Lecture 7:
Producer Behavior

October 10, 2023

Course Administration

1. 10/17: Midterm next week. Dumb calculator only.
2. Confirmed final exam times
   - December 13, 3:30 to 5:30 pm
   - December 14, 3:30 to 5:30 pm
3. Hopefully I have finished your Use Numbers 2
4. Anything else?

Next Week: Ripped from the Headlines

Finder	Presenter
Hannah	Emily

This Week: Ripped from the Headlines

Finder	Presenter
Trenton	Kari

The Logic of the Next Couple Weeks

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
- First class after midterm
  - Costs – what goes into how much things cost to firms
  - Economies of scope and scale
- Second class after midterm
  - How firms choose how much to produce
  - Maximizing profit

Today's Production Lecture

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

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

The Production Function

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

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

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

Parallels: Consumer and Producer Problems

What is the producer parallel of the utility function?

Consumer	Producer
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	

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Production in the Short Run

Measuring Changes in Production

1. Marginal product of $X \equiv$ additional output from an additional unit of input X (X is K or L), holding all other inputs fixed

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

Measuring Changes in Production

1. Marginal product of $X \equiv$ additional output from an additional unit of input X (X is K or L), holding all other inputs fixed

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

2. Average product of X

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

Average vs Marginal Products of Labor

Examples

1. You work somewhere: compare your average vs marginal product of labor

Average vs Marginal Products of Labor

Examples

1. You work somewhere: compare your average vs marginal product of labor
2. Restaurants
   - 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?

Calculating Average vs Marginal Products of Labor

Find average and marginal products of labor

Q	L	K	AP_L	MP_L
1	1	3		

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Calculating Average vs Marginal Products of Labor

Find average and marginal products of labor

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5	2	3		

Calculating Average vs Marginal Products of Labor

Find average and marginal products of labor

Q	L	K	AP_L	MP_L
1	1	3	$\frac{Q}{L} = \frac{1}{1}$	.
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	AP_L	MP_L
1	1	3	$\frac{Q}{L} = \frac{1}{1}$	.
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8	3	3		

Calculating Average vs Marginal Products of Labor

Find average and marginal products of labor

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10	4	3		

Calculating Average vs Marginal Products of Labor

Find average and marginal products of labor

Q	L	K	AP_L	MP_L
1	1	3	$\frac{Q}{L} = \frac{1}{1}$	.
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

Measuring Changes in the Short Run

- Short run production function
  - Recall: We assume that in the short run K is fixed and L can change
  - Suppose $K = 5$, and $Q = f(K, L)$
  - Then the short run production function is

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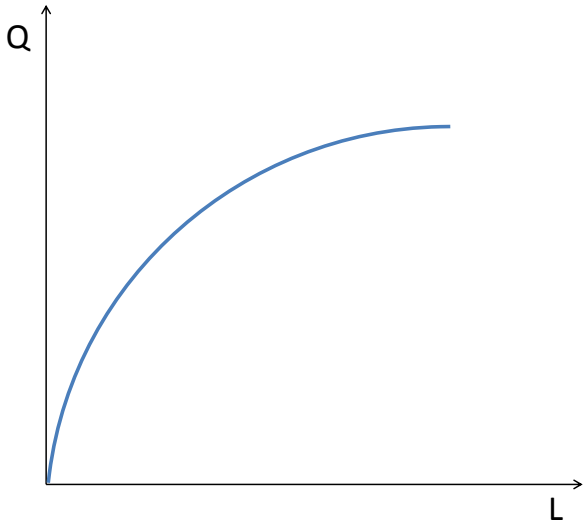
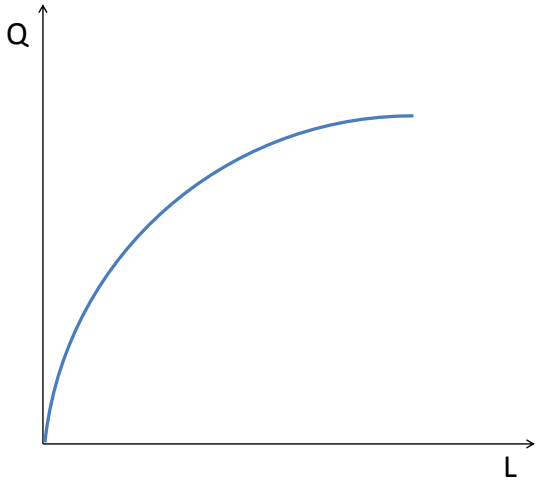
Measuring Changes in the Short Run

- Short run production function
  - Recall: We assume that in the short run K is fixed and L can change
  - Suppose $K = 5$, and $Q = f(K, L)$
  - Then the short run production function is $Q = f(5, L)$
- Recall that we assumed diminishing marginal product of labor
- Draw short-run output as a function of labor (Q on the y axis, L on the x axis)

Short Run Production Function

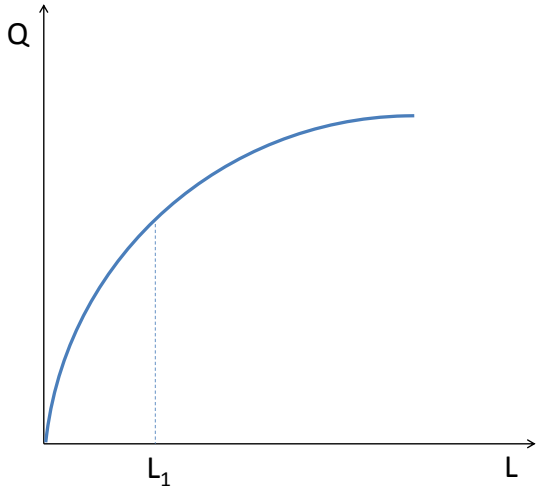


Finding the Marginal Product of Labor from the Production Function



Finding the Marginal Product of Labor from the Production Function

What is the marginal product of labor here?



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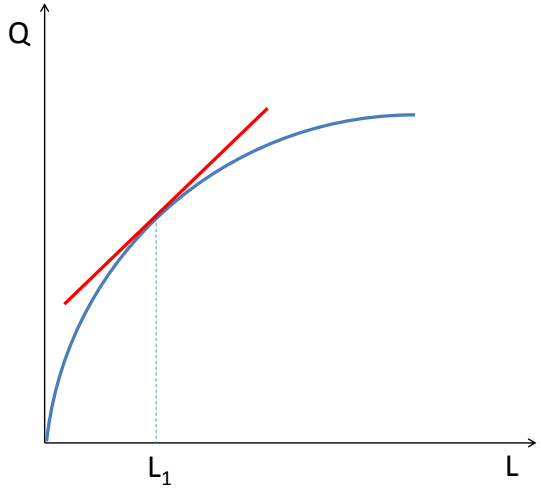

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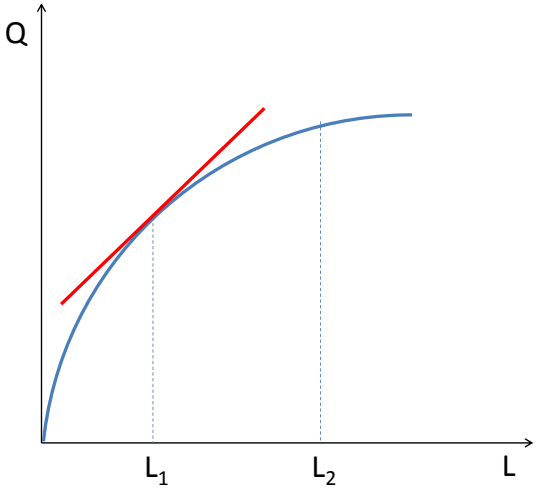

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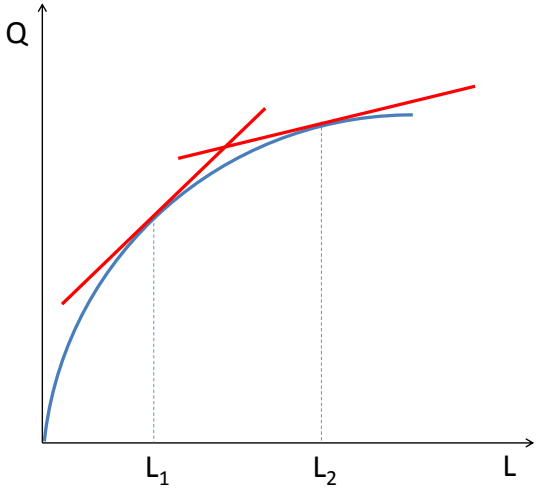

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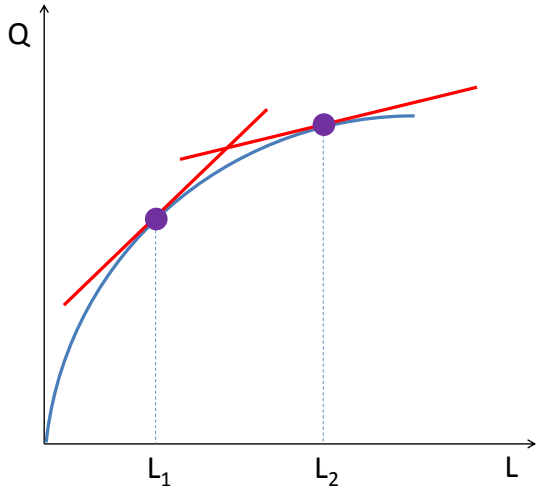
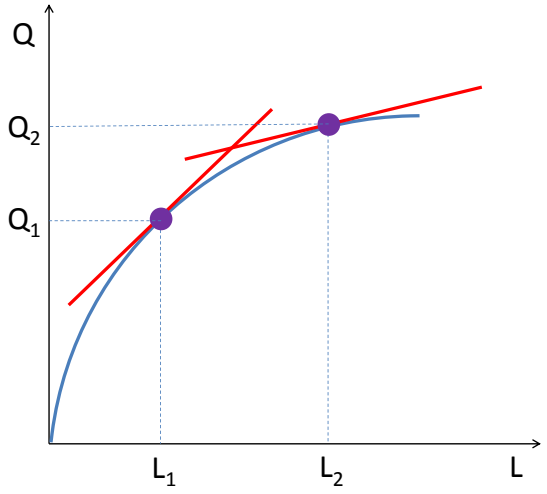


Finding the Marginal Product of Labor from the Production Function

So what does a graph of MP_L as a function of Q look like?



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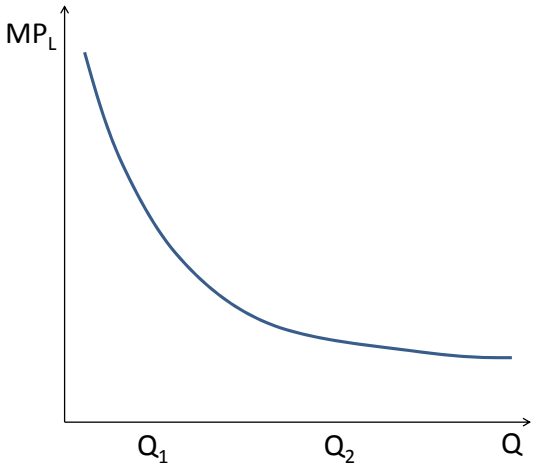

Parallels: Consumer and Producer Problems

What is the producer parallel of diminishing marginal utility?

Consumer	Producer
Diminishing marginal utility	
max U s.t. budget constraint	
Utility function	production function
Indifference curves	
$MRS_{X,Y}$	
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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

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?

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Diminishing marginal utility	diminishing marginal product
max U s.t. budget constraint	
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Indifference curves	
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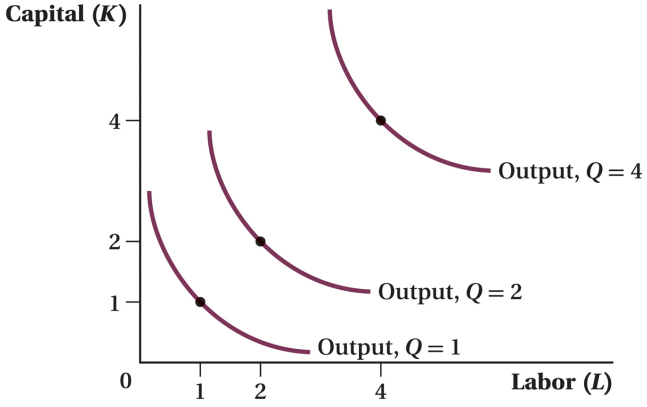
Isoquants

- "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

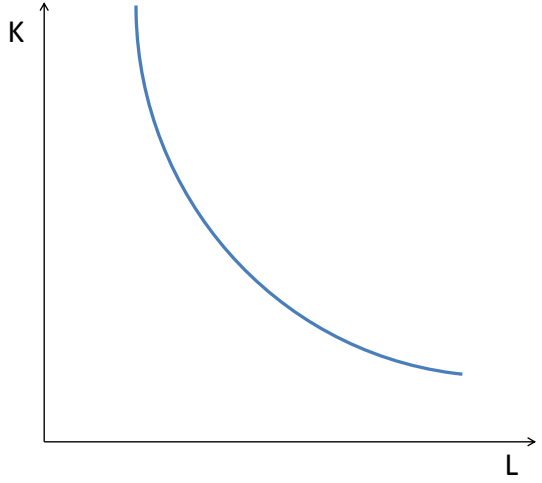


Marginal Rate of Technical Substitution

- $MRTS_{XY} \equiv$ slope of the isoquant
- Or, the rate at which firm can trade input L for input K, holding output constant

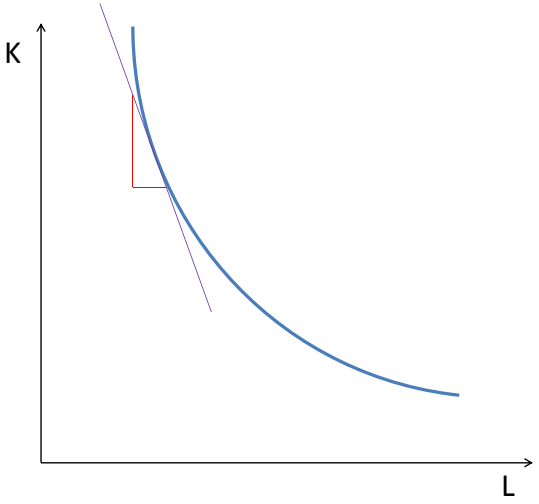
Marginal Rate of Technical Substitution Along an Isoquant

What Does the Shape of the Isoquant Tell Us About the Trade-off Between Capital and Labor?



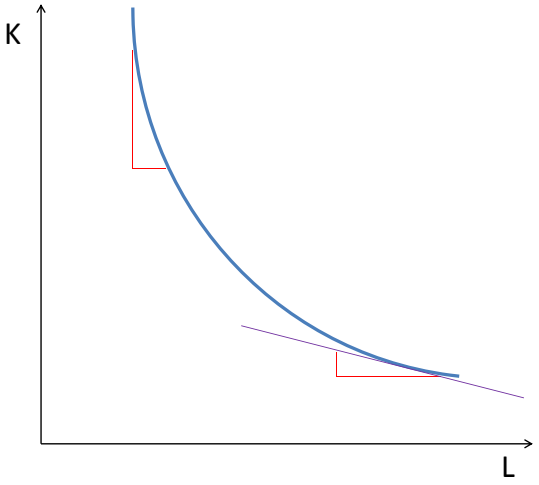
Marginal Rate of Technical Substitution Along an Isoquant

And at the Other End?



Marginal Rate of Technical Substitution Along an Isoquant

Diminishing Marginal Product in Action



Parallels: Consumer and Producer Problems

What is the producer parallel of indifference curve?

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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	
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Parallels: Consumer and Producer Problems

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

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Parallels: Consumer and Producer Problems

Isoquants and *MRTS*

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Input Substitutability and Complementarity

What Does it Mean for the Production Function?

Isoquants if inputs are perfect substitutes?

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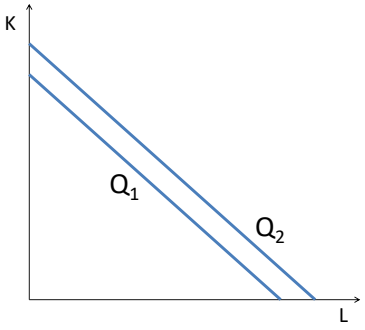
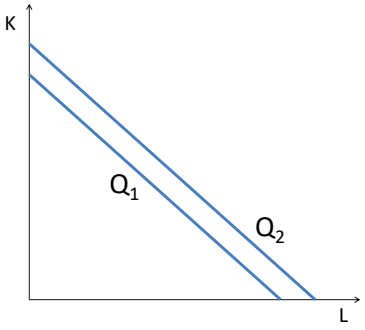


Input Substitutability and Complementarity

What Does it Mean for the Production Function?

Isoquants if inputs are perfect substitutes? if inputs are perfect complements?



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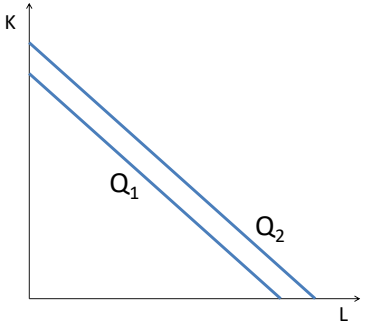

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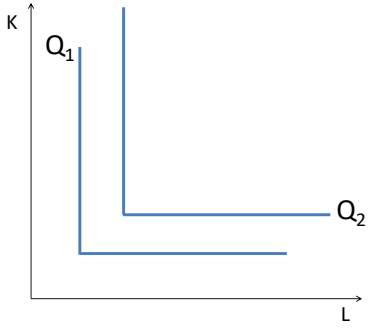

Isocost Lines

- 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

$$C = RK + WL$$

Isocost Lines

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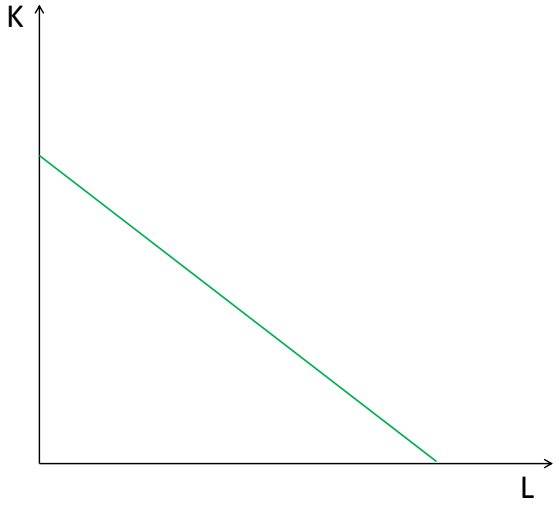
- Total cost: C
- Isocost curve is therefore

$$C = RK + WL$$

- Now think about the shape of the isocost line

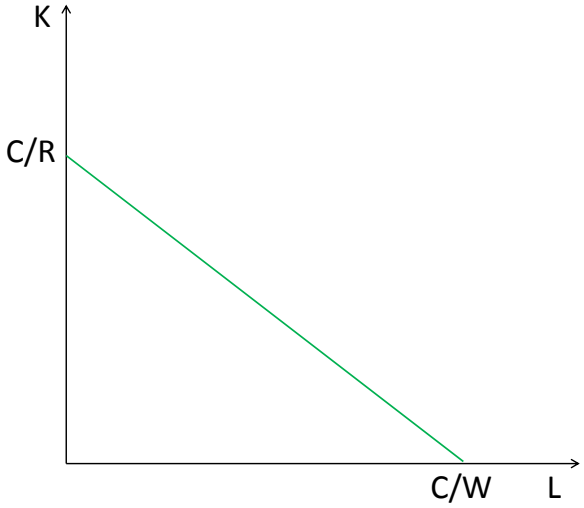
Drawing the Isocost Curve

What are the endpoints of the isocost curve?



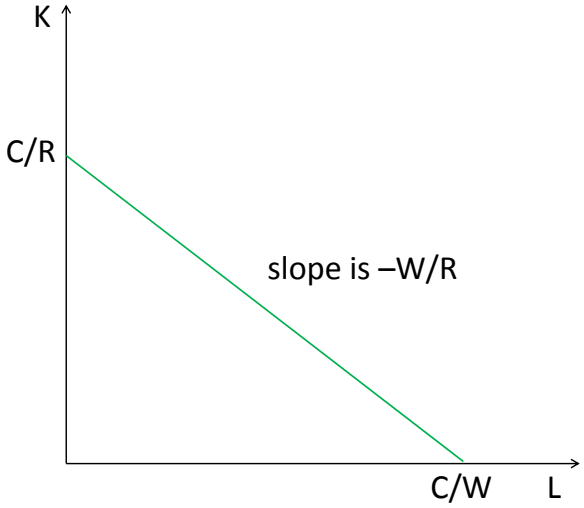
Drawing the Isocost Curve

Endpoints of the isocost curve



Drawing the Isocost Curve

Slope of the isocost curve

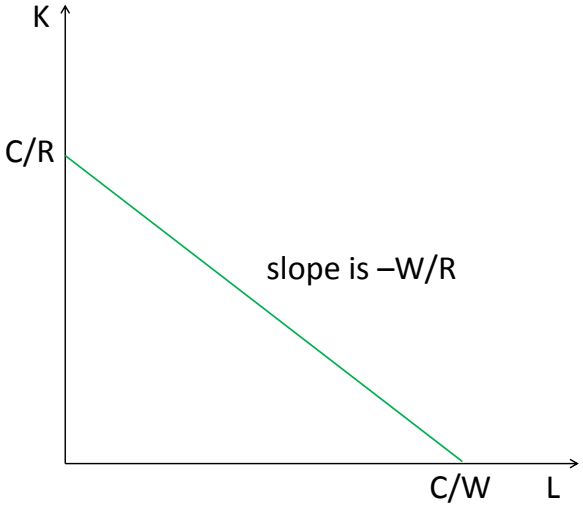


Implications of Isocost Line

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

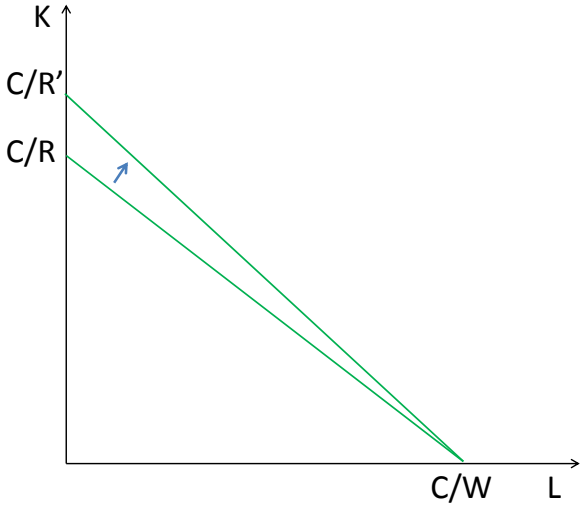
Changes to the Isocost Curve

What if the price of capital declines?



Changes to the Isocost Curve

The isocost curve twists



Parallels: Consumer and Producer Problems

What are the relevant producer prices?

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	
Budget Constraint	
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

What is the producer parallel 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	
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

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

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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

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

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

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
- Goal: what is the lowest cost at which it can produce output $Q = a$?

Finding Minimum Cost

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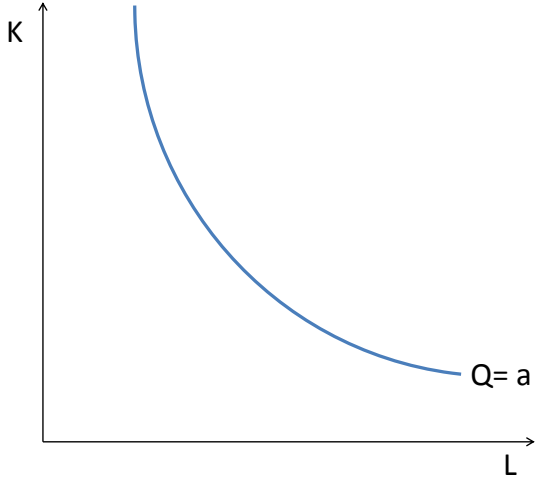
- A constrained minimization problem
- Constraint is that firm produces some level of output Q
  - Think of this as a given: $Q = a$
  - Consumer problem: income is given, we find maximum happiness
  - Producer problem: Q is given, and we find minimum cost
- Goal: what is the lowest cost at which it can produce output $Q = a$?
- Cost minimization is necessary but not sufficient for profit maximization – more on this later

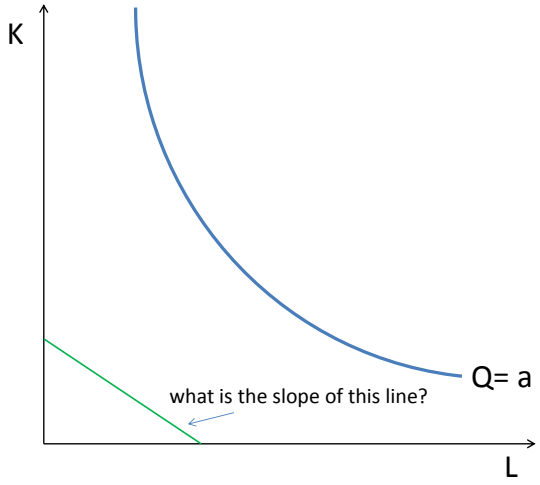
Cost Minimization in Pictures

How Can You Produce $Q = a$ at Minimum Cost?



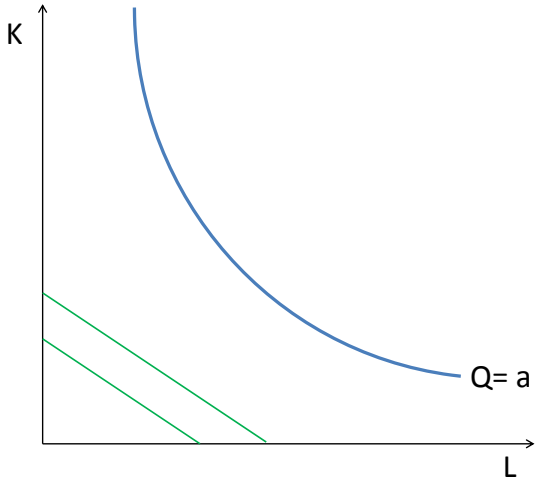
Cost Minimization in Pictures

Find the Slope of the Isocost Line



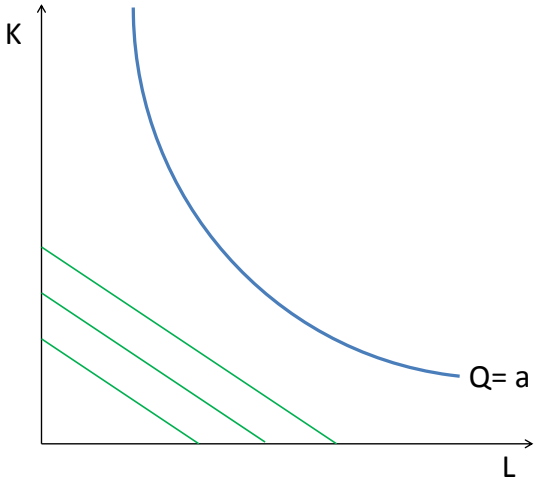
Cost Minimization in Pictures

Not Enough Inputs to Make *a*



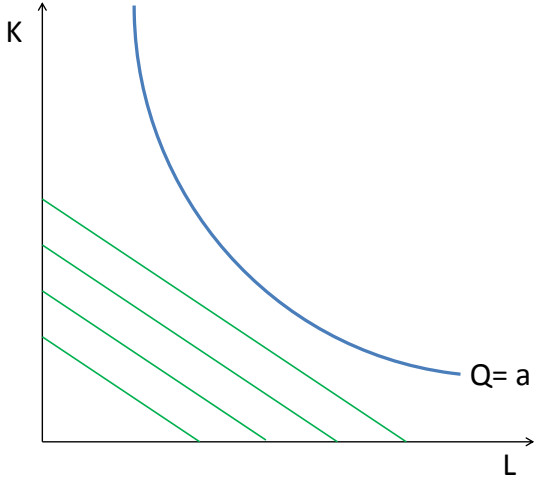
Cost Minimization in Pictures

Still Not Enough



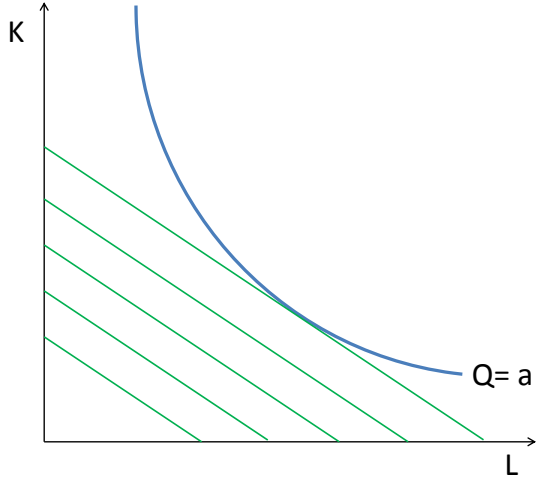
Cost Minimization in Pictures

Still Not Enough



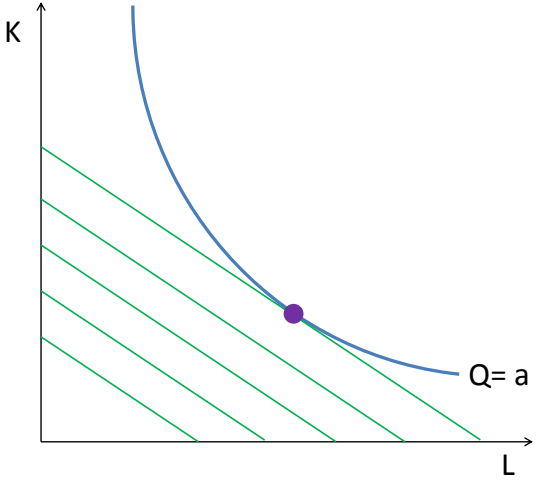
Cost Minimization in Pictures

Enough?



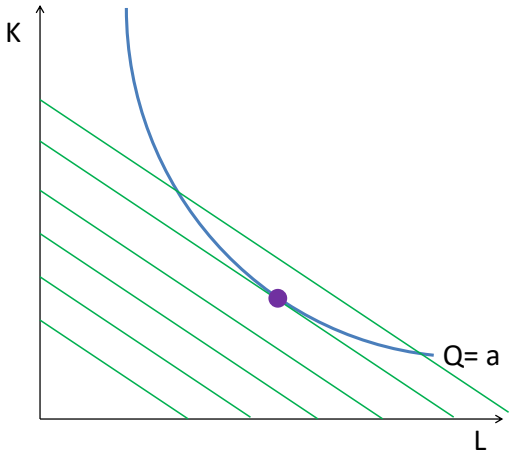
Cost Minimization in Pictures

The Optimal Combination of K and L



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

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

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

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

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

- 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
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 $= -\frac{P_X}{P_Y}$	Slope of isocost $= -\frac{W}{R}$
Optimality at $MRS_{XY} = \frac{P_X}{P_Y}$	
Income expansion path	

Parallels: Consumer and Producer Problems

Think tangency!

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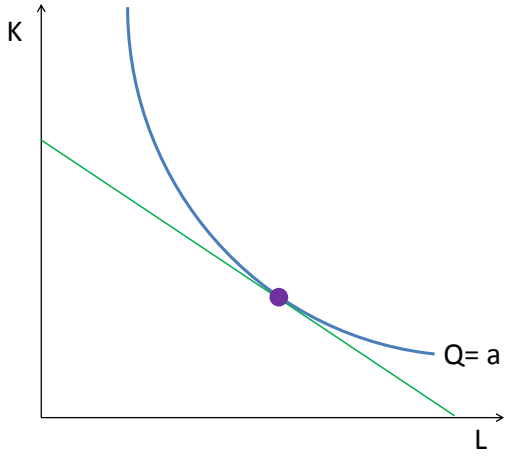
Income expansion path	

What if Input Prices Change?

- Price of labor increases, and price of capital decreases



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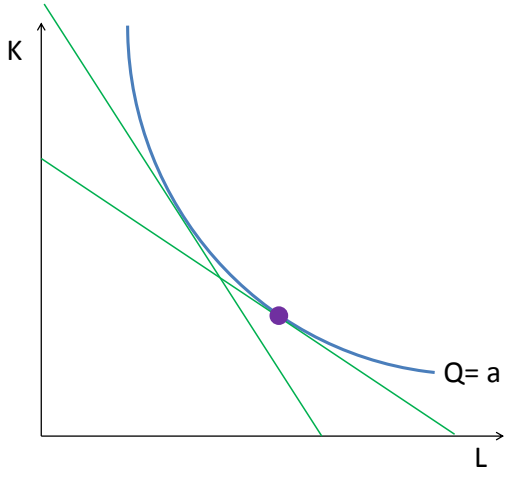
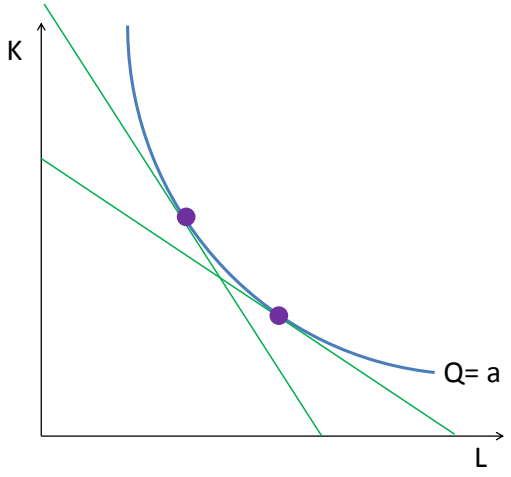


What if Input Prices Change?

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



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.

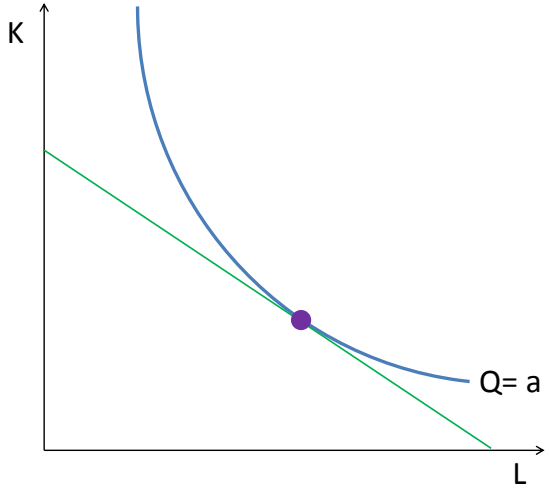
Expansion Path

How Does Production Change at 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 Qs
  - 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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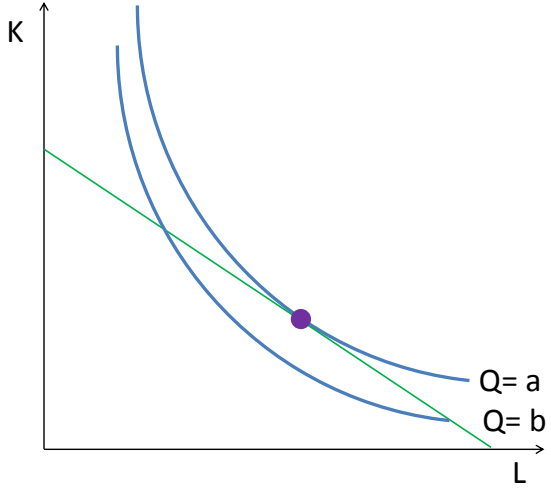
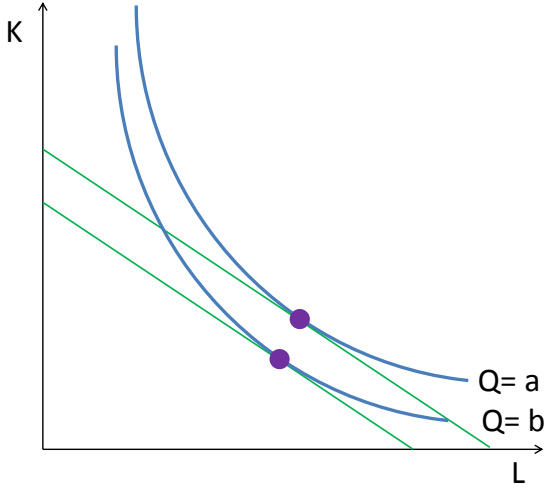


Drawing a Total Cost Curve

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



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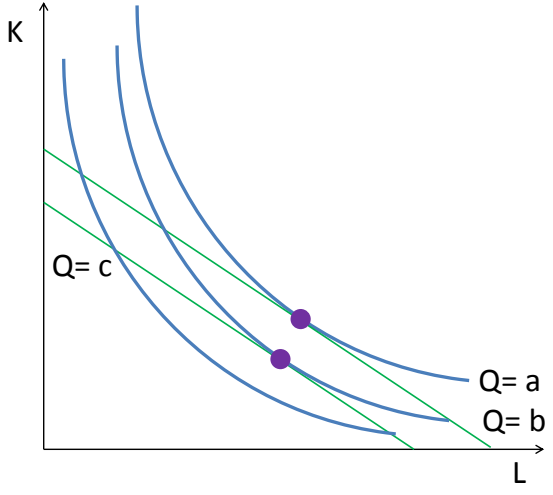

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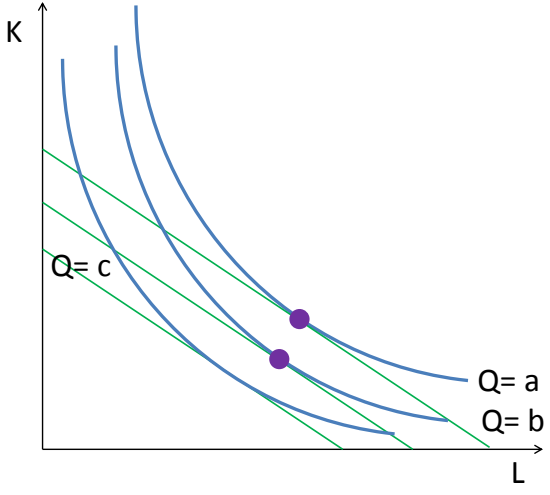
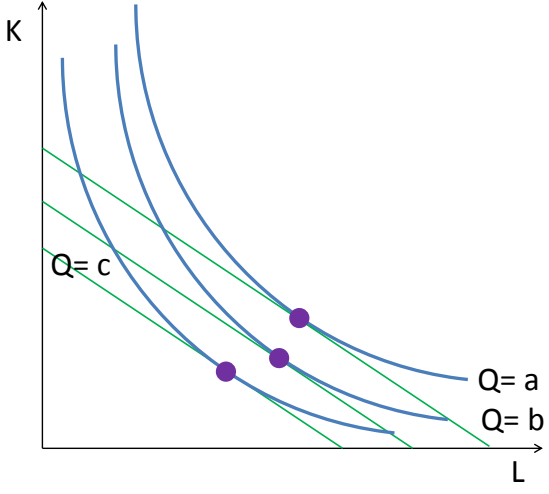


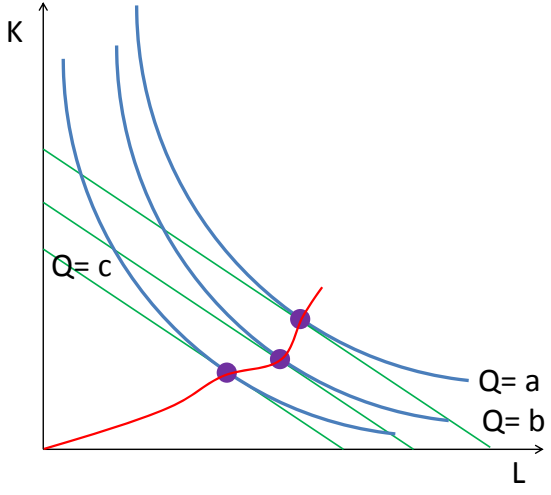
Drawing a Total Cost Curve

Optimum!



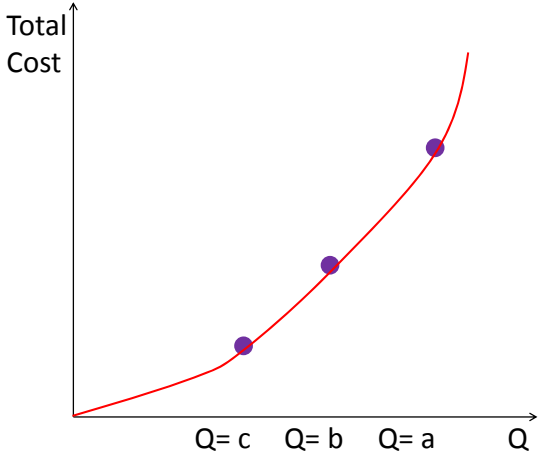
Drawing a Total Cost Curve

Expansion Path in Red



Drawing a Total Cost Curve

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



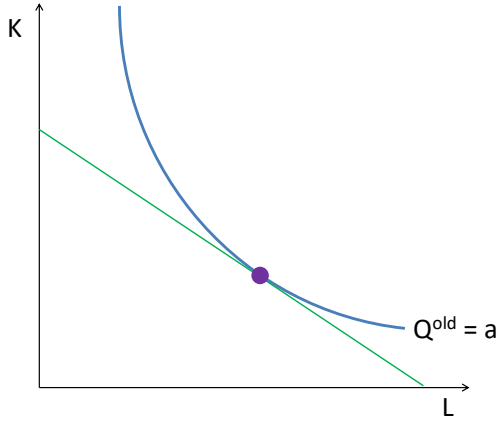
Technological Change

What if Technology Changes?

- Total factor productivity $\equiv$ change in output not accounted for by measured inputs, here K and L
- Total factor productivity growth can be technical change, management improvements
- We usually write TFP as A, where $Q = Af(K, L)$
- If A increases
  - there is growth in TFP
  - in which direction does the isoquant move?

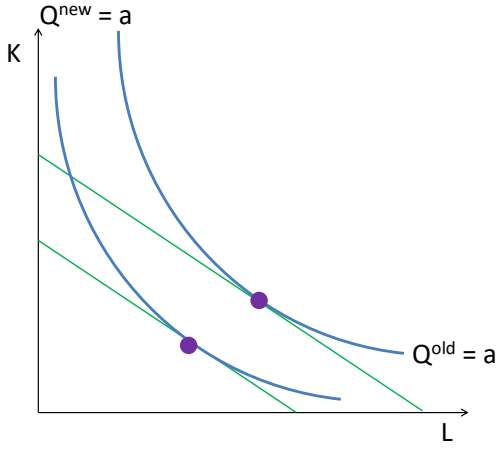
Shifting the Isoquant

Suppose the Firm Can Now Produce the Same Quantity with Fewer Inputs. What Changes?



Shifting the Isoquant

Isoquant Shifts Inward and Can Change Shape



Drivers of Technological Change: Injera

Making *injera*

- What are the inputs?
- Which is the expensive input in the US? In Ethiopia?
- Which input will technology target in the US?
- In Ethiopia?

Drivers of Technological Change: Injera

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Wudneh Admassu
Prof. of Chemical Engineering
University of Idaho
Born in Ethiopia
Educated in US

Drivers of Technological Change: Injera

Making *injera*

- What are the inputs?
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- Which input will technology target in the US?
- In Ethiopia?

Wudneh Admassu
Prof. of Chemical Engineering
University of Idaho
Born in Ethiopia
Educated in US

- Patented the first injera-making machine
- Such machines now imported into Ethiopia

Technological change changes everything!

Recap of Today

- Production Assumptions and Basics
- Production in the Short Run
- Production in the Long Run
- Cost Minimization Problem
- Expansion Path and Total Cost
- Technological Change
- (For Lecture 9: Returns to Scale)

Next Classes

- Next class: midterm
- Next class
  - Use Numbers assignment 3 coming
  - Costs!
  - GLS Chapter 7, but not 7.5. Return to 6.5.