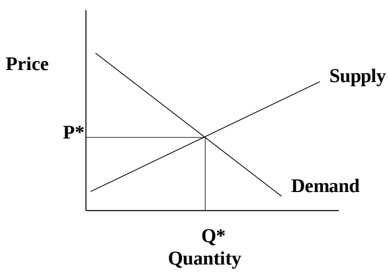
Production and Resource Use - Supply Side

Chapters 3, 4, and 6

Review - Where We are Going



Review - Demand

- Started with Utility Theory
  - Marginal utility
- Consumer equilibrium - The law of demand
  - Indifference curves
  - Budget constraint
- Individual vs. Market Demand curve
  - Change in quantity demanded vs. change in demand
  - Shifters of demand
- Use of Demand
  - Consumer surplus – consumer welfare
  - Elasticities – own price, income, cross price

Topics of Discussion

- Conditions of perfect competition
- Classification of inputs
- Important production relationships (for one variable input –TPP, APP, MPP)
- Assessing short run business costs (TC, AC,TVC, AVC, MC)
- Economics of short-run decisions

Topics of Discussion

- Expand production concepts to two inputs
- Concepts are analogous consumers
  - Isoquants – Indifference curves
  - MRTS – MRS
  - Iso-cost lines - Budget constraint
  - Least cost combinations – Consumer equilibrium
- Firm Specific
  - Production Possibility Frontier
  - Iso-revenue
  - Long-run firm size

Conditions for Perfect Competition

- **Homogeneous products**
  - Products from different producers are perfect substitutes
- **No barriers to entry or exit**
  - Resources are free to move in and out of the sector
- **Large number of buyers and sellers**
  - No market power – price takers
- **Perfect information**
  - Including quantities, prices, quality, sources of resources etc.

Classification of Inputs

- **Land -** **includes renewable (forests) and non-renewable (minerals) resources**
- **Labor -** **all owner and hired labor services, excluding management**
- **Capital -** **manufactured goods such as fuel, chemicals, tractors and buildings**
- **Management -** **production decisions designed to achieve specific economic goal**

What Are Production Functions?

- **Mathematical relationship that characterizes the *physical* relationship between the use of inputs and the level of outputs**

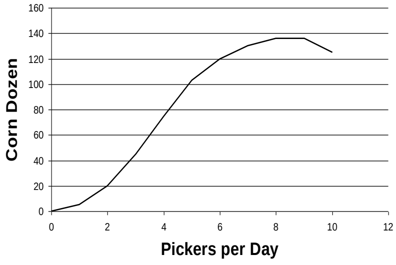
Output = f(labor | capital, land, and management)

Start with one variable input

Assume all other inputs fixed at their current levels…

Total Physical Production (TPP) Curve

Pickers	Corn Dozen
0	0
1	5
2	20
3	45
4	75
5	103
6	120
7	130
8	136
9	136.1
10	125



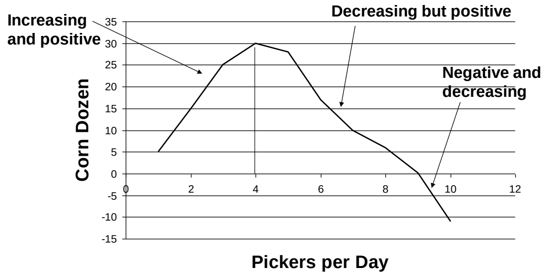
Marginal Physical Product (MPP)

Pickers	Corn Dozen	MPP
0	0	--
1	5	= (5-0)/(1-0) = 5
2	20	=(20-5)/(2-1) = 15
3	45	=(45-20)/(3-2) = 25
4	75	=(75-45)/(4-3) = 30
5	103	28
6	120	17
7	130	10
8	136	6
9	136.1	0.1
10	125	-11.1

- **The change in the level of output associated with the change in the use of an input**
- $\text{MPP} = \frac{\Delta \text{ output}}{\Delta \text{ input}}$

MPP Graphically

- **Three segments**



Law of Diminishing Marginal Product - Know

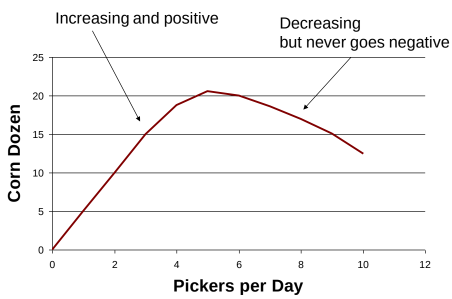
"As successive units of a *variable input* are added to a production process with the other inputs held constant, the marginal physical product (MPP) eventually *declines*"

Average Physical Product (APP)

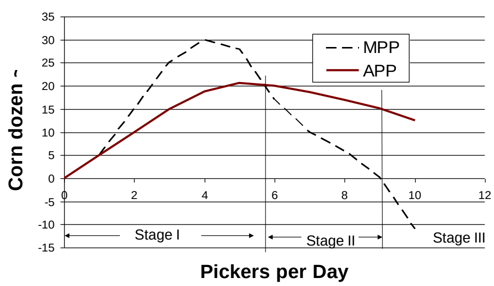
Pickers	Corn Dozen	APP
0	0	= 0 /0 = --
1	5	= 5/1 = 5
2	20	= 20/2 = 10
3	45	=45/3 = 15
4	75	=75/4 = 18.75
5	103	20.6
6	120	20
7	130	18.57
8	136	17
9	136.1	15.12
10	125	12.5

- **Represents the output per unit of input**
- **Always positive except at zero input – not defined**
  - **Why**
- $$APP = \frac{\text{total output}}{\text{total input}}$$

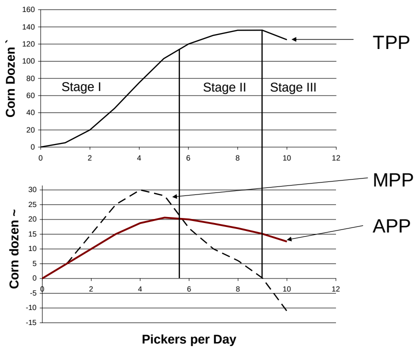
APP Graphically



Stages of Production



Relationships - Know



Short-Run Costs

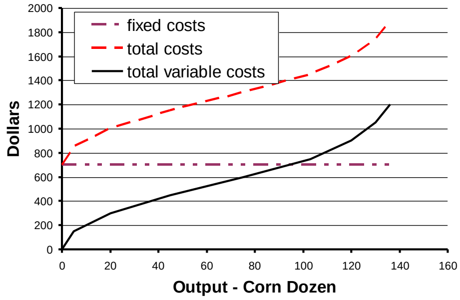
- **Fixed costs – do not vary with the level of input use**
- **Variable costs – vary with the level of input use**
- **Similar to production can obtain curves such as total, average, and marginal costs**

Total Costs

- Fixed costs $700 / day
- Cost $150 / picker / day = $18.75 / hour

Pickers	Corn Dozen	Fixed Costs (FC)	Total Variable Costs (TVC)	Total Costs TC = FC + TVC
0	0	700	0 x 150 = 0	700 + 0 = 700
1	5	700	1 x 150 = 150	700 + 150 = 850
2	20	700	2 x 150 = 300	700 + 300 = 1000
3	45	700	3 x 150 = 450	700 + 450 = 1150
4	75	700	4 x 150 = 600	700 + 600 = 1300
5	103	700	750	1450
6	120	700	900	1600
7	130	700	1050	1750
8	136	700	1200	1900

Total Costs - Graphically

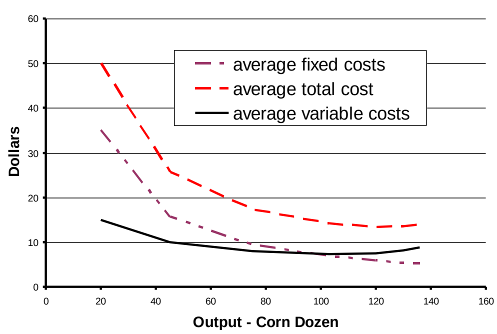


Average Costs

- Average = cost of interest / output

Corn or Output	Fixed Costs	Total Variable Costs	Total Costs	AFC FC/output	AVC TVC/output	ATC TC/output
0	700	0	700	700/0 = ?	0/0= ?	700/0 = ?
5	700	150	850	700/5 = 140	150/5 = 30	850/5=170
20	700	300	1000	700/20=35	300/20 = 15	1000/20 = 50
45	700	450	1150	700/45=15.5	450/45 = 10	1150/45=25.6
75	700	600	1300	700/75=9.3	600/75 = 8	1300/75=17.3
103	700	750	1450	6.8	7.2	14.1
120	700	900	1600	5.8	7.5	13.3
130	700	1050	1750	5.3	8.1	13.5
136	700	1200	1900	5.1	8.8	14

Average Costs - Graphically

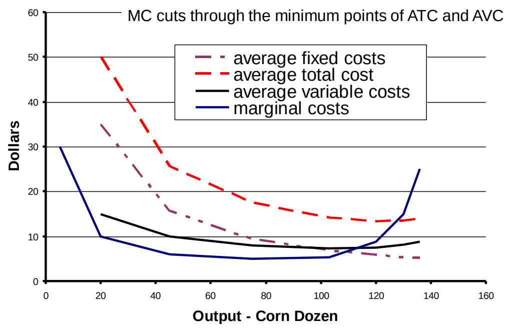


Marginal Costs

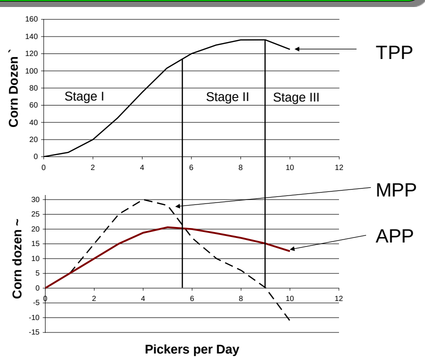
Marginal costs = change in total costs / change in output

Corn Dozen	Total Costs	Marginal Costs
0	700	--
5	850	(850-700)/(5-0) = 30
20	1000	(1000-850)/(20-5)= 10
45	1150	(1150-1000)/(45-20) = 6
75	1300	(1300-1150)/(75-45) = 5
103	1450	5.4
120	1600	8.8
130	1750	15
136	1900	25

Marginal Costs - Graphically



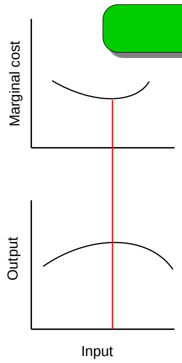
Relationships - Know



Cost / Production Relationships

- **MC**
  - **Increasing MC is associated with diminishing marginal returns – decreasing MPP**
  - **Decreasing MC is associated with increasing MPP**
- **AVC and ATC**
  - **Decreasing AVC & ATC are associated with increasing APP**
  - **Increasing AVC & ATC are associated with decreasing APP**
- **FC**
  - **Decreasing AFC is associated with a constant FC and increasing output**

Graphically



U – Shaped MC

- Increasing MC – decreasing MPP
  - Increasing output per unit of input
- Decreasing MC - increasing MPP
  - Decreasing output per unit of input

Similarly – U Shaped AVC and ATC

- Decreasing ATC or AVC - increasing APP
- Increasing ATC or AVC – decreasing APP

Short-Run Decisions

Similar to what we have been doing

- **Total Revenue =** **price x quantity – WHY?**
- **Average Revenue –** **revenue per unit of output**
- **Marginal Revenue –** **change in total revenue as output changes**

$$AR = \frac{total\ revenue}{total\ output} \qquad MR = \frac{\Delta\ revenue}{\Delta\ output}$$

- **Objective maximize economic profits given something is held fixed**

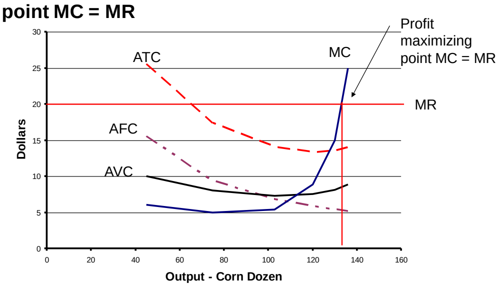
Economic Profits

- Recall price of $20 / dozen   Note, $MR = \frac{\Delta \text{ revenue}}{\Delta \text{ output}}$

Corn Dozen	TC	MC	Total Revenue P x Q	MR	Economic Profit TR - TC
0	700		0 x 20 = 0		0 – 700 = -700
5	850	30	5 x 20 = 100	(100-0)/(5-0) = 20	100 - 850 = -750
20	1000	10	20 x 20 = 400	(400-100)/(20-5) =20	400 - 1000 = -600
45	1150	6	45 x 20 = 900	20	900 – 1150 = -250
75	1300	5	75 x 20 = 1500	20	1500 – 1300 = 200
103	1450	5.4	2060	20	610
120	1600	8.8	2400	20	800
130	1750	15	2600	20	850
136	1900	25	2720	20	820

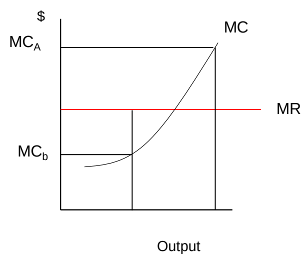
Level of Output MC = MR

- **Perfect competition in the short run produce at the point MC = MR**



Level of Output MC = MR

- **Why? Examine MR and MC curves**



MC > MR
Produce less – Why?

MC = MR
Correct output level – Why?

MC < MR
Produce more – Why?

Profit Maximizing Point

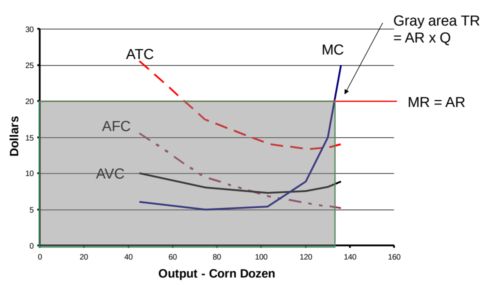
- Why not exact?

Corn Dozen	TC	MC	Total Revenue	MR	Economic Profit TR - TC
Profit max occurs between the two red rows					
120	1600	8.8	2400	20	800
130	1750	15	2600	20	850
136	1900	25	2720	20	820
Approximate profit max point					
134	1825	~20	2680	20	855

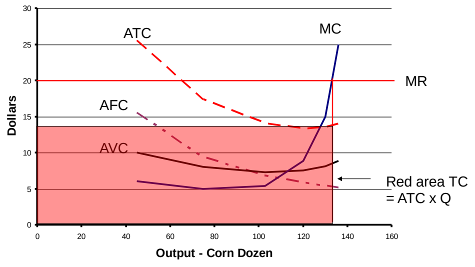
Revenue Side

- Covered by the HW 5, know how to calculate total revenue, MR, and economic profit tables.

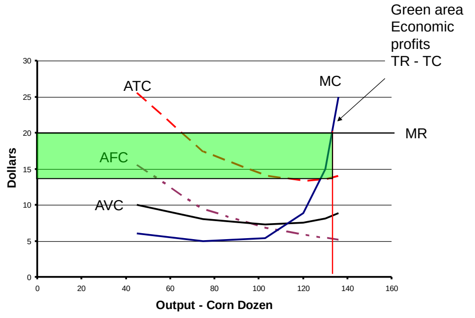
TR and TC Areas



TR and TC Areas

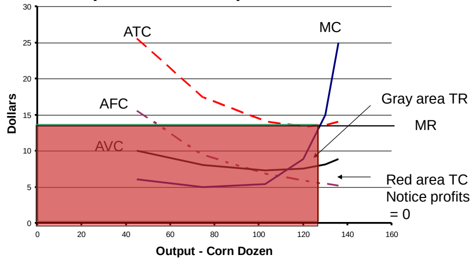


Economic Profits



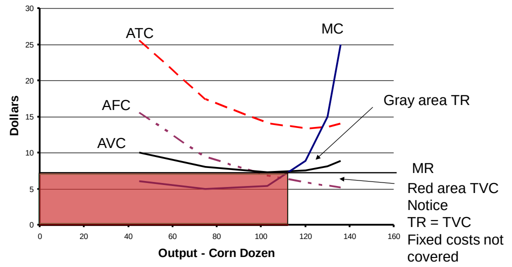
Breakeven Price

- **Breakeven price - price that just covers total costs**
- **TR = TC implies economic profits are zero**



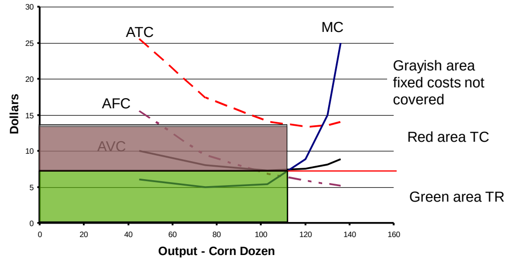
Shutdown Price

- **Shutdown price - price that just covers total variable costs**

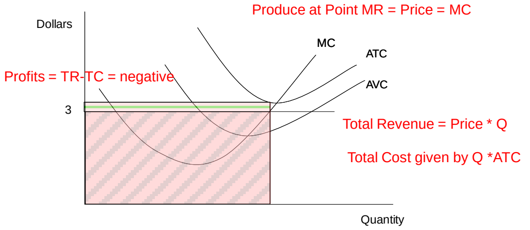


Shutdown Price

- **Fixed costs are not covered but variable costs covered**

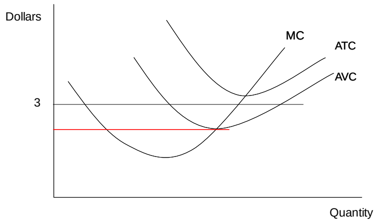


Review



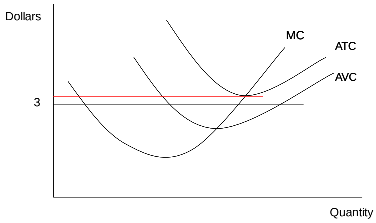
At a price of $3 should you produce? Label TC, TR, and profits.

Review



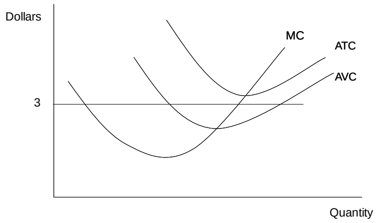
Shutdown Price – WHY?

Review



Breakeven Price – WHY?

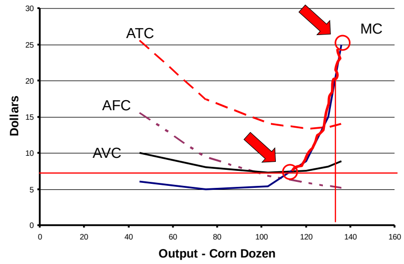
Review



At a price of $3 should you produce? YES in the short run price above shutdown price – covering some of fixed costs.

Firm's Short-Run Supply Curve

- **MC curve above the AVC**



Own-Price Elasticity of Supply

- Measures the relationship between change in quantity supplied and a change in price

$$\text{Own-price Elasticity of Supply} = \frac{\text{Percentage change in quantity supplied}}{\text{Percentage change in own price}}$$

$$= \frac{(Q_{SA} - Q_{SB}) / [(Q_{SA} + Q_{SB})/2]}{(P_A - P_B) / [(P_A + P_B)/2]}$$

Own-Price Elasticity of Supply

- Positive – Why?

If the elasticity is	Supply is	% Δ in quantity is
Greater than 1.0	Elastic	Greater than % Δ in price
Less than 1.0	Inelastic	Less as % Δ in price
Equal to 1.0	Unitary	Equal to % Δ in price
Equal to 0	Perfectly inelastic	Zero Vertical supply curve
Equal to positive infinity	Perfectly elastic	%Δ in price = zero Horizontal supply curve

Math Details

- Recall change in quantity = 3 to 4.5 and price 1 to 1.5

$$\frac{\%\ \text{change in quantity}}{\%\ \text{change in own price}} =$$

$$\frac{(4.5-3)/[(4.5+3)/2]}{(1.5-1)/[(1.5+1)/2]} = \frac{0.4}{0.4} = 1.0$$

- Interpretation -- 1% increase in price leads to a 1% increase in quantity supplied over this arc

Determinants

- Availability of raw materials
  - Limited availability - less opportunities to respond
- Length and complexity of the production process
  - Less production time and complexity – more opportunities to respond
- Time to respond
  - Short vs. long run – long run more able to respond
- Excess capacity
  - Unused capacity can and will respond quicker
- Inventories
  - If have inventory can quickly increase supply to market

Elasticity

- We have discussed all types of elasticities. By this point you should be able to pick up new elasticity on your own. This is what college is about! As such be sure to understand:
  - Elasticity of supply of inputs -- p.104
  - Cross-price elasticity of supply -- p. 105

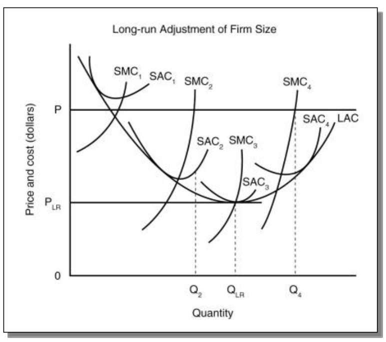
Long Run Average Cost Curve

The long run average cost (LAC) curve reflects points of tangency with a series of short run average total cost (SAC) curves. The point on the LAC where the following holds is the *long run equilibrium* position (Q_{LR}) of the firm:

$$SAC = LAC = SMC = P_{LR}$$

where P_{LR} represents the long run price and SMC short run marginal costs.

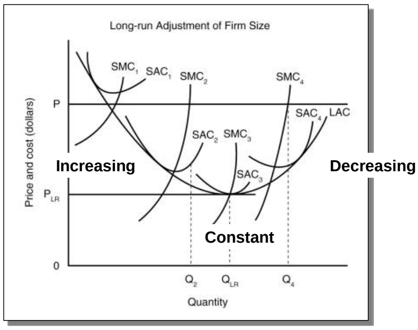
Developing the LAC



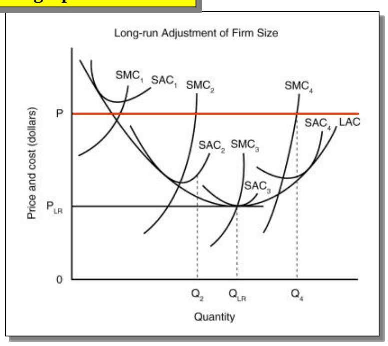
Economies of Size

- Increasing returns to size – increase in output is more than proportional increase in input use
  - LAC is decreasing when firm is expanded
- Decreasing returns to size - increase in output is less than proportional increase in input use
  - LAC is increasing when firm is expanded
- Constant returns to size - increase in output is equal to the proportional increase in input use
  - LAC is horizontal when firm is expanded

Returns to Size

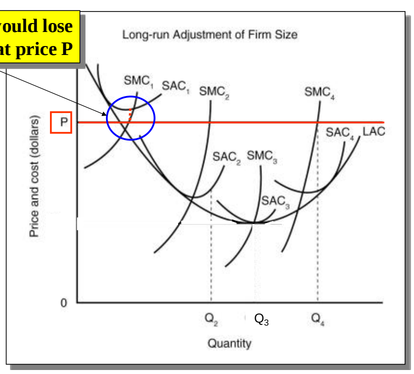


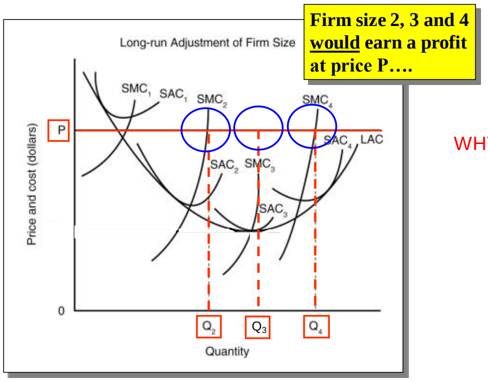
What can we say about the four firms in this graph?



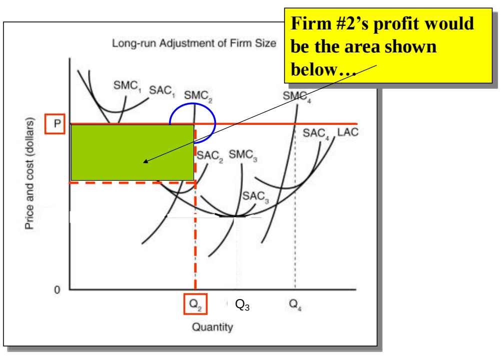
Size 1 would lose money at price P

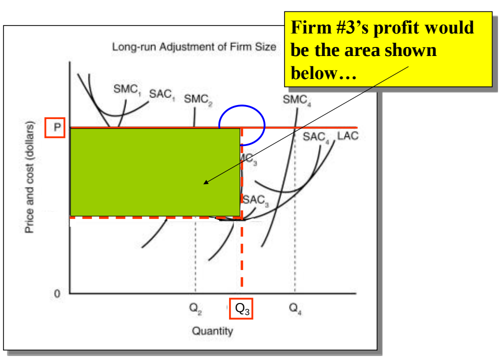
WHY?

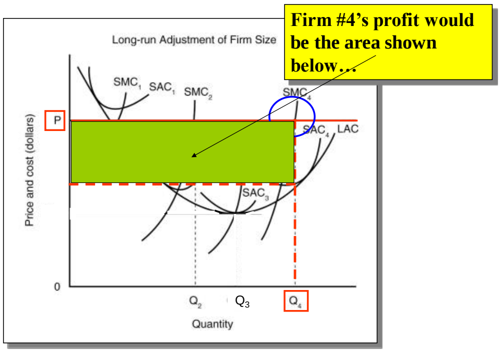


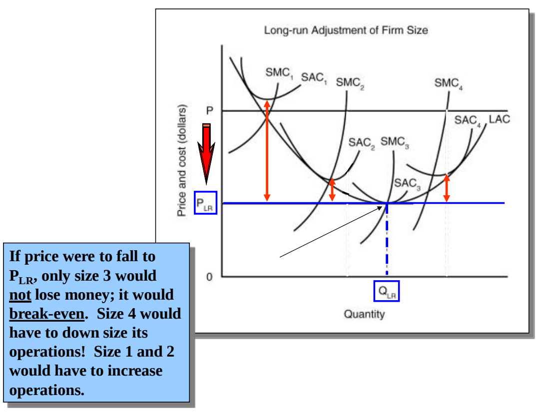

Firm size 2, 3 and 4 would earn a profit at price P….
Long-run Adjustment of Firm Size
Price and cost (dollars)
Quantity
P
0
SMC1
SAC1
SMC2
SMC4
SAC2
SMC3
SAC3
SAC4
LAC
Q2
Q3
Q4

WHY?


Firm #2's profit would be the area shown below…
Long-run Adjustment of Firm Size
Price and cost (dollars)
Quantity
P
0
SMC1
SAC1
SMC2
SMC4
SAC2
SMC3
SAC3
SAC4
LAC
Q2
Q3
Q4


Firm #3's profit would be the area shown below…
Long-run Adjustment of Firm Size
Price and cost (dollars)
Quantity
P
0
SMC1
SAC1
SMC2
SMC4
SAC3
SAC4
LAC
Q2
Q3
Q4





Marginal Value Product

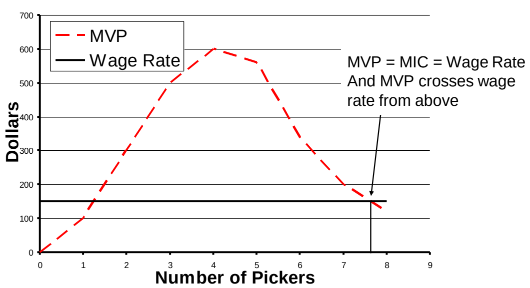
- Additional revenue earned from employing another unit of input
- MVP = $\frac{\text{Price x change in output}}{\text{change in input}}$ = Price x MPP

Marginal Value Product

- **Additional revenue earned from employing another picker – unit of input**

Pickers	Corn Dozen	MPP	MVP = MPP x price
0	0		
1	5	5	5 x 20 = 100
2	20	15	15 x 20 = 300
3	45	25	25 x 20 = 500
4	75	30	30 x 20 = 600
5	103	28	560
6	120	17	340
7	130	10	200
8	136	6	120

Profit Maximizing Level of Input



Relationship Input and Output Side

Output	Input	Marginal Revenue	Marginal Costs	MVP	MIC
0	0	20	--		150
5	1	20	30	100	150
20	2	20	10	300	150
45	3	20	6	500	150
75	4	20	5	600	150
103	5	20	5.4	560	150
120	6	20	8.8	340	150
130	7	20	15	200	150
136	8	20	25	120	150

Within discrete natural of the data, if continuous data exact.

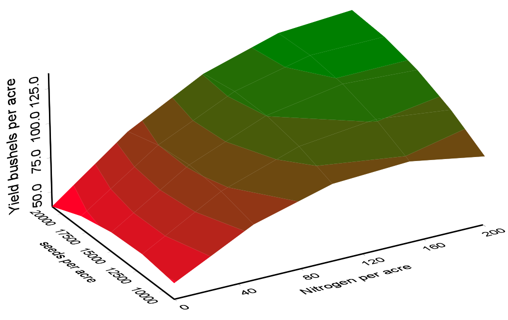
Exam One to this point

- Exam one will cover all material to this point

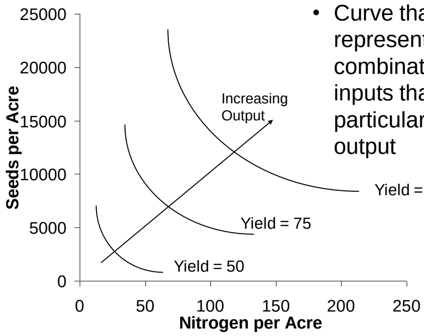
Production Example

Corn Yields bushel per Acre					
Nitrogen lbs / acre	Seeds / Acre				
	9000	12000	15000	18000	21000
0	50.6	54.2	53.2	48.5	39.2
50	78.7	85.9	**88.8**	87.5	81.9
100	94.4	105.3	**111.9**	114.2	112.2
150	97.8	**112.4**	122.6	128.6	**130.3**
200	**88.9**	107.1	121	**130.6**	135.9

3-D Production Function



Isoquants



- Curve that represents the combinations of two inputs that result in a particular level of output

From This

- http://www.daughertyinc.com/html/antique_tractor_show.html

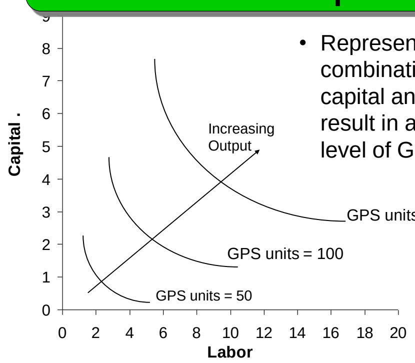
To This

Moving to This

GPS and GIS for Production

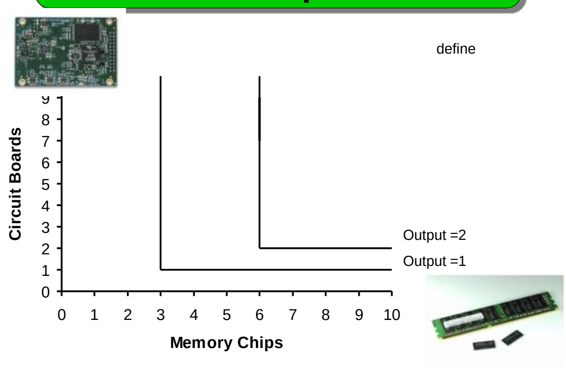
- What is it?
  - Global position system
  - Geographic information system
    - http://winebusiness.com/wbm/?go=getArticle&dataId=30473
- Manufacture GPS Units
  - Inputs
    - Labor
    - Capital
  - Output
    - GPS Units

GPS Units Isoquants

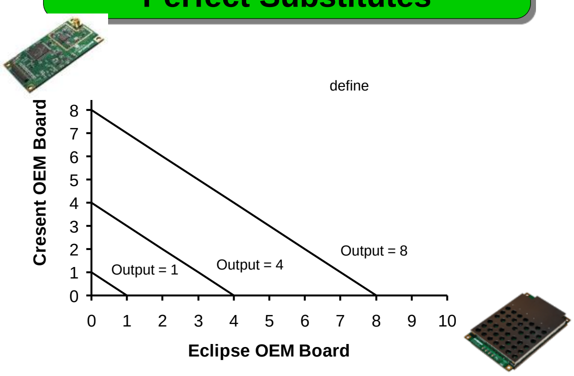


- Represents the combinations of capital and labor that result in a particular level of GPS output

Perfect Complements



Perfect Substitutes



Marginal Rate of Technical Substitution MRTS

- Amount of input B which can be substituted for input A in such a way that output is held constant
- The slope of the isoquant
- MRTS = $\frac{\text{Change in capital}}{\text{Change in labor}} = -\frac{MPP_{labor}}{MPP_{capital}}$

Why?

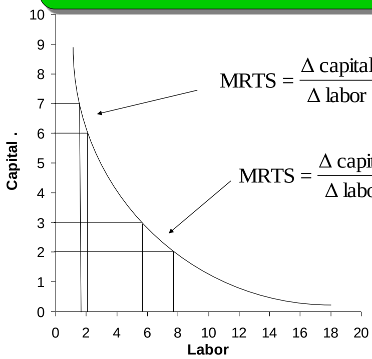
$$MPP_{capital} = \frac{\Delta \text{ output}}{\Delta \text{ capital}} \quad \text{and} \quad MPP_{labor} = \frac{\Delta \text{ ouput}}{\Delta \text{ labor}}$$

$$-\frac{MPP_{labor}}{MPP_{capital}} = -\frac{\frac{\Delta \text{ output}}{\Delta \text{ labor}}}{\frac{\Delta \text{ output}}{\Delta \text{ capital}}} = -\frac{\Delta \text{ capital}}{\Delta \text{ labor}} = MRTS$$

- Analogous to consumer indifference curves

$$MRS_{\text{B to A}} = -\frac{MU_{\text{good A}}}{MU_{\text{good B}}}$$

MRTS - Calculations

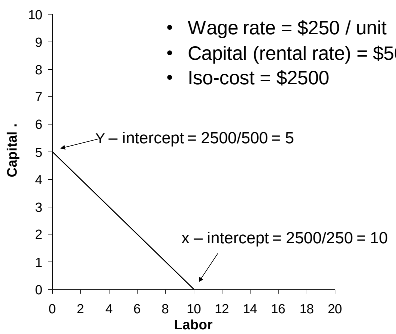


$$MRTS = \frac{\Delta \text{ capital}}{\Delta \text{ labor}} = \frac{7-6}{1.75-2} = -4$$

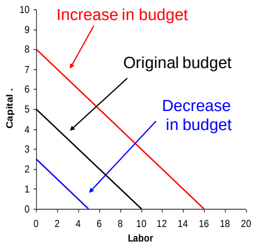
$$MRTS = \frac{\Delta \text{ capital}}{\Delta \text{ labor}} = \frac{3-2}{5.75-7.75} = -0.5$$

Iso-cost – Add Input Prices

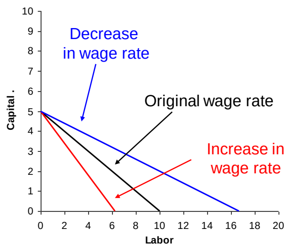
- Wage rate = $250 / unit
- Capital (rental rate) = $500 / unit
- Iso-cost = $2500



Change in Budget / Prices



Change in budget



Change in wage rate

What about change in capital costs?

Marginal Rate of Substitution in Exchange

- Represents how you can change input usage and not change costs
- The slope of the iso-cost line
- $= \dfrac{\text{Change in cost of capital}}{\text{Change in cost of labor}} = -\dfrac{\text{Wage rate}}{\text{Rental rate}}$
- Analogous to consumer budget constraint
  - Slope of budget constraint = price ratios

Why?

- Calculate slope using the two axis intercepts

$$\text{slope} = \text{rise} / \text{run} = \Delta\,\text{capital} / \Delta\,\text{labor}$$

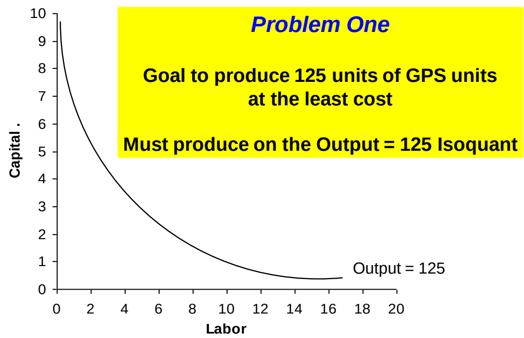
$$= (\text{y intercept} - 0) / (0 - \text{x intercept})$$

$$= \frac{\left(\dfrac{\text{Budget}}{\text{Rental rate}} - 0\right)}{\left(0 - \dfrac{\text{Budget}}{\text{wage rate}}\right)} = -\frac{\text{wage rate}}{\text{rental rate}}$$

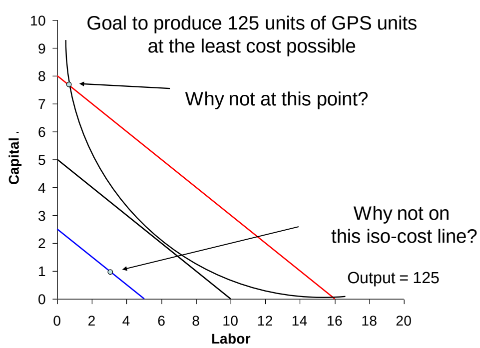
Least Cost Input Combinations

- Problem one - for a given output, what is the least cost combinations of inputs?
- Problem two – for a given cost, what is the least cost combination of inputs and associated maximum output level?
- Decision Rule
  - The least cost combination of two inputs (labor and capital in our example) occurs where the slope of the iso-cost line is *tangent* to the isoquant.
  - Analogous to consumer equilibrium

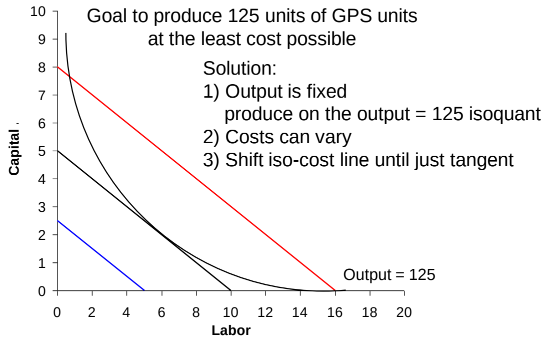
Least Cost Combination



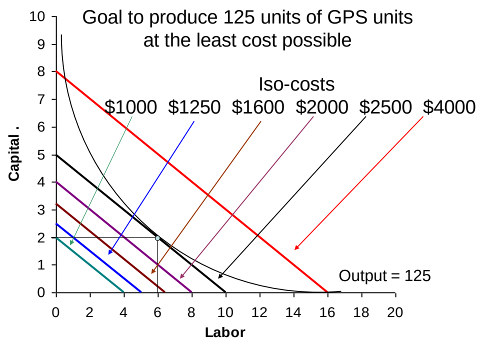
Least Cost Combination



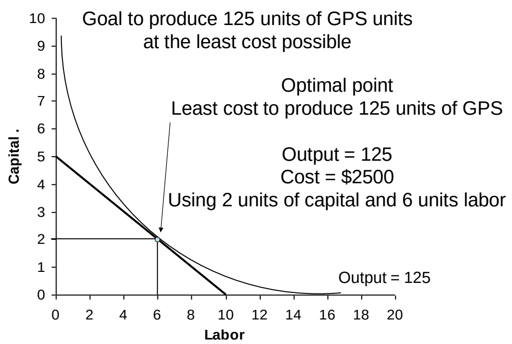
Least Cost Combination



Least Cost Combination



Least Cost Combination

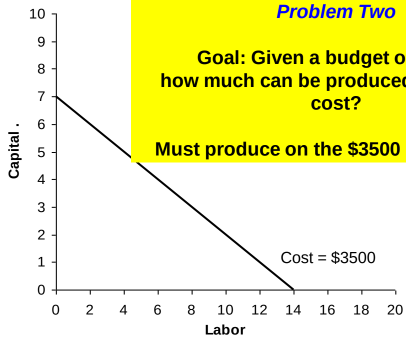


Least Cost Combination

Problem Two

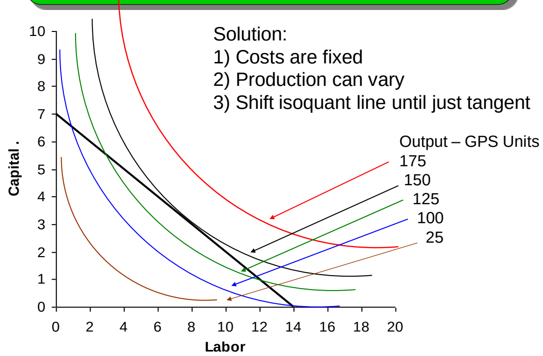
Goal: Given a budget of $3500, how much can be produced at the least cost?

Must produce on the $3500 Iso-cost line



Least Cost Combination

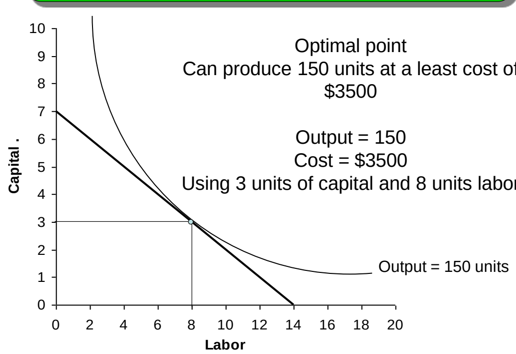
Solution:
1) Costs are fixed
2) Production can vary
3) Shift isoquant line until just tangent



Least Cost Combination

Optimal point
Can produce 150 units at a least cost of $3500

Output = 150
Cost = $3500
Using 3 units of capital and 8 units labor



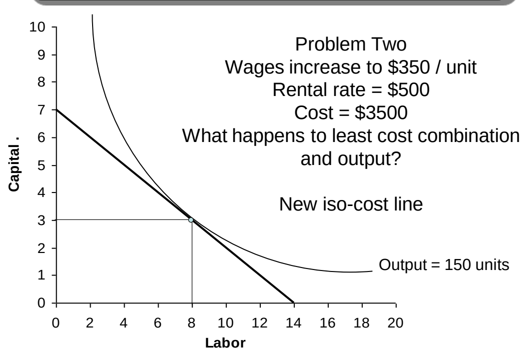
Least Cost – Both Problems

- Least cost combination given by tangent point of isoquant and iso-cost = slopes equal (see earlier slides)

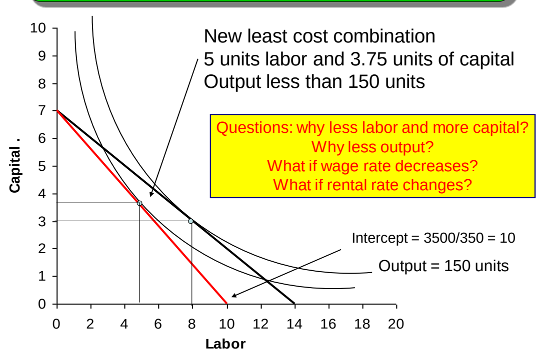
$$- \frac{MPP_{labor}}{MPP_{capital}} = - \frac{\text{Wage rate}}{\text{Rental rate}}$$

- Therefore, $\frac{MPP_{labor}}{\text{Wage rate}} = \frac{\text{MPP capital}}{\text{Rental rate}}$
- Analogous to consumer equilibrium point
  - MU good 1 / price good 1 = MU good 2 / price good 2

Least Cost Combination



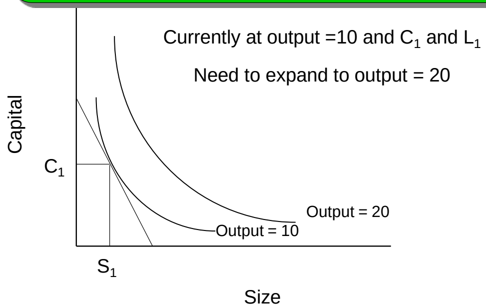
Labor Wages Increase



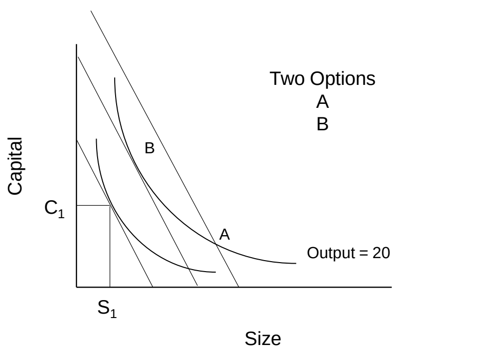
Thought Question

- What is the relationship between the optimal answer for the following two problems?
  - Problem one - for a given output, what is the least cost combinations of inputs?
  - Problem two – for a given cost, what is the least cost combination and output level?

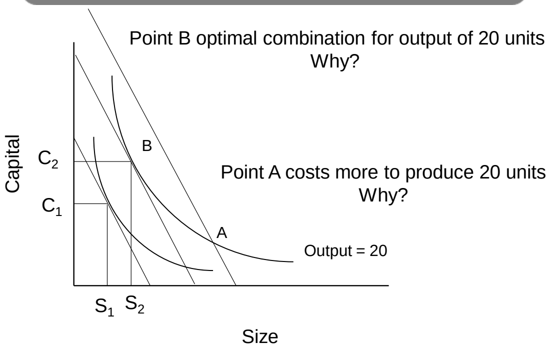
Review - Least Cost and Firm Size



Least Cost and Firm Size



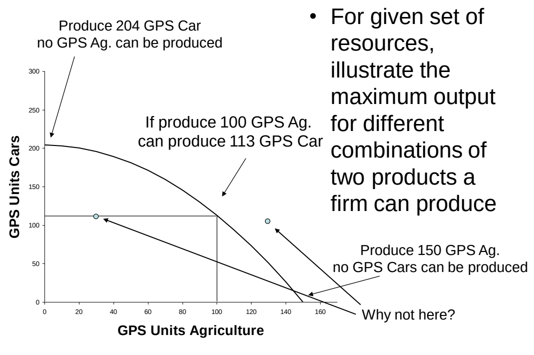
Least Cost and Firm Size



Can the Firm Do Better?

- Currently manufacture 150 GPS units for agriculture using
  - 3 units of capital
  - 8 units of labor
  - Cost of $3500
- Sell agriculture GPS units at a wholesale price of $50 / unit
- Can sell car GPS units wholesale for $40 / unit

Production Possibility Curves



- For given set of resources, illustrate the maximum output for different combinations of two products a firm can produce

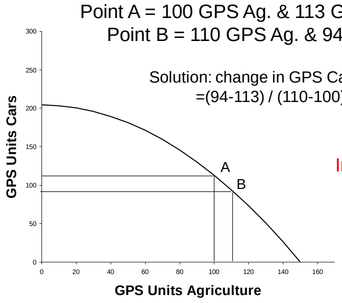
Marginal Rate of Product Transformation

- Represents the rate at which one product (GPS Cars) must increase (decrease) for a decrease (increase) in the other product (GPS Ag.)
- MRPT = $\frac{\text{Change in GPS Cars}}{\text{Change in GPS Ag.}}$
- MRPT = the slope of production possibility curve

MRPT Example

What is MRPT between points A to B?
Point A = 100 GPS Ag. & 113 GPS Cars
Point B = 110 GPS Ag. & 94 Cars

Solution: change in GPS Cars / change in GPS Ag.
=(94-113) / (110-100) = -19/10 = - 1.9



Interpretation?

Iso-Revenue Lines

- Represents the combinations of the two products (goods) that provide the same revenue
- Total Revenue = price good A x quantity good A + price good B x quantity good B
- Total Revenue = $40 x GPS Cars + $50 x GPS Ag
- Gives the rate the market is willing to exchange one product (good) for another

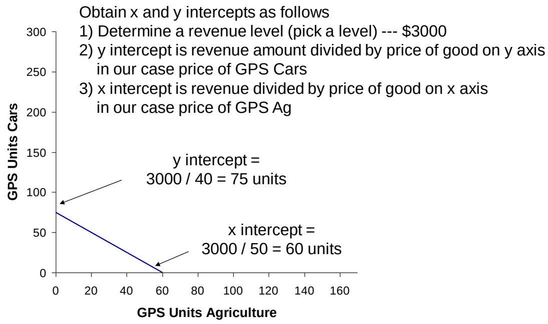
Slope Iso-Revenue Lines

- Slope = $\dfrac{\text{Change in revenue good A}}{\text{Change in revenue good B}}$

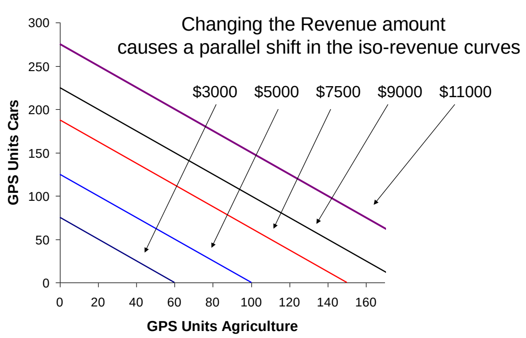
$$= -\frac{\text{Price of good B}}{\text{Price of good A}} \qquad = -\frac{\text{Price of GPS Ag}}{\text{Price of GPS Car}}$$

- Analogous to budget constraint consumer (& iso-cost)
  - \- price good A / price good B
  - Why? See homework!

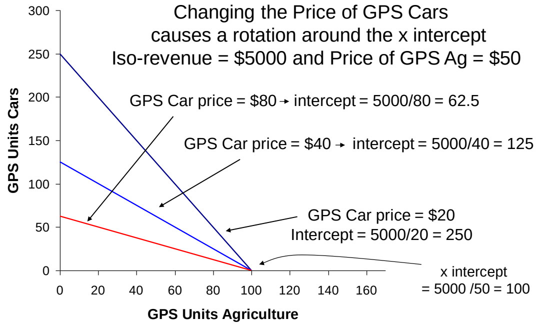
Graphing Iso-Revenue Lines



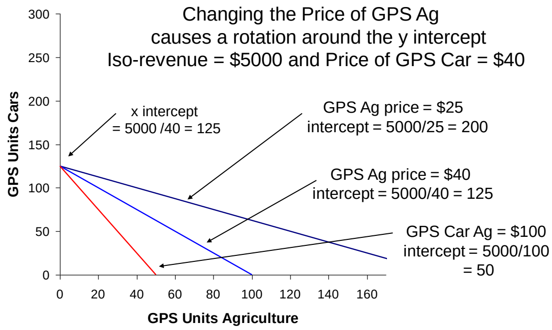
Changing Revenue



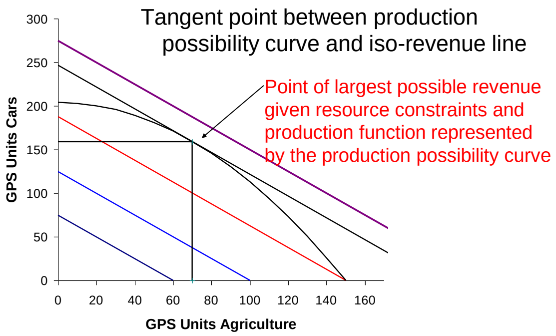
Changing Prices – GPS Cars



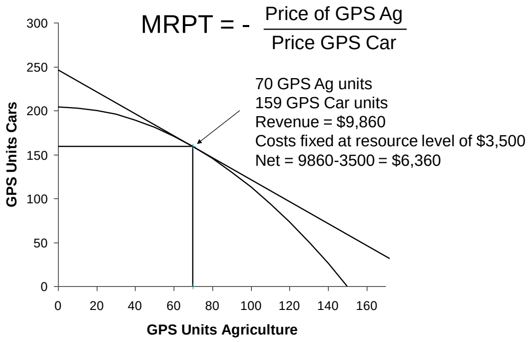
Changing Prices – GPS Ag



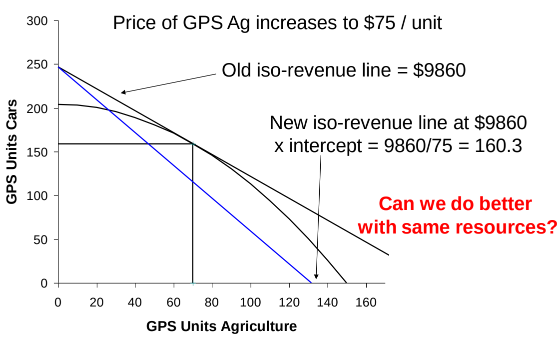
Profit Maximizing Output Levels



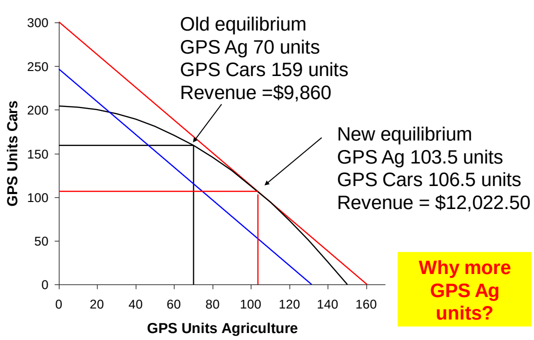
Profit Maximizing Output Levels



Change in Product Price



Change in Product Price



Summary #1 - Know

- Production function and related curves
  - TPP, APP, and MPP
- Cost Curves
  - FC, AVC, VC, AVC, TC, ATC, and MC
- Revenue Curves
  - TR, AR, and MR
- Input Side - MVP
- Profit maximizing points
  - MR = MC, MVP = MIC
- Short-run supply curve
  - MC above AVC

Summary #2

- **Concepts of iso-cost line and isoquants**
- **Marginal rate of technical substitution (MRTS)**
- **Least cost combination of inputs for a specific output level**
- **Effects of change in input price**
- **Level of output and combination of inputs for a specific budget**
- ***Key decision rule*** **…seek point where MRTS = ratio of input prices, or where MPP per dollar spent on inputs are equal.**

Summary #3

- **Concepts of iso-revenue line and the production possibilities frontier**
- **Marginal rate of product transformation (MRPT)**
- **Concept of profit maximizing combination of products**
- **Effects of change in product price**
- ***Key decision rule*** **– maximize profits where MRPT equals the ratio of the product prices**