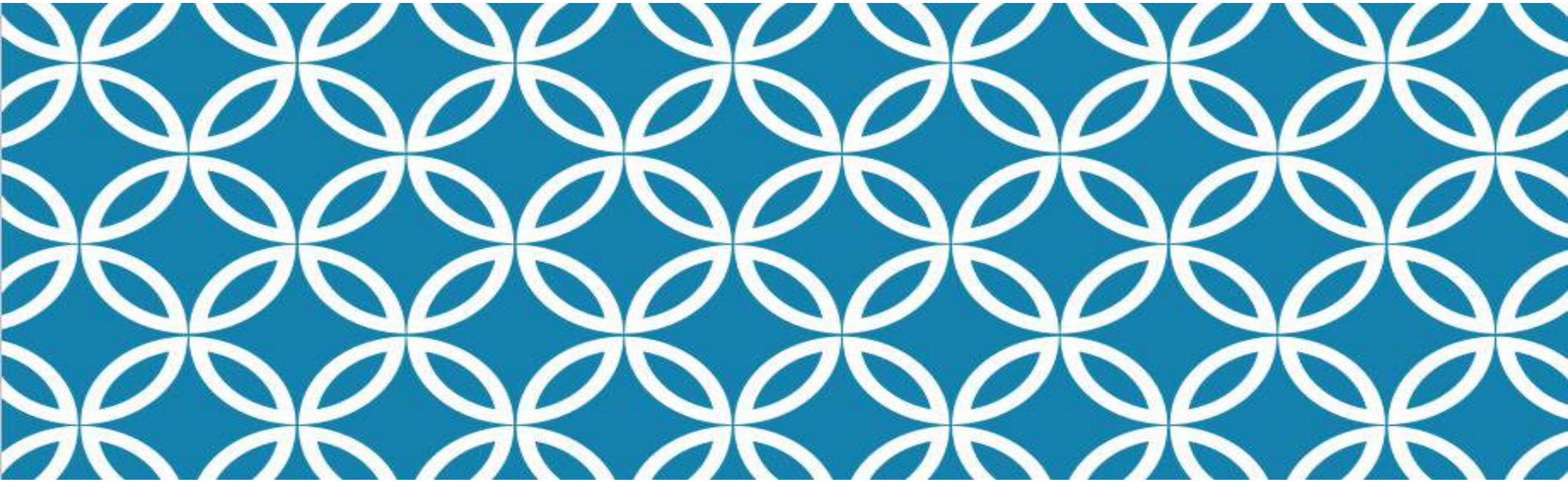


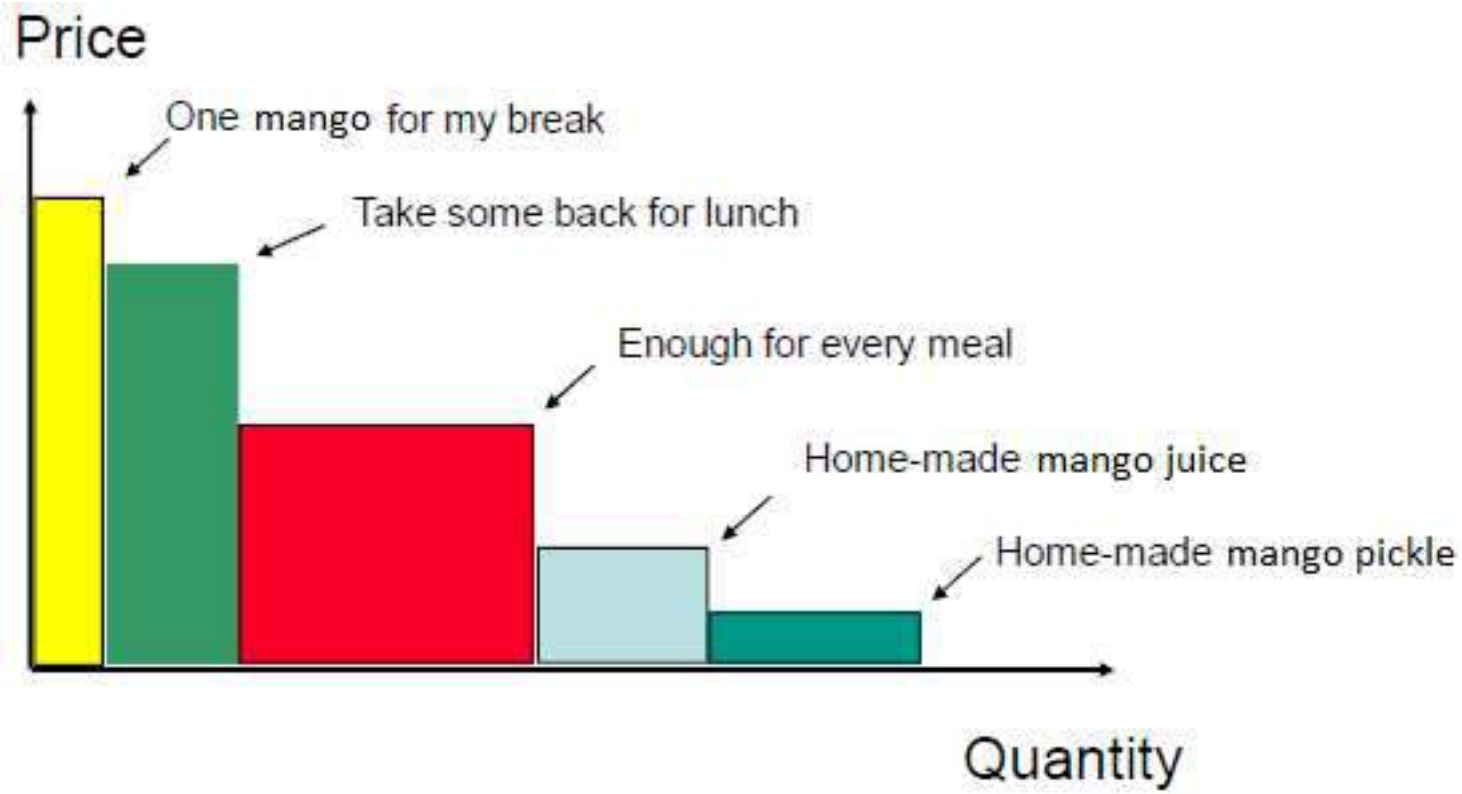
Basics of Power System Economics

EMP @ LUMS
July 17-22, 2018

Let us go to the market...

- Opportunity for buyers and sellers to:
  - compare prices
  - estimate demand
  - estimate supply
- Achieve an equilibrium between supply and demand

How much do I value Mangoes?

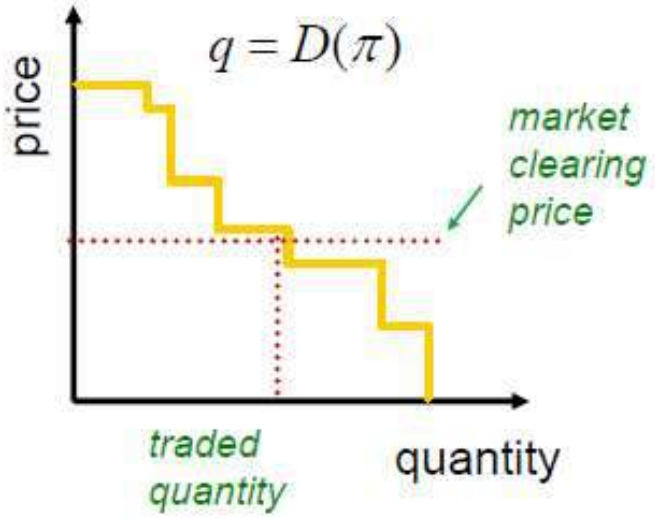


Consumers spend until the price is equal to their marginal utility

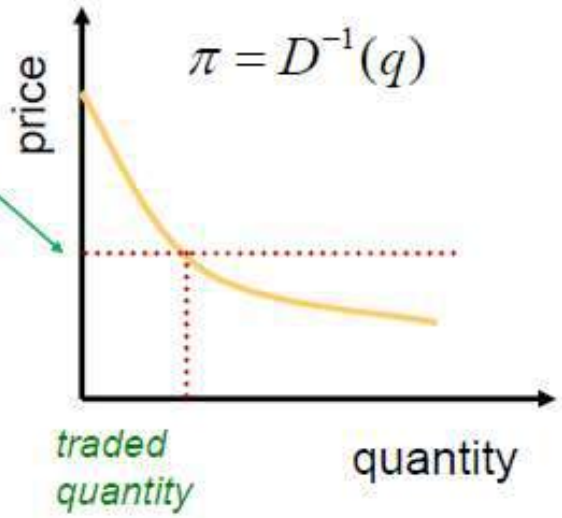
Modeling Consumers

- Consumers behaviour is modelled by the demand curve – aggregation of the individual demands of all consumers

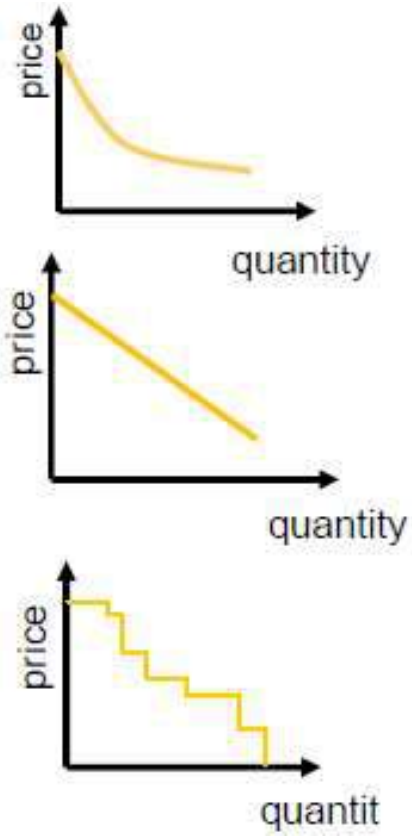
Demand Function



Inverse Demand Function

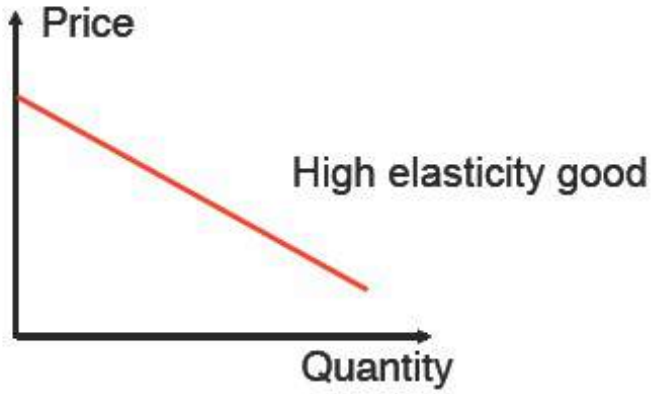


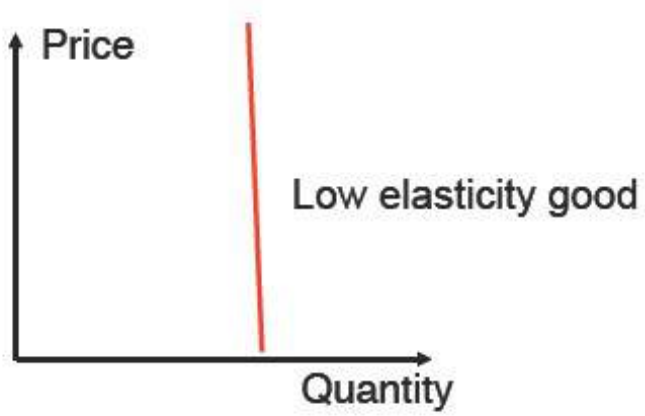
Modeling Consumers



- *Consumers spend until the price is equal to their marginal utility*
- What does that mean?
  - If you produce pickle, you will buy only when a price is sufficiently low so that after selling it you have earned some profit
  - ….. or if it is less expensive than buying pickle at a store ….

Elasticity of the demand





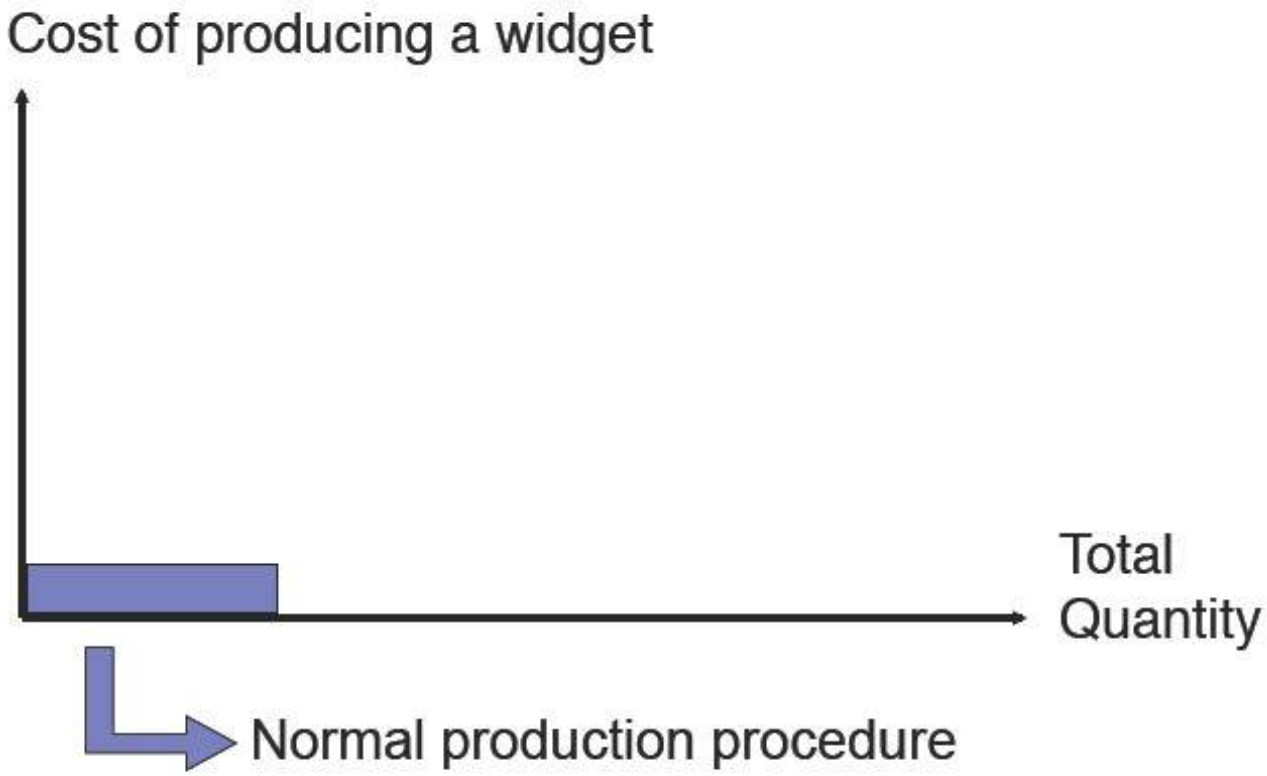
- Slope is an indication of the elasticity of the demand
- High elasticity
  - Non-essential good
  - Easy substitution
- Low elasticity
  - Essential good
  - No substitutes
- Electrical energy has a very low elasticity in the short term

Supply side

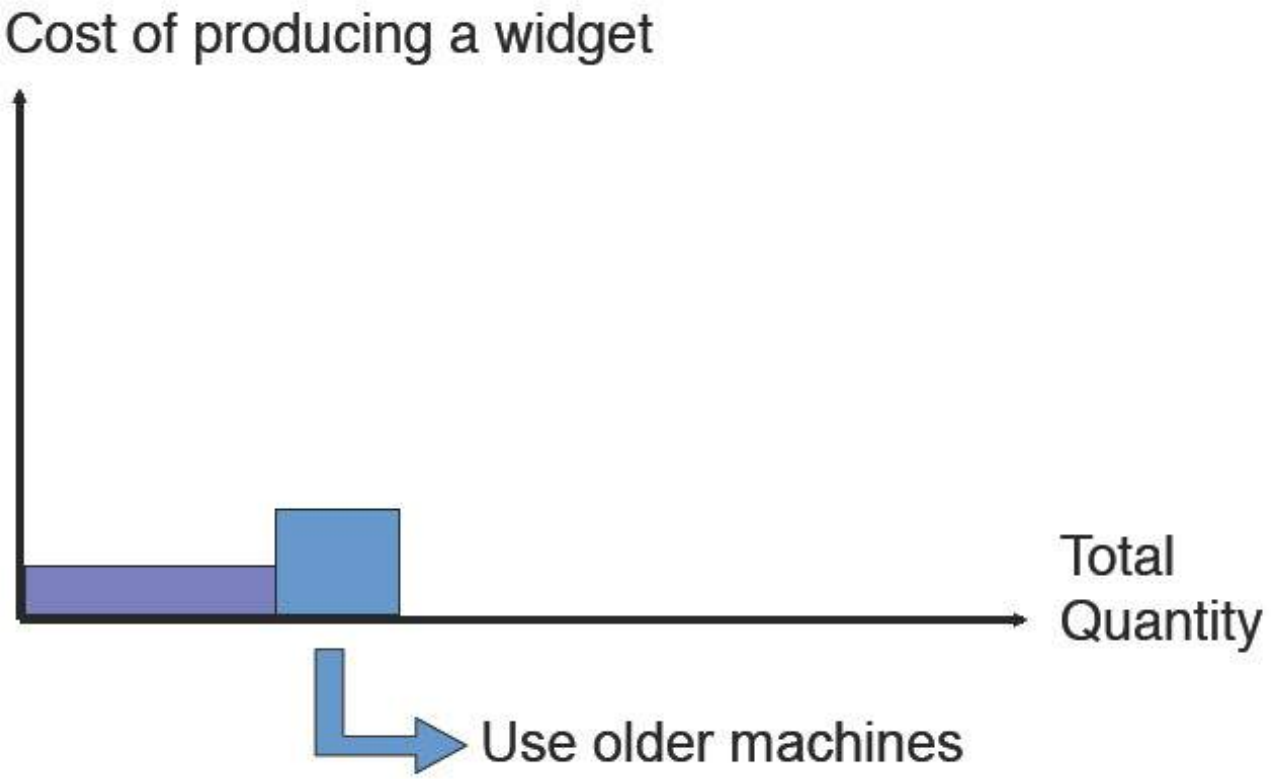
- How many widgets shall I produce?
  - Goal: make a profit on each widget sold
  - Produce one more widget if and only if the cost of producing it is less than the market price

- Need to know the cost of producing the next widget
- Considers only the variable costs
- Ignores the fixed costs
  - Investments in production plants and machines

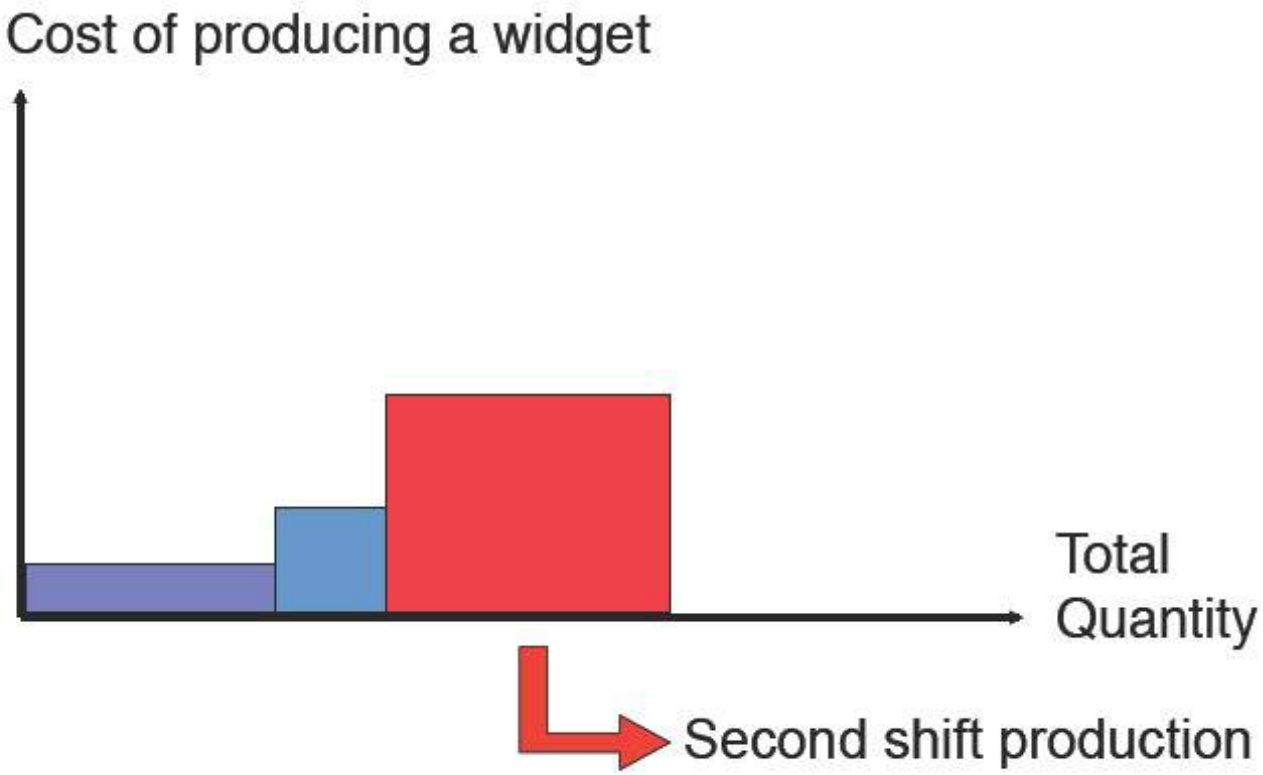
How much does the next one costs?



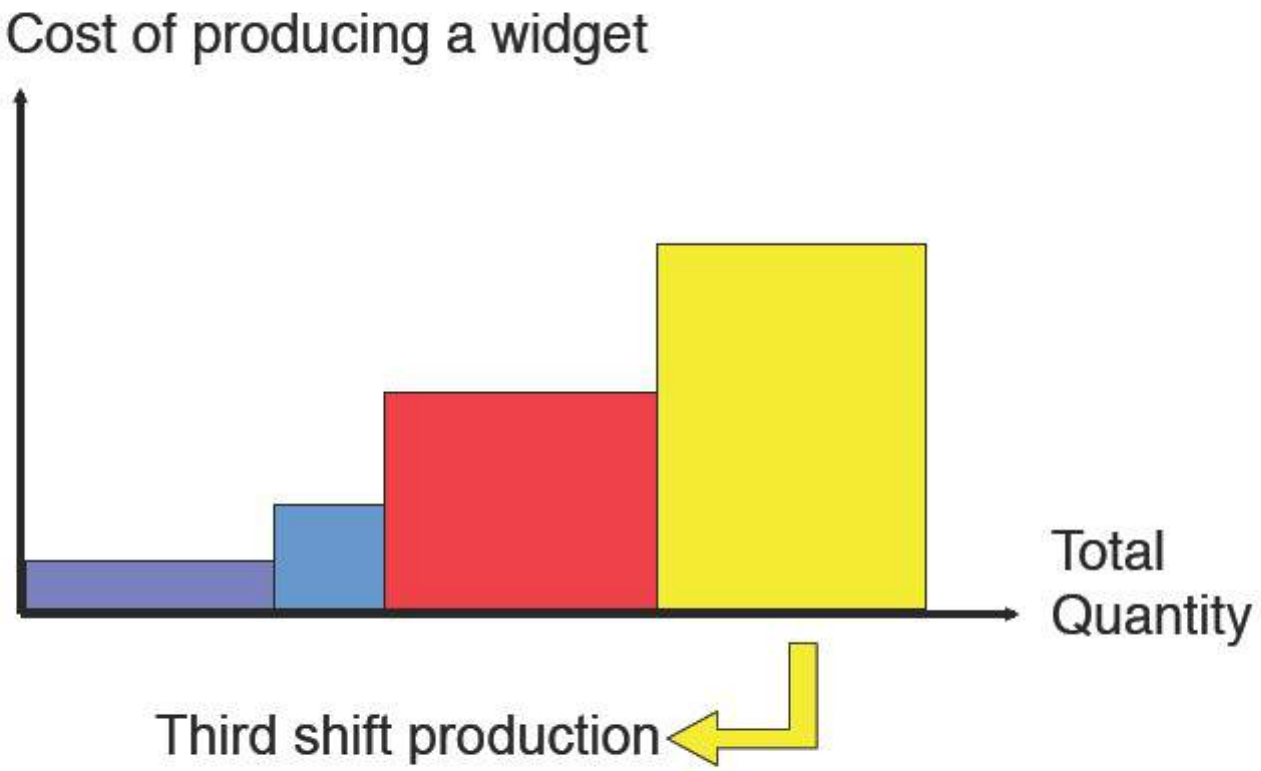
How much does the next one costs?



How much does the next one costs?

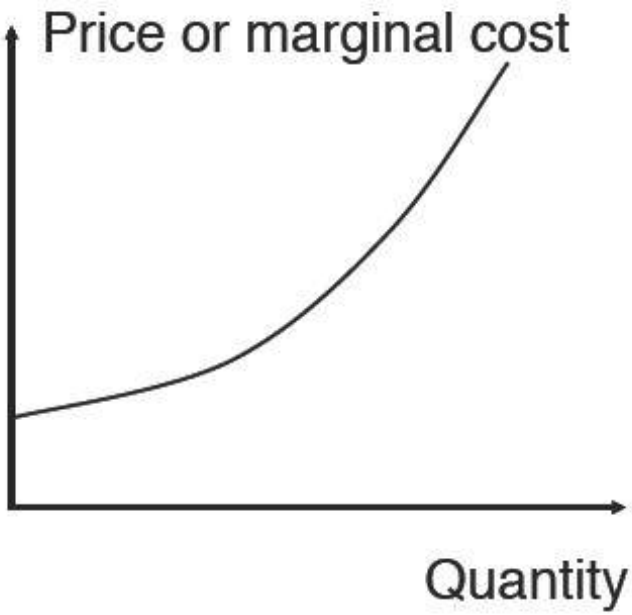


How much does the next one costs?



How much does the next one costs?

Supply curve



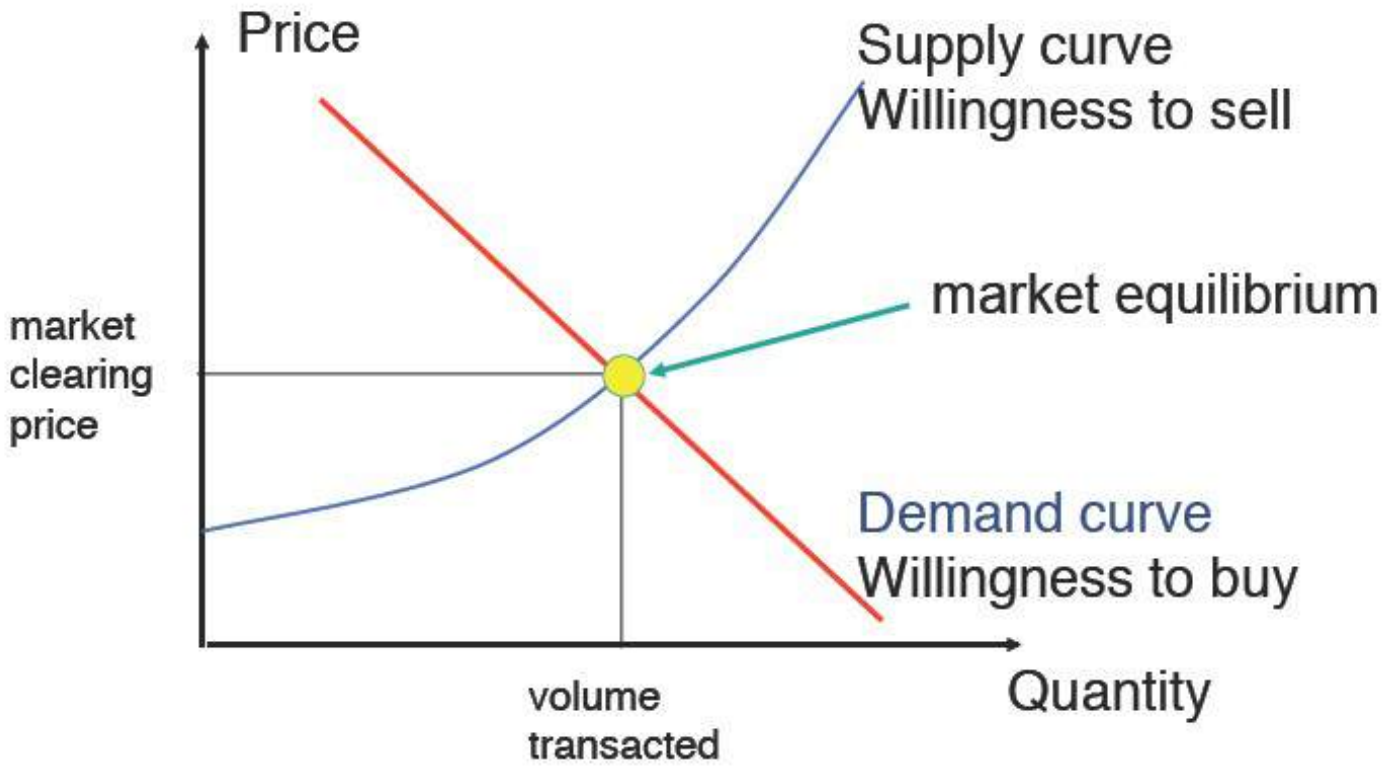
- Aggregation of marginal cost curves of all suppliers
- Considers only variable operating costs
- Does not take cost of investments into account
- Supply function:

$$\pi = S^{-1}(q)$$

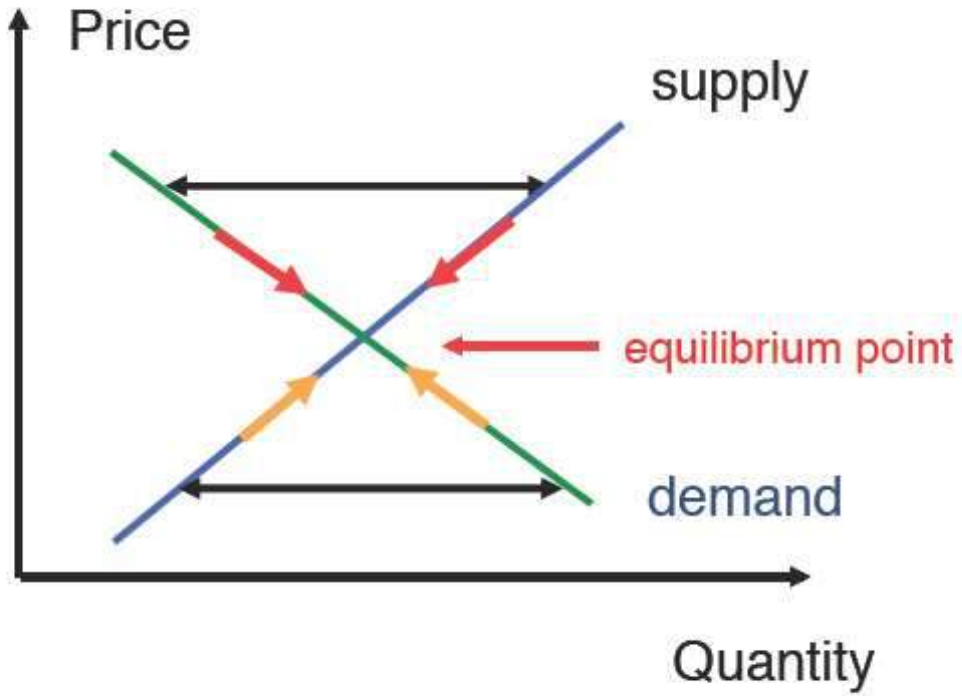
- Inverse supply function:

$$q = S(\pi)$$

Market equilibrium



Supply and Demand

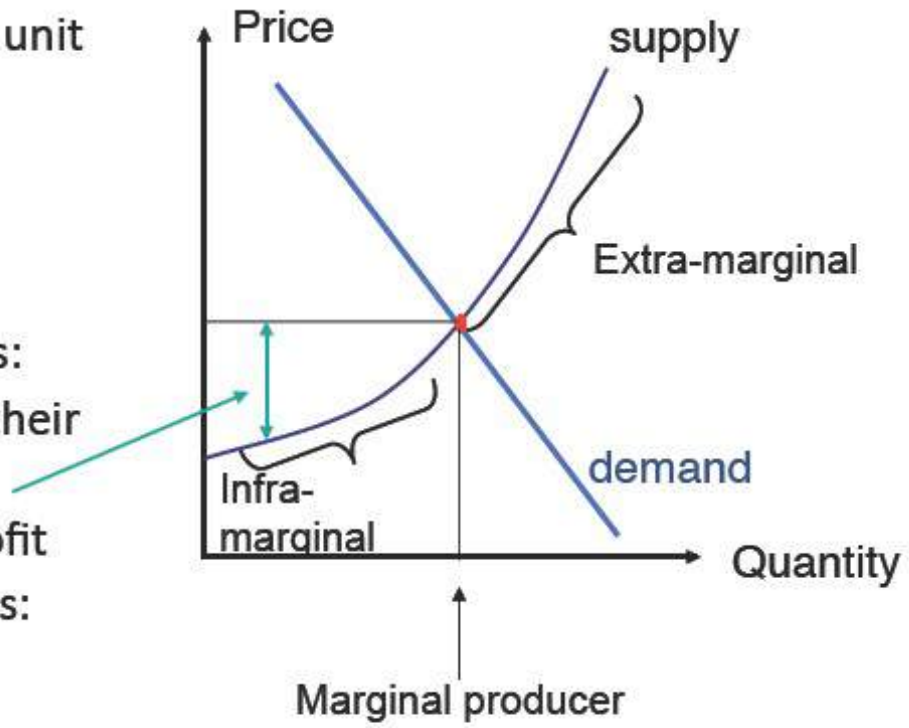


Centralized auction

- Producers enter their offers: quantity and price
  - Offers are stacked up to construct the supply curve
- Consumers enter their bids: quantity and price
  - Bids are stacked up to construct the demand curve
- Intersection determines the market equilibrium:
  - Market clearing price
  - Transacted quantity

Centralized auction

- Everything is sold at the market clearing price
- Price is set by the "last" unit sold
- Marginal producer:
  - Sells this last unit
  - Gets exactly its offer
- Infra-marginal producers:
  - Get paid more than their offer
  - Collect economic profit
- Extra-marginal producers:
  - Sell nothing



Bilateral transactions

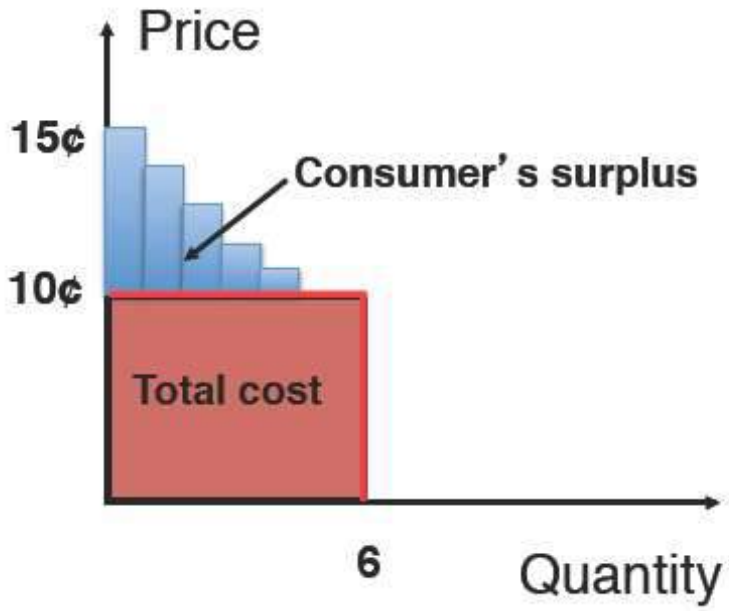
- Producers and consumers trade directly and independently
- Consumers "shop around" for the best deal
- Producers check the competition's prices
- An efficient market "discovers" the equilibrium price

What makes a market efficient?

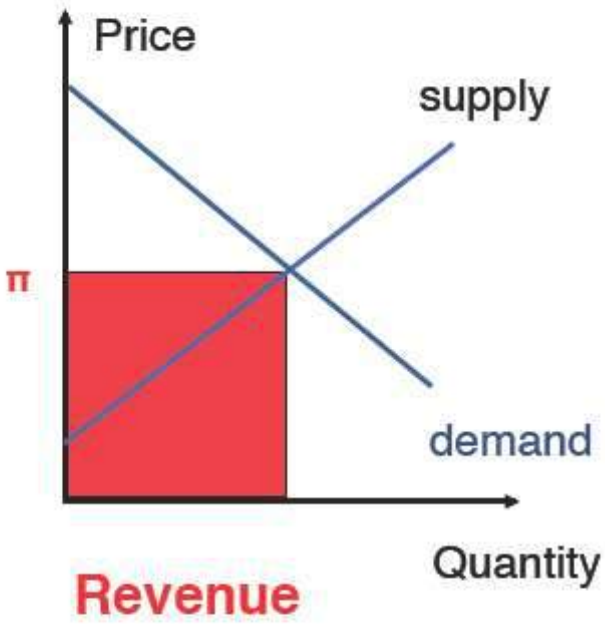
- All buyers and sellers have access to sufficient information about prices, supply and demand
- Factors favouring an efficient market
  - Number of participants
  - Standard definition of commodities
  - Good information exchange mechanisms

Consumer's Surplus

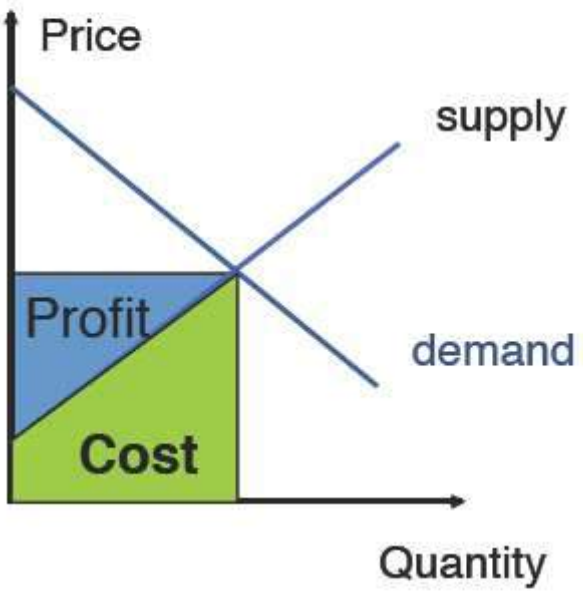
- Buy 6 apples at 10¢
- Total cost = 60¢
- At that price I am getting apples for which I would have been ready to pay more
- Surplus: 5+4+3+2+1=15¢



Economic Profit of Suppliers

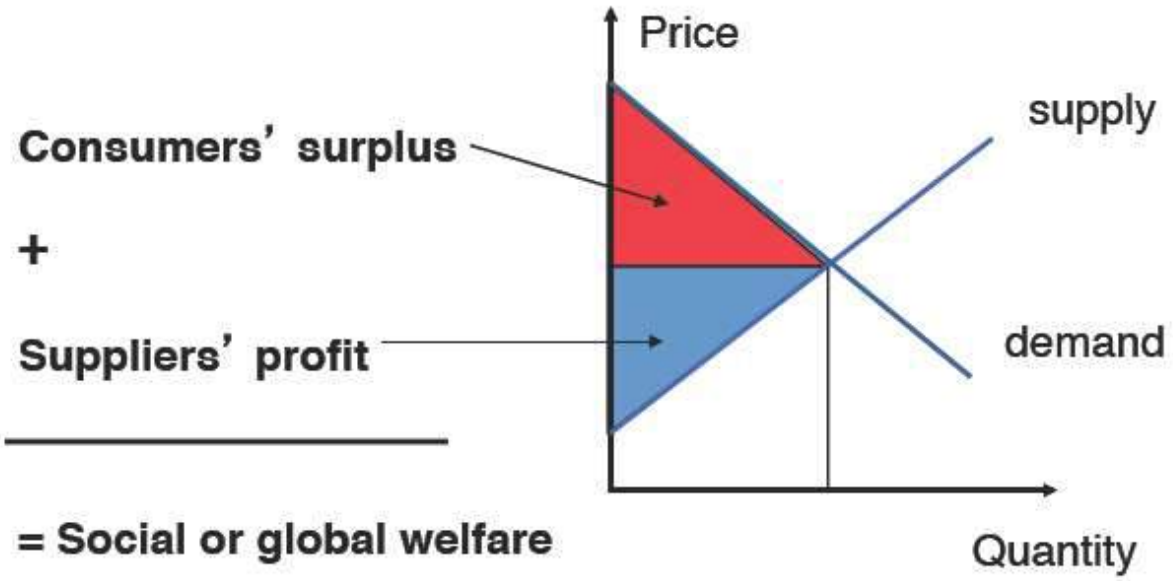


Revenue

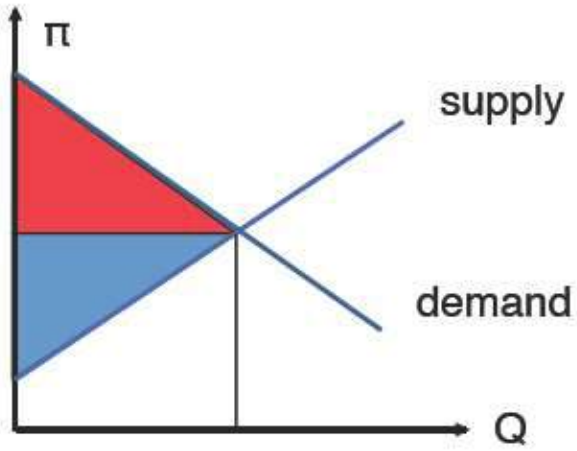


- Cost includes only the variable cost of production
- Economic profit covers fixed costs and shareholders' returns

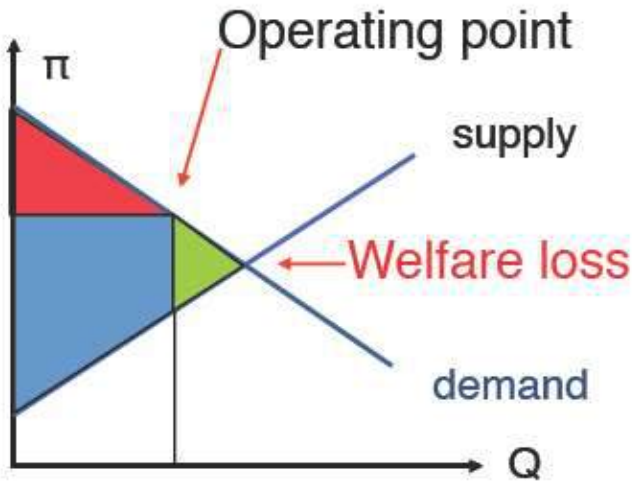
Social or Global Welfare



Market equilibrium and social welfare

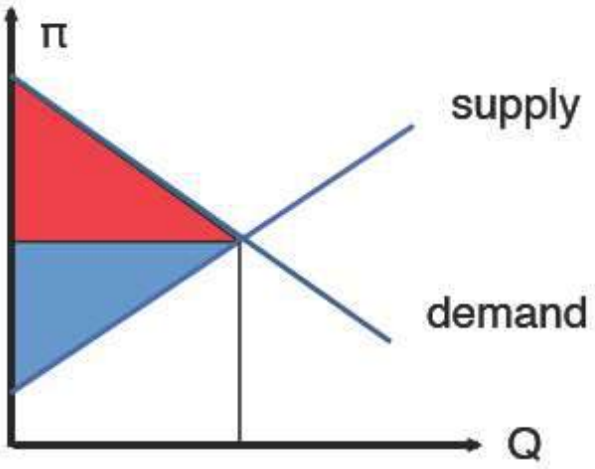


Market equilibrium

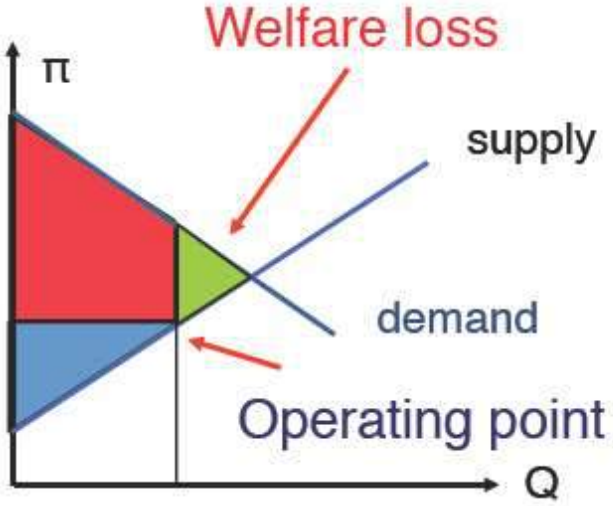


Artificially high price:
- larger supplier profit
- smaller consumer surplus
- smaller social welfare

Market equilibrium and social welfare



Market equilibrium



Artificially low price:
- smaller supplier profit
- higher consumer surplus
- smaller social welfare

Market Equilibrium: Summary

- Price = marginal revenue of supplier
  = marginal cost of supplier
  = marginal cost of consumer
  = marginal utility to consumer

Time varying prices

- Market price varies with offer and demand:
  - If demand increases
    - Price increases beyond utility for some consumers
    - Demand decreases
    - Market settles at a new equilibrium
  - If demand decreases
    - Price decreases
    - Some producers leave the market
    - Market settles at a new equilibrium
- In theory, there should never be a shortage
- Encourages efficient use of resources

Time-varying prices vs. fixed price

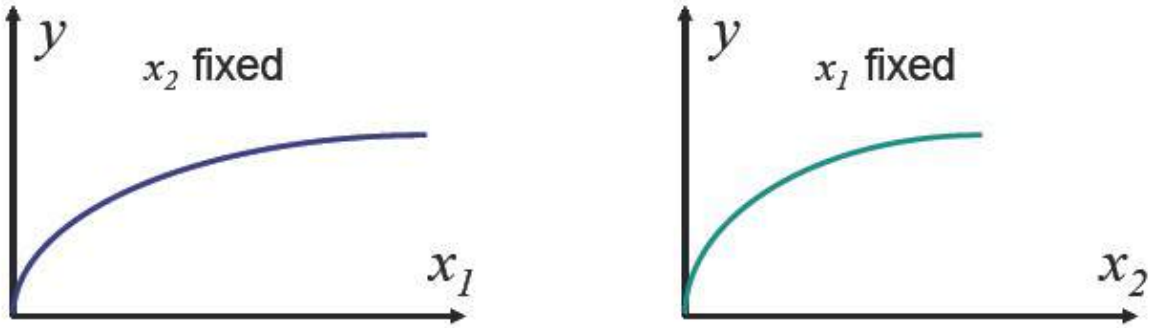
- Assume fixed price = average of market price
- Period of high demand
  - Fixed price < marginal utility and marginal cost
  - Consumers continue buying the commodity rather than switch to another commodity
- Period of low demand
  - Fixed price > marginal utility and marginal cost
  - Consumers do not switch from other commodities
- Inefficient allocation of resources

Concepts from the Theory of the Firm

Production function

$$y = f(x_1, x_2)$$

- y: output
- x_1 , x_2: factors of production



Law of diminishing marginal return

Long run and short run

- Some factors of production can be adjusted faster than others
  - Example: fertilizer vs. planting more trees
- Long run: all factors can be changed
- Short run: some factors cannot be changed
- No specific duration separates long and short run
- Long run = long term
- Short run = short term

Input-output function

$y = f(x_1, \overline{x_2})$ $\overline{x_2}$ fixed

The inverse of the production function is the input-output function

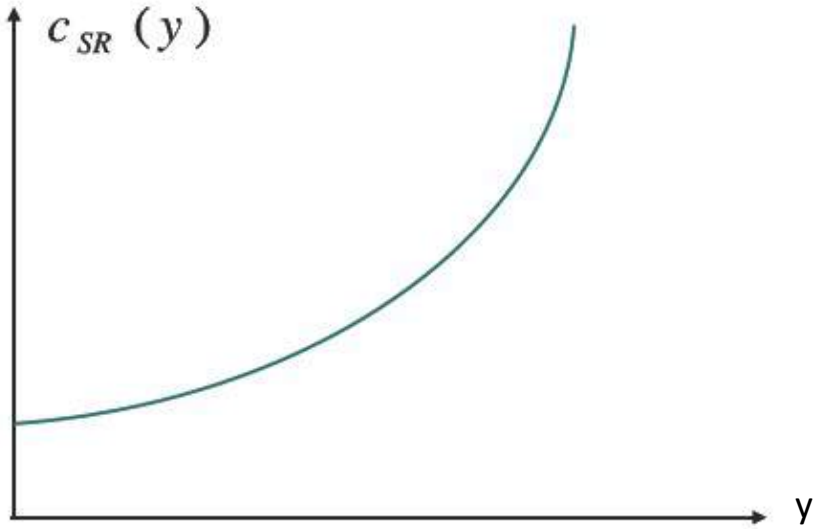
$x_1 = g(y)$ for $x_2 = \overline{x_2}$

Example: amount of fuel required to produce a certain amount of power with a given plant

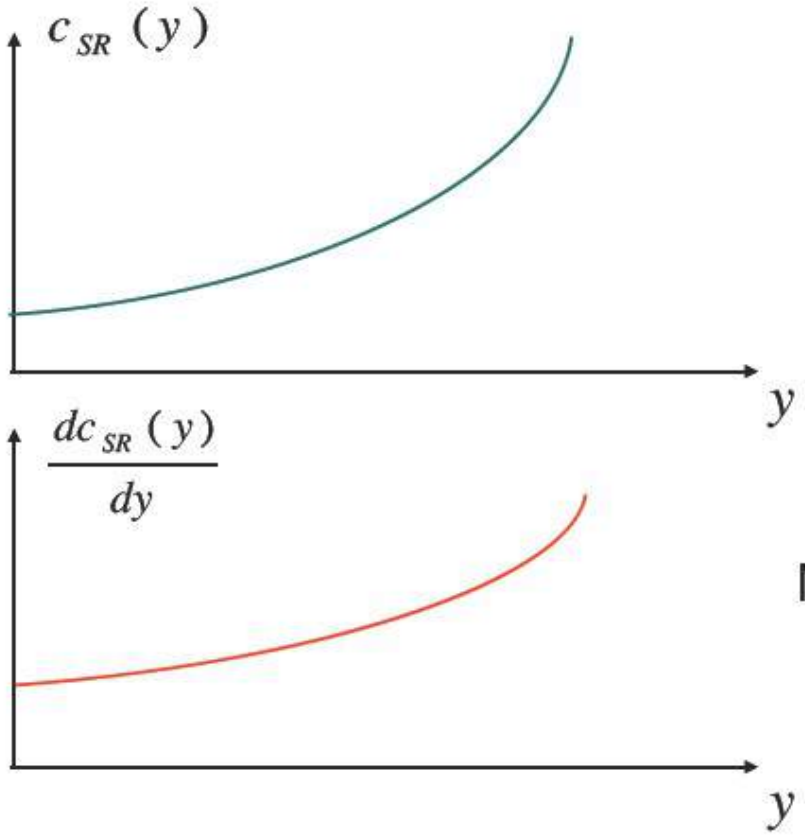
Short run cost function

$$c_{SR}(y) = w_1 \cdot x_1 + w_2 \cdot \overline{x_2} = w_1 \cdot g(y) + w_2 \cdot \overline{x_2}$$

- w_1, w_2: unit cost of factors of production x_1, x_2



Short run marginal cost function



Convex due to law of marginal returns

Non-decreasing function

Optimal production

- Production that maximizes profit:

$$\max_{y}\left\{\pi \cdot y - c_{SR}(y)\right\}$$

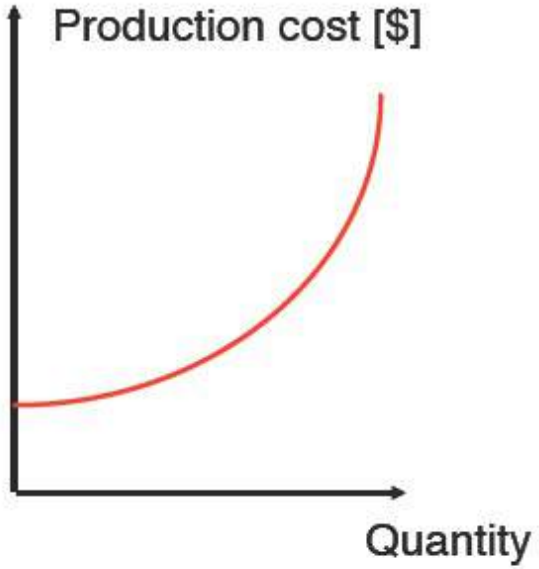
$$\frac{d\left\{\pi \cdot y - c_{SR}(y)\right\}}{dy} = 0$$

$$\pi = \frac{dc_{SR}(y)}{dy}$$

Only if the price π does not depend on y ➔ perfect competition

Costs: Accountant's perspective

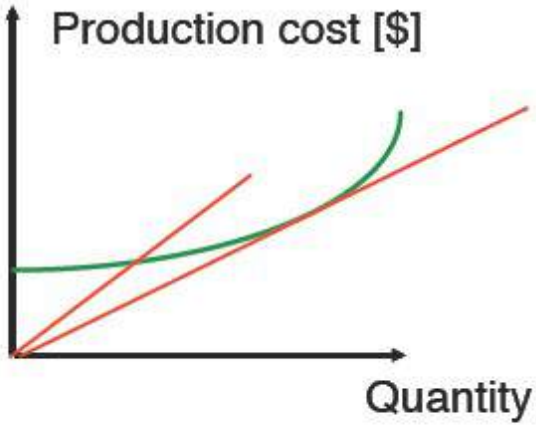
- In the short run, some costs are variable and others are fixed
- Variable costs:
  - labour
  - materials
  - fuel
  - transportation
- Fixed costs (amortized):
  - equipment
  - land
  - Overheads
- Quasi-fixed costs
  - Start-up cost of power plant
- Sunk costs vs. recoverable costs

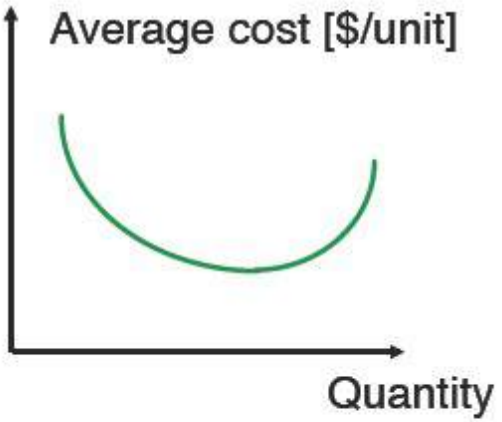


Average cost

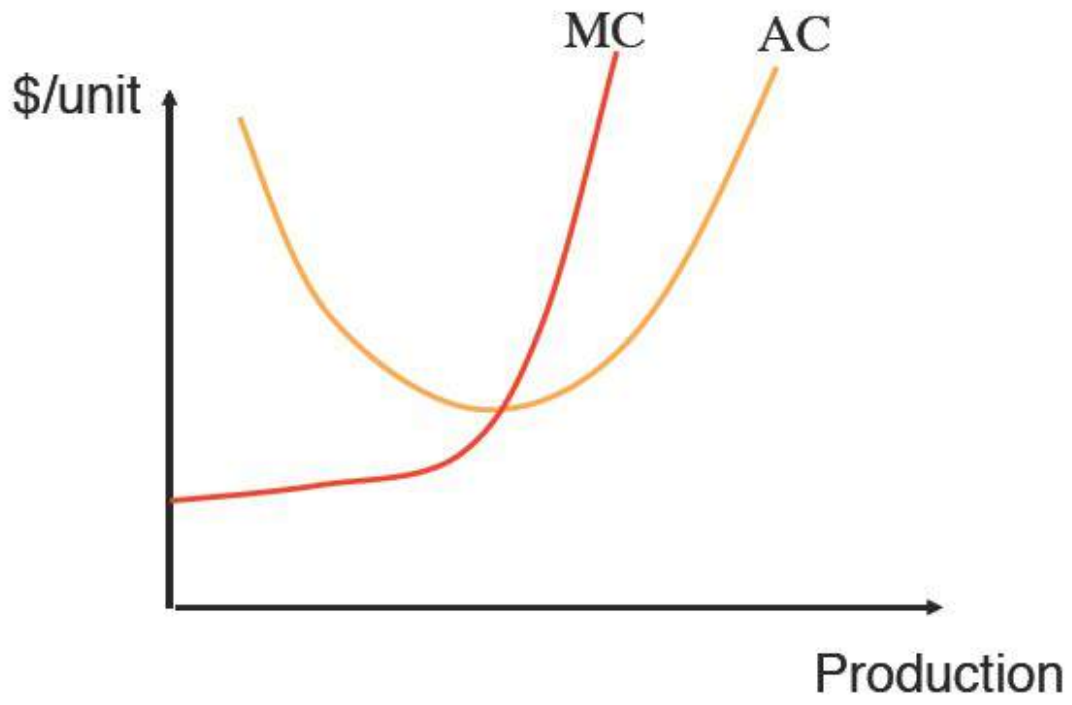
$$c(y) = c_v(y) + c_f$$

$$AC(y) = \frac{c(y)}{y} = \frac{c_v(y)}{y} + \frac{c_f}{y} = AVC(y) + AFC(y)$$



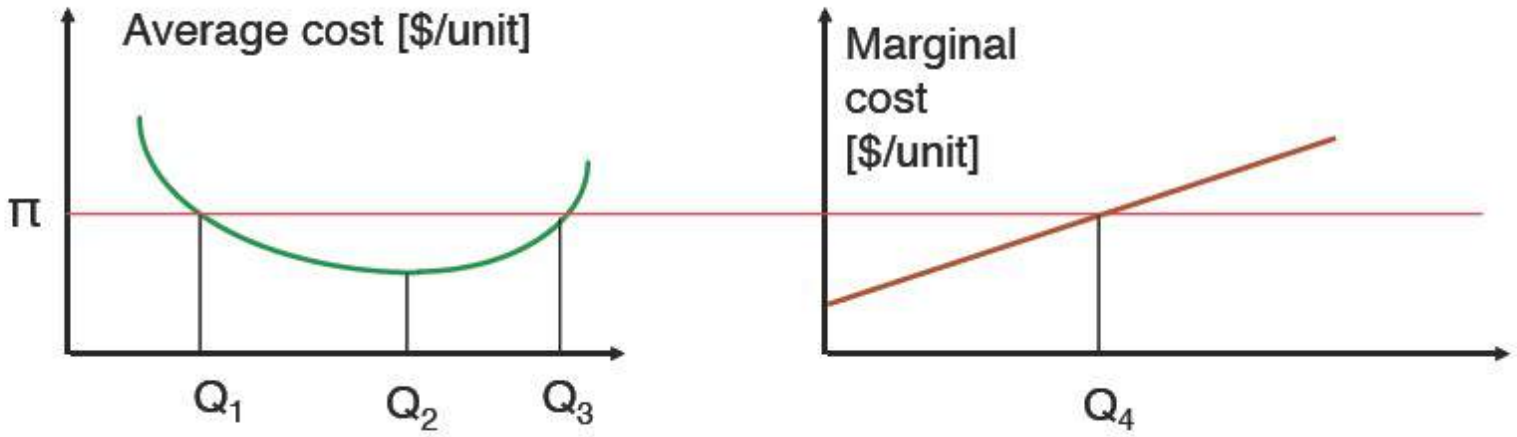


Marginal vs. average cost



When should I stop producing?

- Marginal cost = cost of producing one more unit
- If MC > π next unit costs more than it returns
- If MC < π next unit returns more than it costs
- Profitable only if $Q_4 > Q_1$ because of fixed costs



Costs: Economist's perspective

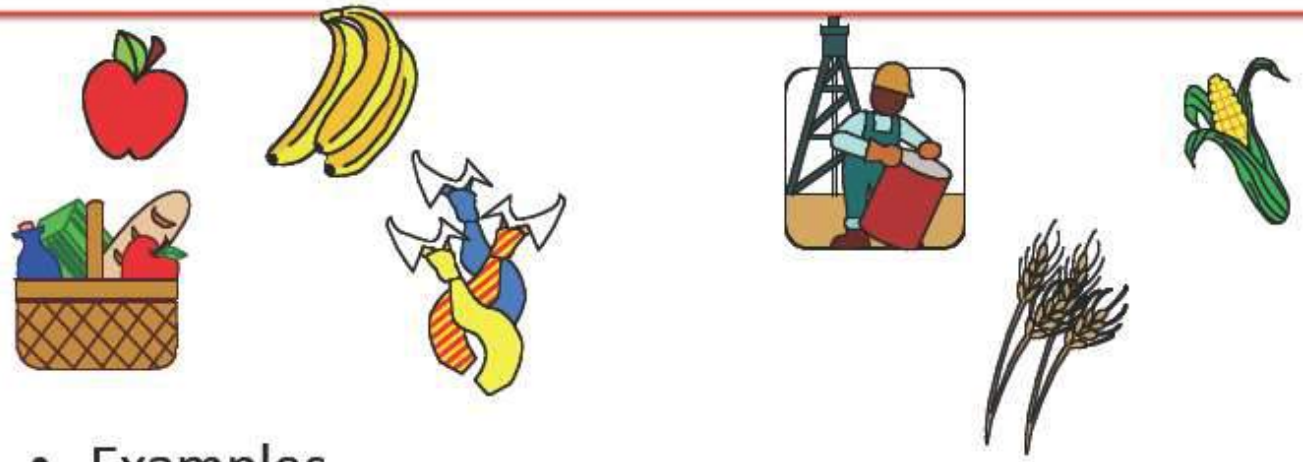
- Opportunity cost:
  - What would be the best use of the money spent to make the product ?
  - Not taking the opportunity to sell at a higher price represents a cost
- Examples:
  - Use the money to grow apples or put it in the bank where it earns interests?
  - Growing apples or growing kiwis?
- Comparisons should be made against a "normal profit"
  - What putting money in the bank would bring
- Selling "at cost" means making a "normal profit"
  - Usually not good enough because it does not compensate for the risk involved in the business

Types of Markets

Spot Market

- Immediate market, "On the Spot"
  - Agreement on price
  - Agreement on quantity
  - Agreement on location
  - Unconditional delivery
  - Immediate delivery

Examples of Spot Markets



- Examples
  - Food market
  - Basic shopping
  - Rotterdam spot market for oil
  - Commodities markets: corn, wheat, cocoa, coffee
- Formal or informal

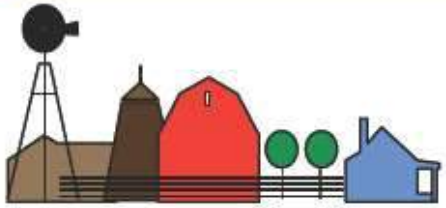
Advantages and Disadvantages

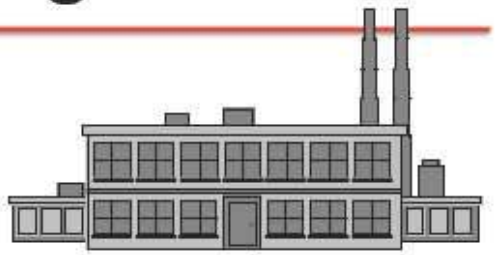
- Advantages:
  - Simple
  - Flexible
  - Immediate
- Disadvantages
  - Prices can fluctuate widely based on circumstances
  - Example:
    - Effect of frost in Brazil on the price of coffee beans
    - Effect of trouble in the Middle East on the price of oil

Spot Market Risks

- Market may not have much depth
  - Not enough sellers: market is short
  - Not enough buyers: market is long
- Lack of depth causes large price fluctuations
  - Small producer may have to sell at a low price
  - Small purchaser may have to buy at a high price
  - "Price risk"
- Relying on the spot market for buying or selling large quantities is a bad idea

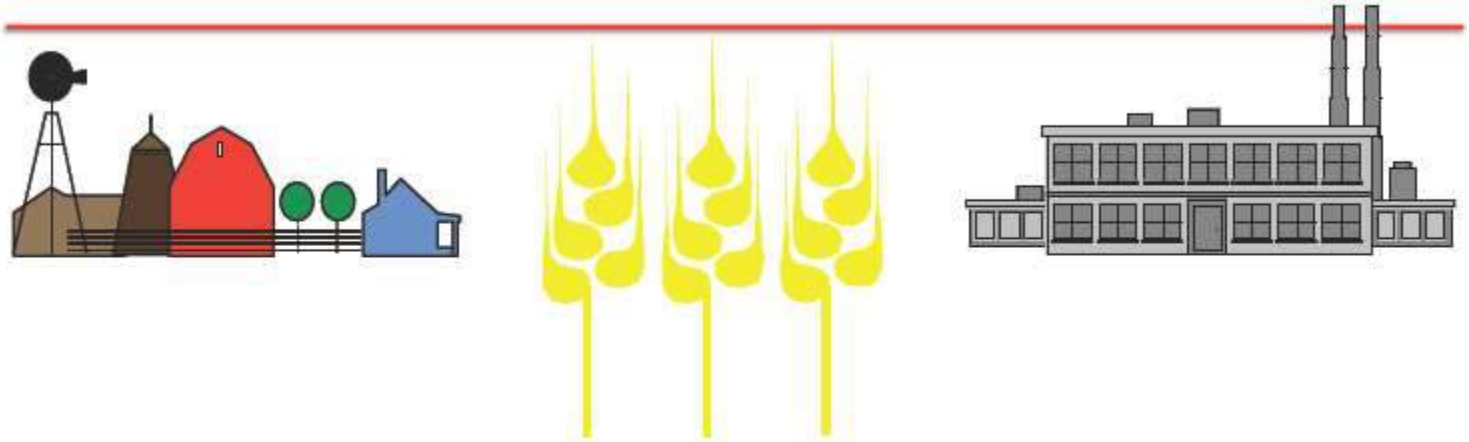
Example: buying and selling wheat





- Farmer produces wheat
- Miller buys wheat to make flour
- Farmer carries the risk of bad weather
- Miller carries the risk of breakdown of flour mill
- Neither farmer nor miller control price of wheat

Harvest time



- If price of wheat is low:
  - Possibly devastating for the farmer
  - Good deal for the miller
- If the price is high:
  - Good deal for the farmer
  - Possibly devastating for the miller

What should they do?

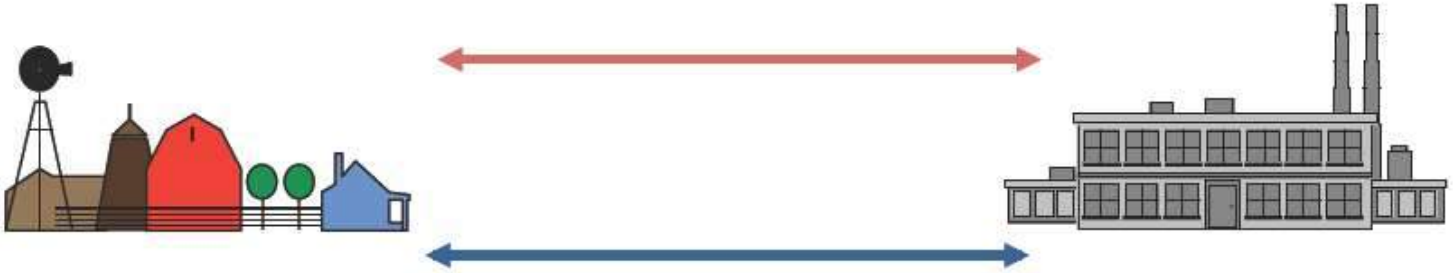
- Option 1: Accept the spot price of wheat
  - Equivalent to gambling
- Option 2: Agree ahead of time on a price that is acceptable to both parties
  - Forward contract

Forward Contract

- Agreement:
  - Quantity and quality
  - Price
  - Date of delivery (not immediate)
- Paid at time of delivery
- Unconditional delivery

Forward Contract

Contract (1June)
1 ton of wheat at $100
on 1 September



Maturity (1 September)
Seller delivers 1 ton of wheat
Buyer pays $100
Spot Price = $90
Profit to seller = $10

How is the forward price set?

- Both parties look at their alternative: spot price
- Both forecast what the spot price is likely to be

Sharing risk

- In a forward contract, the buyer and seller share the risk that the price differs from their expectation
- Difference between contract price and spot price at time of delivery represents a "profit" for one party and a "loss" for the other
- However, in the meantime they have been able to get on with their business
  - Buy new farm machinery
  - Sell the flour to bakeries

Attitudes towards risk

- Suppose that both parties forecast the same value spot price at time of delivery
- Equal attitude towards risk
  - Forward price is equal to expected spot price
- "Risk aversion"

Attitudes towards risk

- If buyer is less risk averse than seller
  - Buyer can negotiate a forward price lower than the expected spot price
  - Seller agrees to this lower price because it reduces its risk
  - Difference between expected spot price and forward price is called a premium
  - Premium = price that seller is willing to pay to reduce risk

Attitudes towards risk

- If buyer is more risk averse than seller
  - Seller can negotiate a forward price higher than the expected spot price
  - Buyer agrees to this higher price because it reduces its risk
  - Buyer is willing to pay the premium to reduce risk

Case 1:

- Farmer estimates that the spot price will be $100
- Miller also forecasts that the spot price will be $100
- They can agree on a forward price of $100

Case 2:

- Farmer estimates that the spot price will be $90
- Miller forecasts that the spot price will be $110
- They can easily agree on a forward price of somewhere between $90 and $110
- Exact price will depend on negotiation ability and relative risk aversion

Case 3:

- Farmer estimates that the spot price will be $110
- Miller forecasts that the spot price will be $90
- Agreeing on a forward price is likely to be difficult unless they have widely different risk aversions

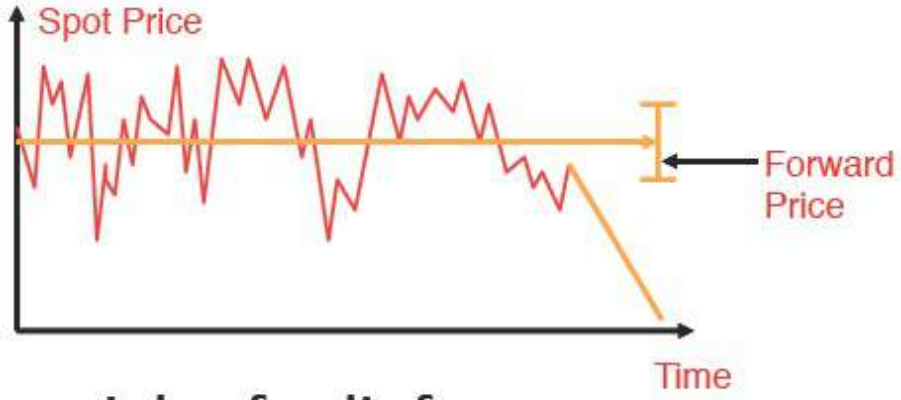
Forward Markets

- Since there are many millers and farmers, a market can be organised for forward contracts
- Forward price represents the aggregated expectation of the spot price, plus or minus a risk premium

What if…

- Suppose that millers are less risk adverse
- Premium below the expected spot price
- Spot price turns out to be much lower than forward price because of a bumper harvest

What if...



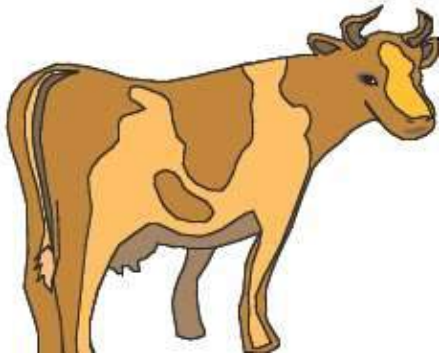
- Farmers breathe a sigh of relief...
- Millers take a big loss
- The following year the millers ask for a much bigger premium
- Is agreement between the millers and the farmers going to be possible?

Undiversified risk

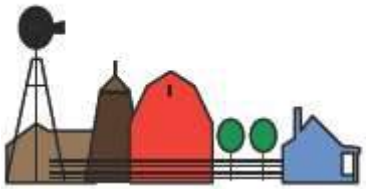
- Farmers and millers deal only in wheat
- Their risk is undiversified
- Can only offset "good years" against "bad years"
- Risk remains high
- Reducing the risk further would help business

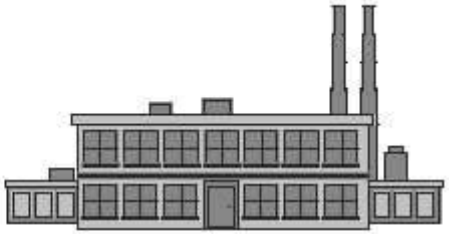
Diversification

- Diversification: deal with more than one commodity
- Average risk over different commodities
- Farmers may not want to diversify their production because it could be inefficient



Physical participants vs. traders





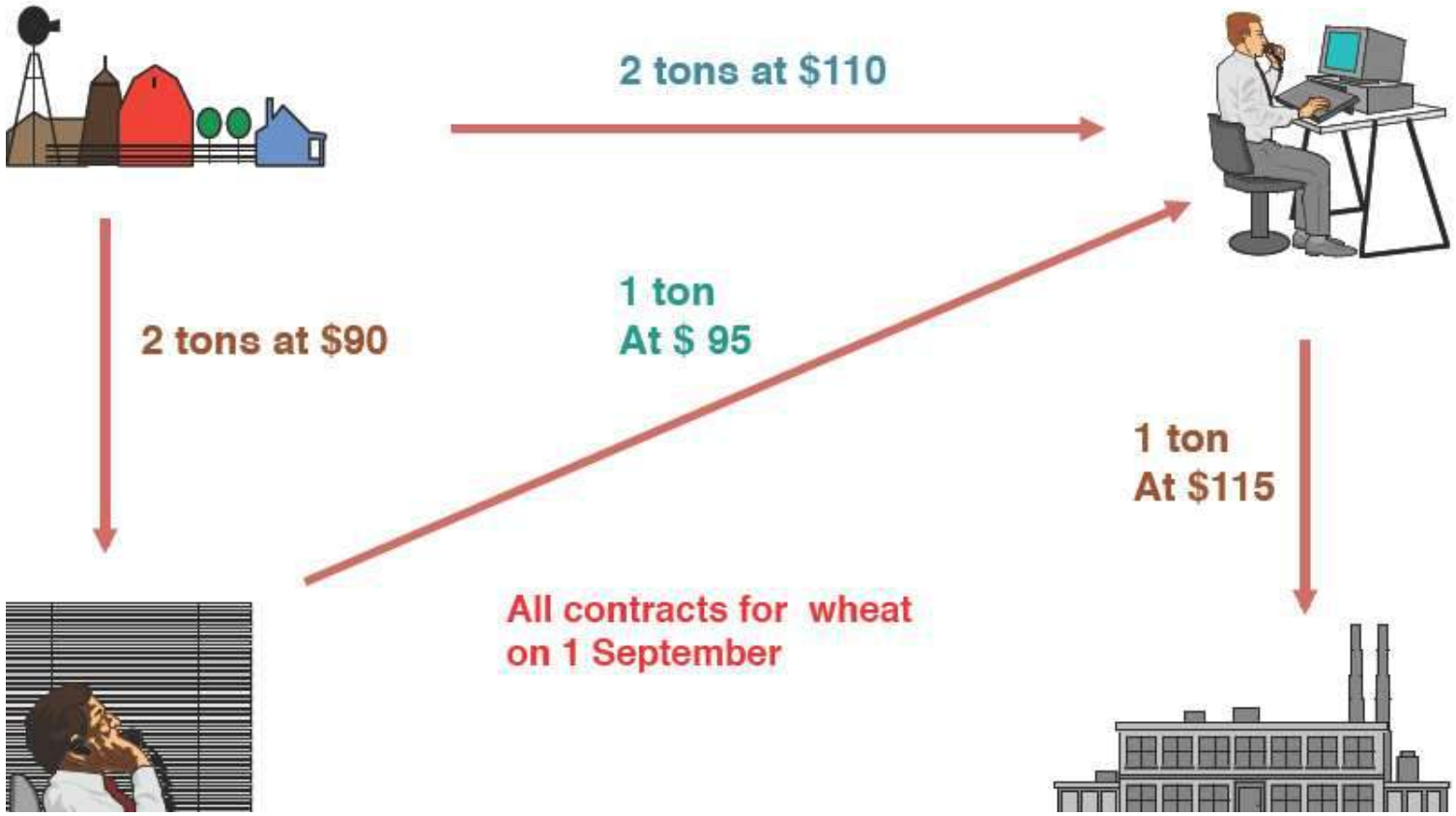
- Physical participants
  - Produce, consume or can store the commodity
  - Face undiversified risk because they deal in only one commodity

- Traders (a.k.a. speculators)
  - Cannot take physical delivery of the commodity
  - Diversify their risk by dealing in many commodities
  - Specialize in risk management

Trading by speculators

- Cannot take physical delivery of the commodity
- Must balance their position on date of delivery
  - Quantity bought must equal quantity sold
  - Buy or sell from spot market if necessary
- May involve many transactions
- Forward contracts limited to parties who can take physical delivery
- Need a standardised contract to reduce the cost of trading: future contract
- Future contracts (futures) allow others to participate in the market and share the risk

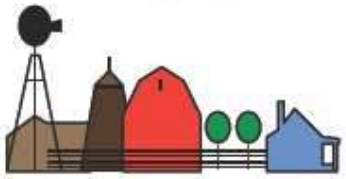
Futures Contract



Futures Contract

Shortly before 1 September

Spot Price $100



sold 2 tons at $110
sold 2 tons at $90

bought 2 tons at $110
bought 1 ton at $95
sold 1 ton at $115

Delivers 4 tons

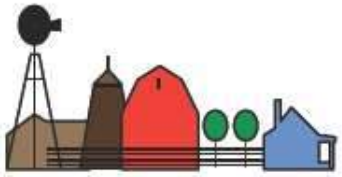
Sells 2 tons at $100

bought 2 tons at $90
sold 1 ton at $95

Sells 1 ton at $100

bought 1 ton at $115

Futures Contract



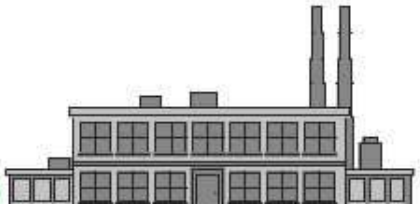
sold 2 tons at $110
sold 2 tons at $90

bought 2 tons at $110
bought 1 ton at $95
sold 1 ton at $115
sold 2 tons at $100
net profit: $0

bought 2 tons at $90
sold 1 ton at $95
sold 1 ton at $100
net profit: $15

Spot Price = $100

bought 1 ton at $115
bought 3 tons at $100



Importance of information

- Speculators own some of the commodity before it is delivered
- They carry the risk of a price change during that period
- Need deep pockets
- Without additional information, this is gambling
- Information helps speculators make money
- Example:
  - Global perspective on the harvest for wheat
  - Long term weather forecast and its effect on the demand for gas and electricity

Options

- Spot, forward and future contracts: unconditional delivery

- Options: conditional delivery
  - Call Option: right to *buy* at a certain price at a certain time
  - Put Option: right to *sell* at a certain price at a certain time
- Two elements of the price:
  - Exercise or strike price = price paid when option is exercised
  - Premium or option fee = price paid for the option itself

Example of Call Option

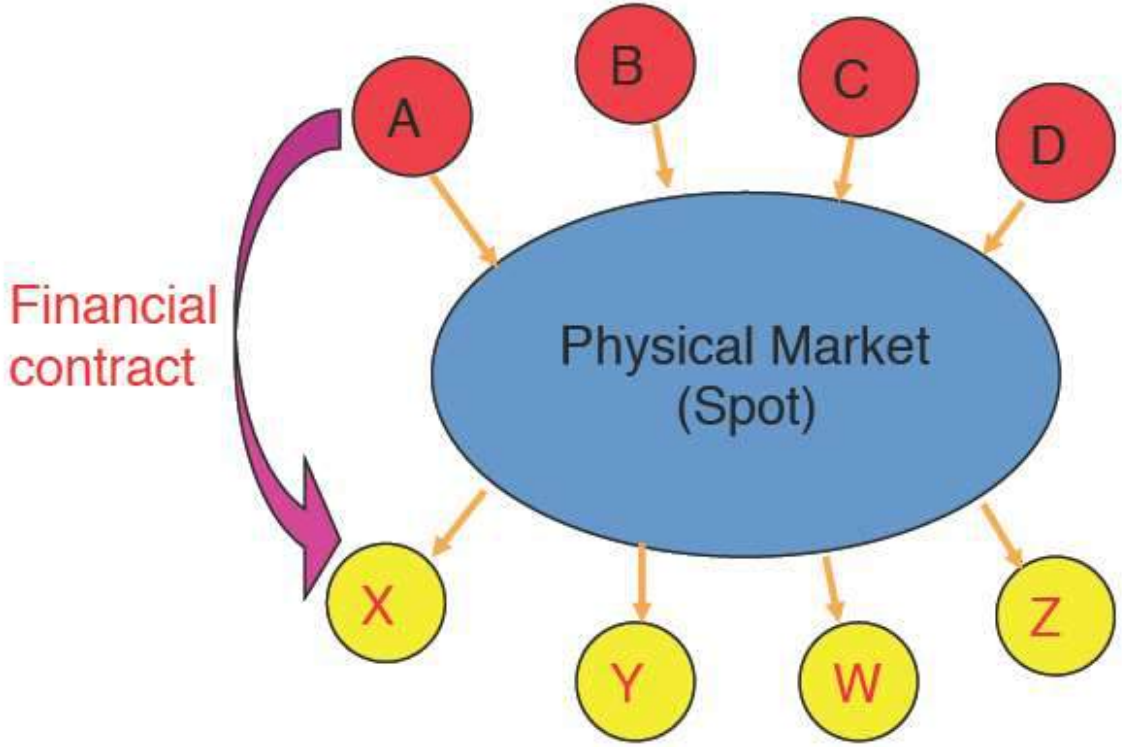
- Call Option with an exercise price of $100
- About to expire
- If the spot market price is $90 the option is worth nothing
- If the spot market price is $110 the option is worth $10
- Holder makes money if value > option fee

Example of Put Option

- Put Option with an exercise price of $100
- About to expire
- If the spot market price is $90 the option is worth $10
- If the spot market price is $110 the option is worth nothing
- Holder makes money if value > option fee

Financial Contracts

- Contracts without any physical delivery



One-way contract for difference

- Example:
  - Buyer has call option for 50 units at $100 per unit
  - Spot price goes up to $110 per unit
  - Buyer pays $5500 for the 50 units in the physical market
  - Seller receives $5500 for the 50 units in the physical market
  - Buyer calls the option to buy 50 units at $100
  - Seller transfers $500 to the buyer to settle the contract

Two-Way Contract for Difference

- Combination of a call and a put option for the same price --> will always be used
- Example 1: CFD for 50 units at $100
  - spot price = $110
  - buyer pays $5500 on physical (spot) market
  - seller receives $5500 from the physical market
  - seller pays buyer $500
  - buyer effectively pays $5000
  - seller effectively gets $5000

Two-Way Contract for Difference

- Example 2: CFD for 50 units at $100
  - spot price = $90
  - buyer pays $4500 to the physical (spot) market
  - seller receives $4500 from the physical market
  - buyer pays seller $500
  - buyer effectively pays $5000
  - seller effectively gets $5000
- Buyer and seller "insulated" from physical market

Is Trading of Energy Contracts on Existing Commodities Exchange Possible?

Differences Between Electricity and Red Chili as a Commodity

#	Characteristics	Electricity as Commodity	Red Chili as a Commodity
1	**No Storage/ Inventory**	Electricity cannot be stored like other commodities. Currently, there are technologies that are under research for the storage of electricity. However, it is still not economical to store large quantities of electrical energy.	Other commodities are storable. For example, red chili can be stored easily and can be used on need basis.
2	**Consumption is linked with real time production**	Because the Electrical Energy is not a storable commodity, it must be produced instantaneously when demanded, e.g. when we switch on light, additional generation must kick-in spontaneously	This is not the case with red chili, e.g. red chili can be stored and consumed whenever needed.
3	**System Operator's Role**	In electric power system, the System Operator keeps the equation "Energy Produced = Energy Demanded" in balance, on second by second basis, otherwise the whole system can collapse. The System Operator also clears the generators for dispatch. The Physical Markets have very tight connection with System Operator who is responsible for the dispatch of electricity on real time basis	There is no such need for central balancing on a real-time basis like in an electricity's market. Chilis can be stored for use later-on. Even in-case of imbalances between demand and supply, the whole market place does not collapse, as in electricity market

#	Characteristics	Electricity	Red Chili as a Commodity
4	**Price Elasticity of Demand**	The short-run price elasticity to demand is low, therefore, balancing supply and demand requires productions facilities to follow large variations in demand. In-order to follow this demand, different generators are run resulting in the changing of marginal cost of electricity to vary throughout the day.	Owing to the availability of the storage facilities, the production does not have to follow the variations in demand on short term basis and thus, the short-run-marginal costs do not change as in electricity
5	**Can't Direct Electricity from a Particular Seller to a Buyer**	Energy produced by one generator can't be directed towards one specific consumer in Grid. The electricity follows the least resistant path. Therefore, the energy generated is pooled and is transferred to consumers following laws of physics	In case of chili's market, any consumer can be supplied the product from any producer. There is an infrastructure of transportation available which can be used freely between the suppliers and demand
6	**Deviations between Contracted Amounts and Actual Consumptions**	As consumers are connected to electrical grid and one can't limit their consumption in real-time, therefore consumers continue to draw electrical energy as per their instantaneous need e.g. even it is more than contracted amount. Therefore, there will always be differences between contracted and consumed quantities. In all markets around the globe these deviations settlement will require a mechanism to settle through Market Operator	The chili's market does not have any such deviations. The buyer purchases, what is contracted.

#	Characteristics	Electricity	Red Chili as a Commodity
7	**Centrally & Self Dispatch Markets**	In wholesale electricity markets there are two types of markets, Centrally dispatched and Self-dispatched. Centrally dispatch market (like Pakistan) requires (non-embedded) generators to be dispatched based on a Security Constrained Economic Dispatch (SCED) by System Operator centrally. In a Self-dispatch market the generators are self-dispatched based on contracts and this also requires System Operator to see the constraints allowing these dispatches. In both cases MO and SO are integral part market.	These concepts are alien for Chili market
8	**Transmission Network (the Market-place)**	The electrical energy between the buyers and sellers is transported over wires (transmission and distribution networks). The transmission and distribution networks, because of extensive constraints, imposes restrictions on dispatch that would limit/distort free trading. The System Operator also clears the generators for dispatch based on such restrictions & consequently impacts the contracted quantities. Therefore, market designs for trading has to account for all such factors.	There is no such physical network other than transportation infrastructure that is required to deliver the chilies. The roads are accessible to everyone and can be used for the purpose of delivery of the product at any time and thus, free trading is possible.
9	**Electricity Regulator's Role**	The electricity regulator approves the capital investments in transmission and distribution lines expansions, approves the operational costs, provides electricity market rules, monitors markets based on those rules, issues technical codes for operation of grid, commercial code for market settlement, etc.	These concepts are alien for commodities market's regulators