expansion Path in Red



Drawing a Total Cost Curve

Total Cost, Now with Q on X axis and dollars on Y axis



Next Classes

- Next class: Midterm October 20
- Next next class
 - Costs!
 - Next Ripped from Headlines presentations
 - GLS Chapter 7, but not 7.5. Return to 6.5.