Energy markets

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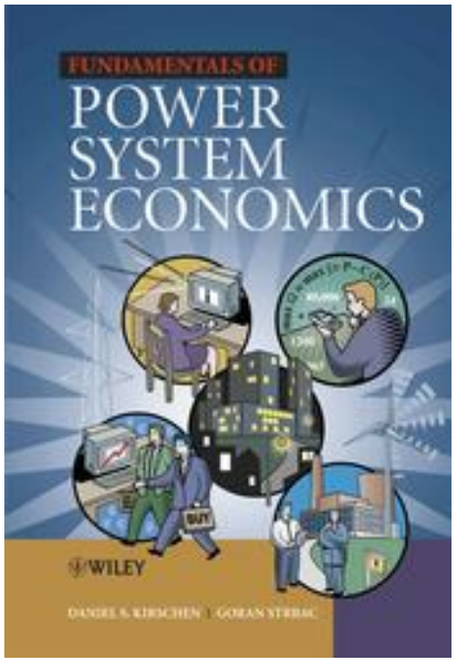
Goal of this class: to learn about energy markets.

Class every Friday between 2pm and 6pm, local R21. 11 classes in total.

How is it organized?: (i) Class 1-6. Fundamentals of power system economics. Teacher: Damien Ernst.

(ii) Class 7-9. Invited speakers. (iii) Class 9. Assignment Q&A - Remaining presentations (iv) Project defenses



Every lesson of the first five classes (except the first one) is divided into four parts: (i) a 'classical' lecture by myself (ii) discussion about a research paper (in an inverse teaching mode) (iii) discussion about the project (iv) oral presentations by the students.

Final note: (i) 6 out of 20 points for the oral presentations of the students and their capacity to discuss correctly the research papers that they will have to read before every lesson (ii) 6 out of 20 points for the project (iii) 8 points for the oral exam.

Chapter 1. Introduction

Key points on electricity market liberalization

Vertically integrated structure (monopoly): same company produces, transmits and distributes (directly or not) the product to the consumers at a single imposed price.

Since the 1980s, it has been argued that this model was inefficient:
1] no incentive to operate efficiently and encourages unnecessary investments
2] politics interfering with good economics, ...

Unbundled structure: generation company and transportation company are different. The consumers choose the provider(s). Price components: product + transportation. Product and transportation managed commercially by different companies. Product traded on specific market(s) according to transactions or contracts (buyer, seller, quantity, price and time of delivery).

Shift in many countries from an vertically integrated to an unbundled structure. Unfortunately, electricity is not a simple commodity...

How to move towards an unbundled structure & competition?

Break up of large electrical generations companies into smaller ones.

Allow the creation of new companies.

Create ISO (Independent System Operator) to perform transmission/distribution in coordination with power plants operation (Europe: TSO / DSO).

Create appropriate trading infrastructures (market places).

Determine the eligibility of the consumers.

Install appropriate metering devices to monitor the transaction performance.

Create a regulating organism to ensure fair and efficient operations for both: electrical energy systems & markets.

Solve all the technical problems appearing with the unbundling of the original system.

Operation and development not taken anymore by a single organization. Is it possible to coordinate the different entities to achieve least cost operation? (e.g., maintenance of transmission system done jointly with the maintenance of operation line, coordination of long-term development in generation and in transmission, etc.)

Will free markets ensure that generation will always match demand?

Definition of the actors & the components

GENco: Generating company (single plant or portfolio of plants). Sells electrical energy through competition in wholesale market. Could compete also to sell ancillary services.

TRANSco: Transmission company. Operates its equipments according to ISO instructions.

ISO: Independent system operator. Responsible for maintaining the security of power system operation. Could also play the role of the Market Operator (MO).

MO: Market operator. Matches generating bids (sellers) and consumption offers (buyers) and issues the contracts according to the mechanism used.

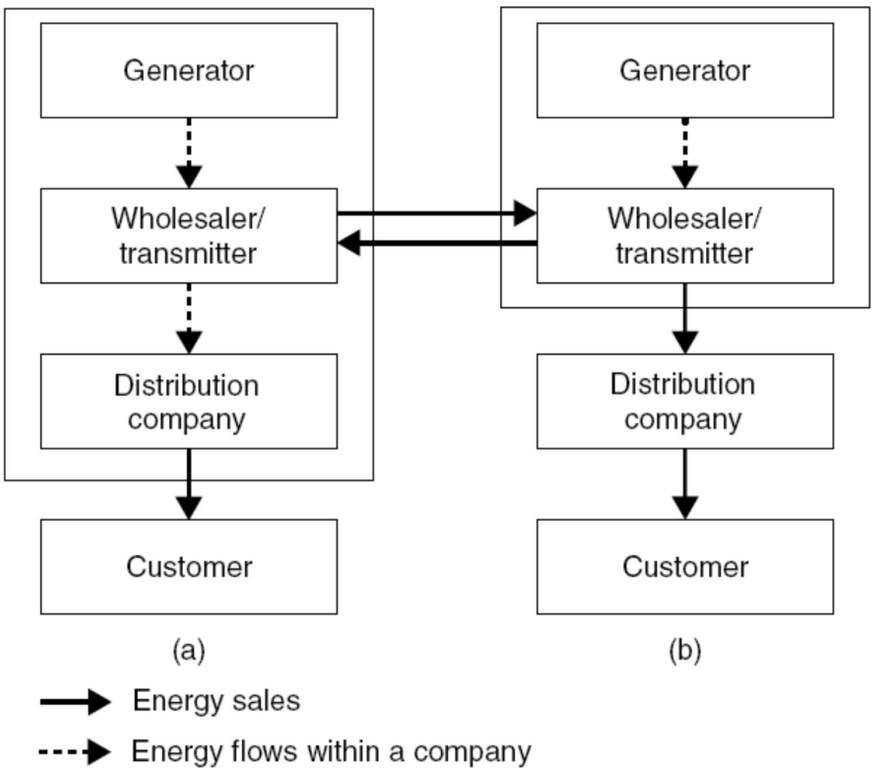
DISco: Distribution company. It operates the distribution network. The sale of electrical energy to the consumers could be through the DISco itself (monopoly or partial deregulation) or retailers (retail markets in fully deregulated environment).

Retailer: buys electrical energy on wholesale markets. Resells it through a retail market to consumers not participating to the wholesale market. DISco can be a particular retailer.

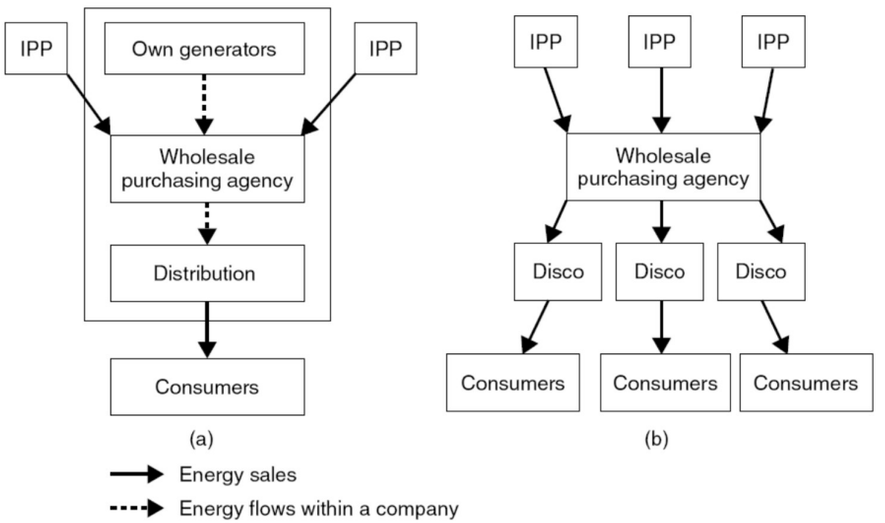
Consumer: large consumers buy the electrical energy through wholesale market. Small consumer buy the electrical energy through retail market or from the DISco to which it is connected.

Regulator: determines or approves the electricity market rules and investigates the suspect cases of abuse (market power). Sets or controls the prices of products and services in the case of monopolies.

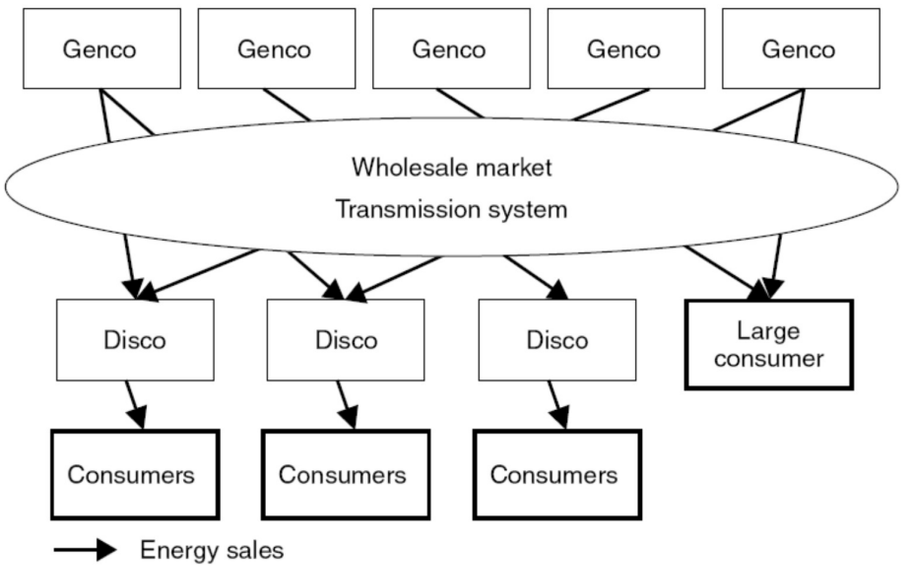
Models of competition



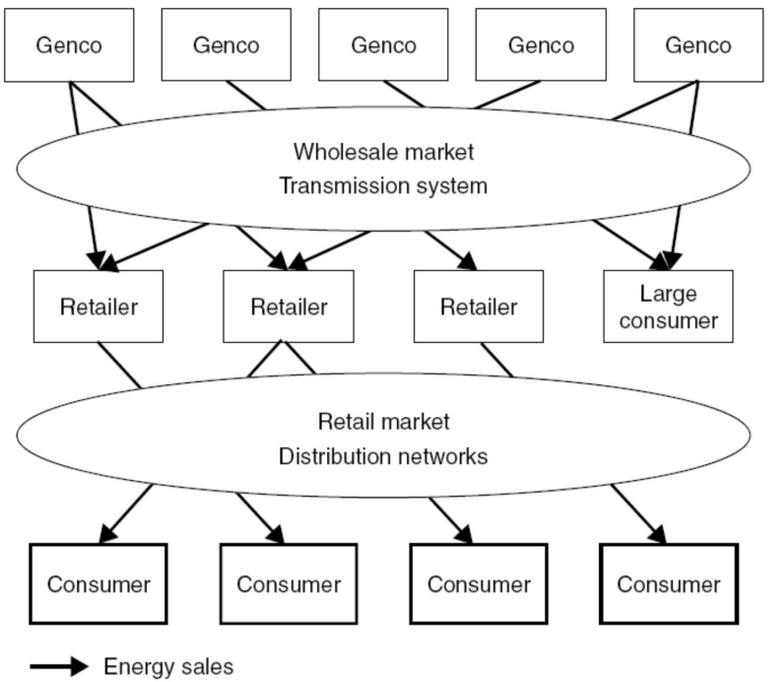
Monopoly: *(a) utility integrates generation, transmission and distribution. (b) one utility integrates generation and distribution which sells energy to local monopoly distribution companies.*



Purchasing agency model: *(a) integrated version (b) disaggregated version.*



Wholesale competition model



Retail competition model

Homework

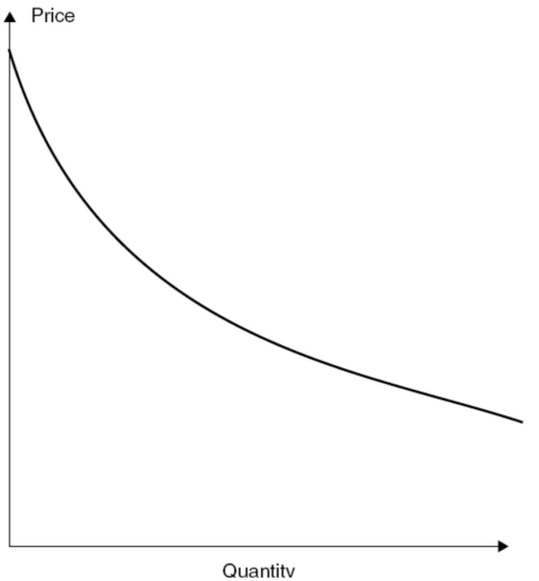
For three groups of two to three students: Describe at the light of the materiel given in this lesson, the electricity sector that exists in one of the following countries/areas: Belgium, the UK, France, California, New-York, Canada and Australia. Description can be done by answering the 5 questions on page 9 of the book "Fundamentals of power system economics". More original presentations are welcomed. You will have 20 minutes to present your work at the next lesson. Possibility to come to my office for questions on Friday afternoon.

Chapter 2. Basic concepts from economics

Market: Place where buyers and sellers meet to see whether a deal can be done.

Microeconomics is a branch of economics that studies the behavior of how the household and firms make decisions to allocate limited resources. Apply to markets where goods or services are being bought and sold. Microeconomics examines how these decisions and behaviours affect the supply and demand for goods and services, which determines prices, and how prices, in turn, determine the quantity supplied and quantity demanded of goods and services.

Consumer

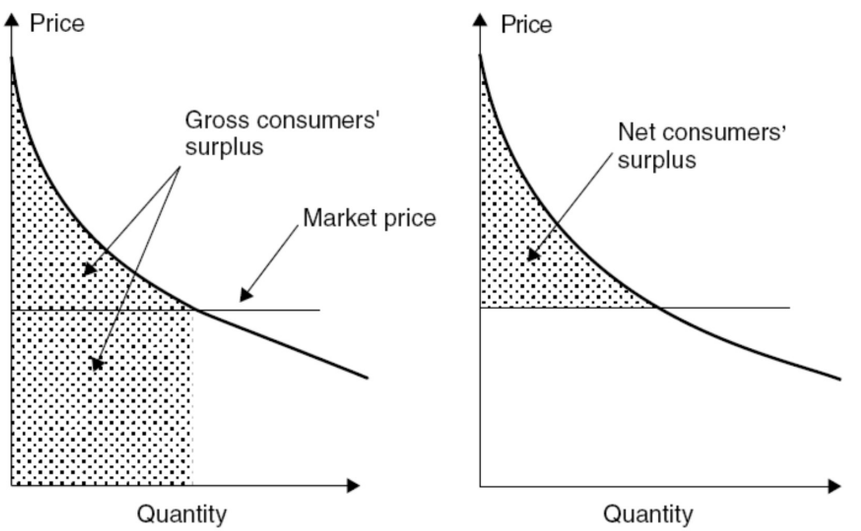


A typical inverse demand function

Let q be the quantity consumed and π the price. The inverse demand function D^{-1} relates π to q : $\pi = D^{-1}(q)$. The demand function is : $q = D(\pi)$.

Consumer surplus: value that the consumers attach to a bought quantity q.

Net consumer surplus: value that the consumers attach to a bought quantity q minus the price they have to pay for it.



Elasticity of demand

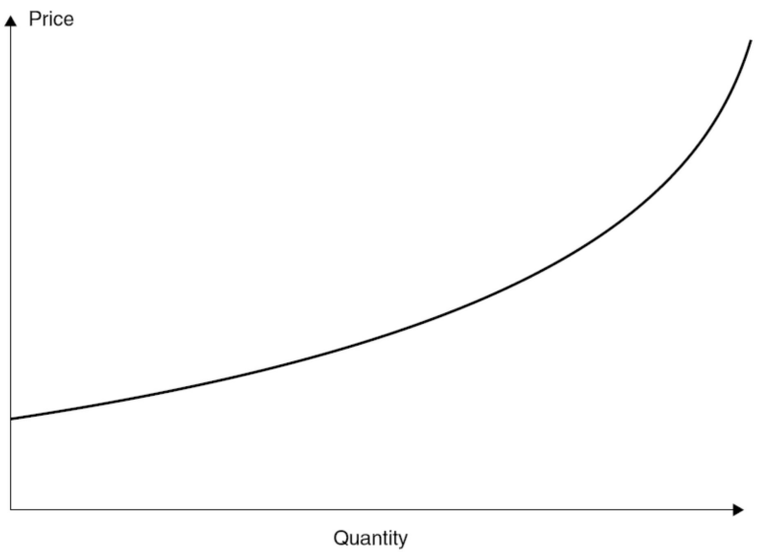
Price elasticity of demand: $\epsilon = \frac{\frac{dq}{q}}{\frac{d\pi}{\pi}}$

Demand elastic: percentage of change in price produces a larger percentage in change in demand. Otherwise it is said to be non-elastic.

Elasticity depends on the availability of substitute.

Cross-elasticity between the demand for commodity i and the price of commodity j: $\epsilon_{ij} = \frac{\frac{dq_i}{q_i}}{\frac{d\pi_j}{\pi_j}} = \frac{\pi_j}{q_i}\frac{dq_i}{d\pi_j}$

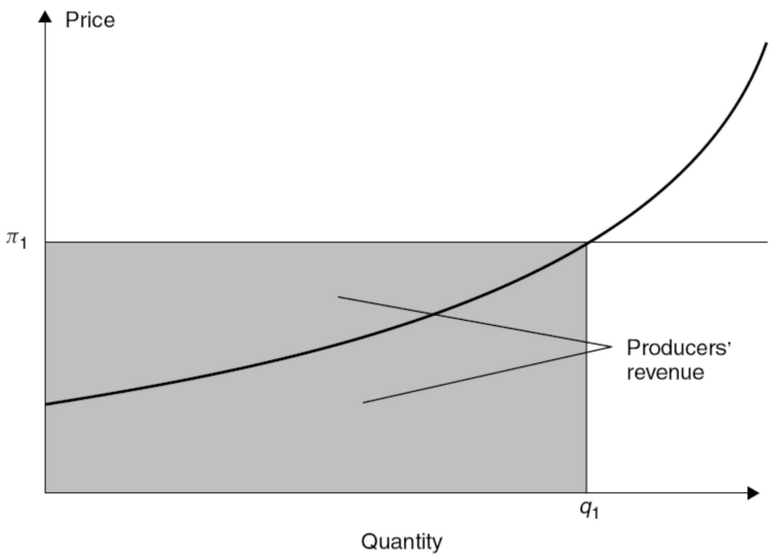
Producers



A typical inverse supply function

Let q be the quantity produced and π the price. The inverse supply function S^{-1} relates π to q : $\pi = S^{-1}(q)$. The supply function is : $q = S(\pi)$.

Price elasticity of supply defined in a similar way that price elasticity of demand.

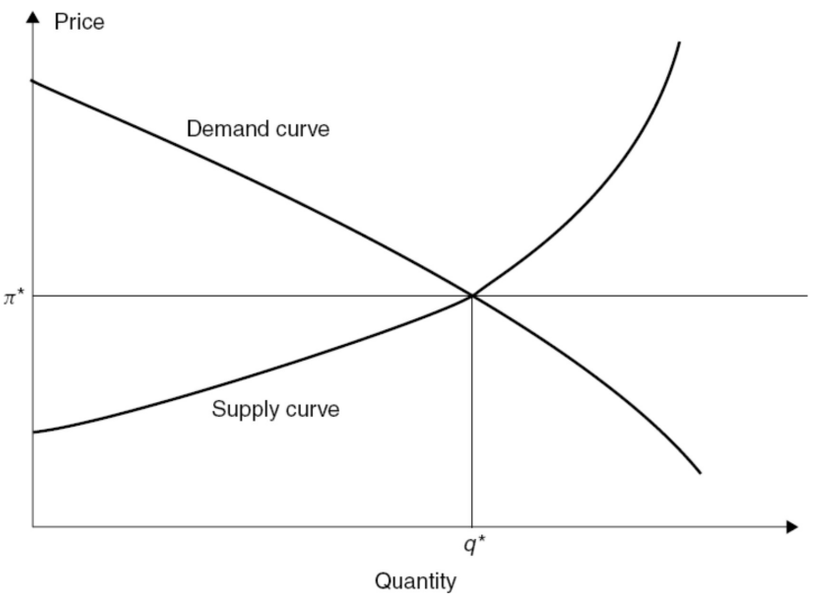


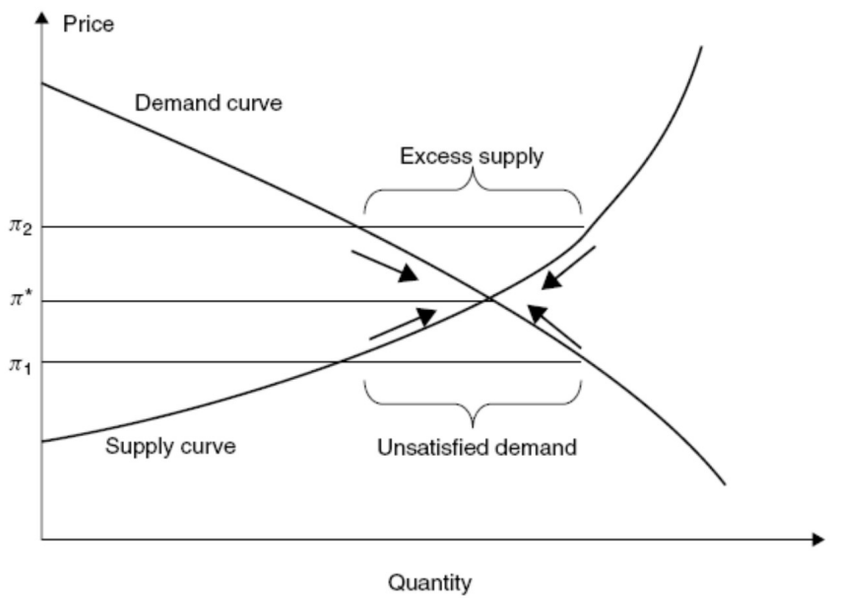
Producers' revenue. *Upper part of the curve is the net producers' revenue.*

Market equilibrium

Each market participant is assumed to be unable to affect the price by its action.

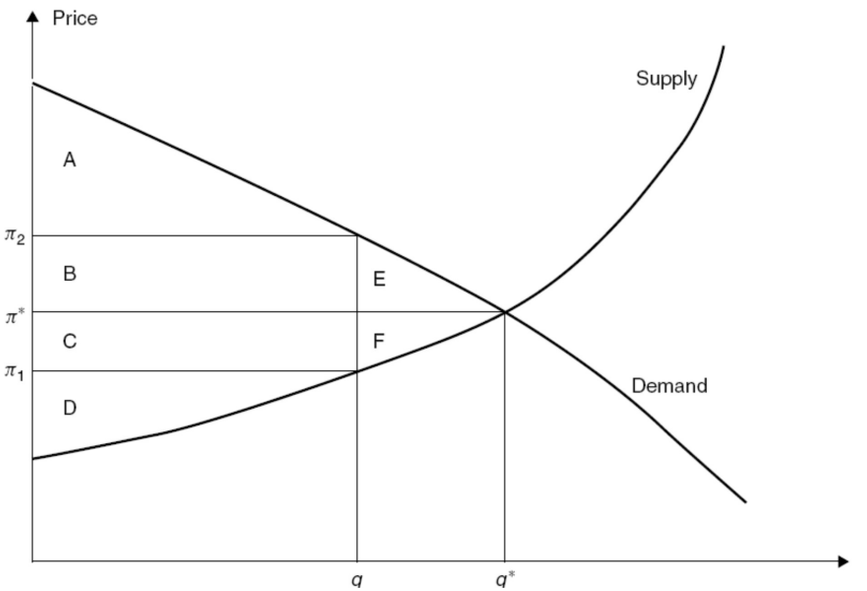
Equilibrium price or market clearing price π^* is such that the quantity that the suppliers are willing to provide is equal to the quantity that the consumers wish to obtain $\Rightarrow D(\pi^*) = S(\pi^*)$.
Similarly, the equilibrium quantity is such that : $D^{-1}(q^*) = S^{-1}(q^*)$.





Stability of the market equilibrium.

Global welfare and deadweight loss



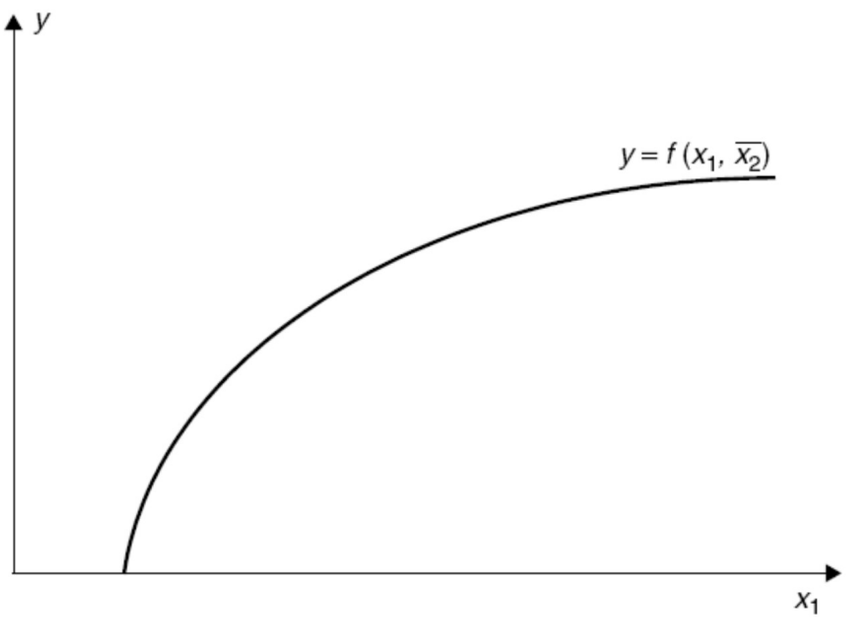
Enforcing a minimum price (π_2), a maximum price (π_1) or taxing the commodity (here by π_2 - π_1) lead to a deadweight loss, a drop in global welfare.

Problem with electricity markets: price of energy is (partially) set through centralized calculation.

Concepts from the theory of the firm

Production function of a firm : $y = f(x_1, x_2)$ where x_1 is here a short-term strategic variable and x_2 a long term one.

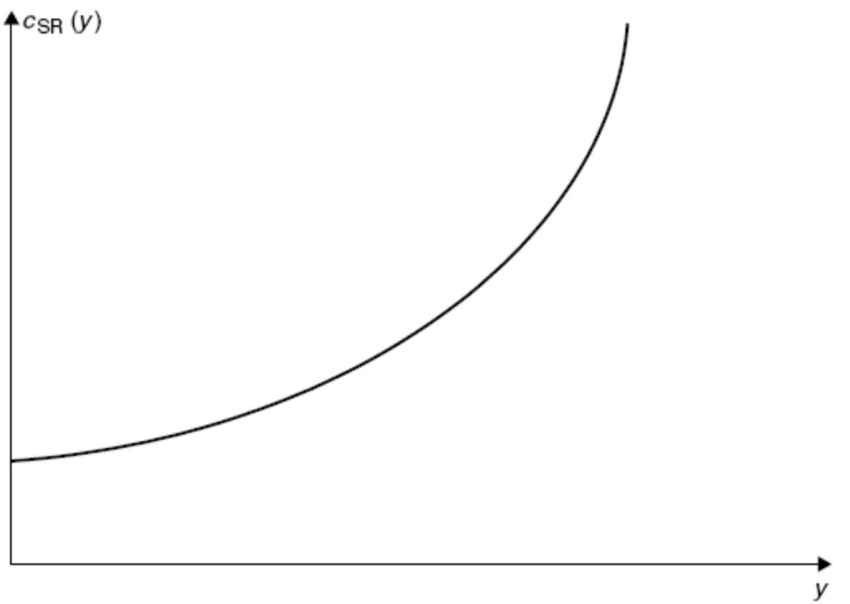
For almost all goods, the rate of increase of y decreases as x_1 get larger.



Short-run costs

Inverse of the production function: $x_1 = g(y)$ for $x_2 = \overline{x_2}$.

Example of short-run cost function
$c_{SR}(y) = w_1 x_1 + w_2 \overline{x_2} = w_1 g(y) + w_2 \overline{x_2}$



Typical short-run cost function

Optimal production level : $\max_y[\pi y - c_{SR}(y)]$

At the optimum: $\pi = \frac{dc_{SR}(y)}{dy} \Rightarrow$ Producers increase their production level until the market price equals their marginal cost of production.

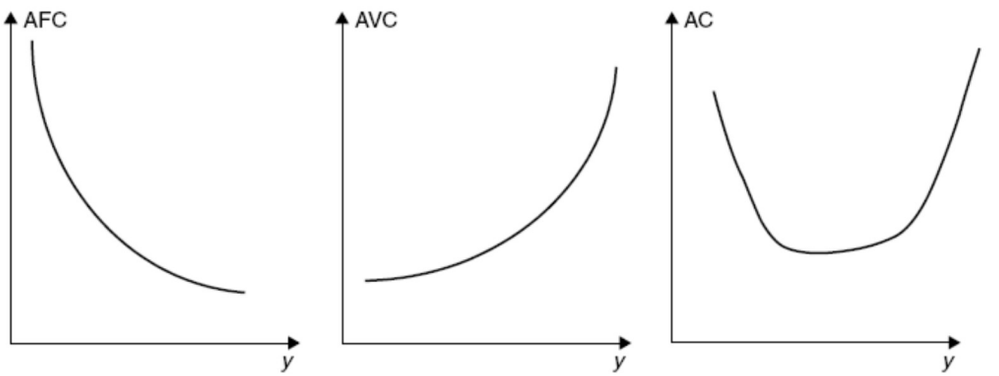
In the long-run, a firm should schedule x_2 by solving for a output y the given optimisation problem: $\min_{x_1,x_2}(w_1x_1 + w_2x_2)$ such that $f(x_1, x_2) = y$.

$c_{LR} = \min_{x_1,x_2}(w_1x_1 + w_2x_2)$ such that $f(x_1, x_2) = y$ is the long-run cost function.

Costs

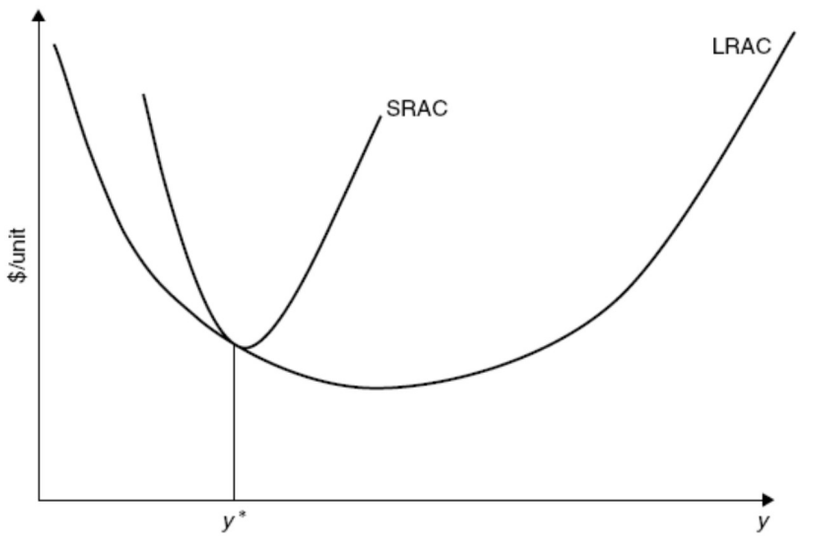
Variable and fixed costs: $c(y) = c_v(y) + c_f$

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



Typical shapes of average cost functions

Relation between short-run AC and long-run AC



Types of markets

Up to now markets where simply seen as a mechanism for matching supply with demand for a commodity through the discovery of an equilibrium price.

But how may a market really operate?

Different types of markets that depend on several matters: the date of delivery of the goods, the mode of settlement, any conditions that might be attached to this transaction.

These matters define the type of contract they conclude and the type of market in which they participate.

Spot market

Spot market: the seller delivers the goods immediately and the buyer pays for them "on the spot".

Advantage of immediacy but problem with volatility: a sudden increase in demand (or a drop in production) sends the price soaring and a dip in demand depresses prices.

Only small amounts traded on the spot market.

Forward contracts and forward markets

A forward contract specifies the following: (i) the quantity and quality of the product to be delivered (ii) the date of delivery (iii) the date of payment following delivery (iv) the penalties if either party fails to honor its commitment (v) the price to be paid.

Reduce exposure to the volatility of the spot market.

A forward market gathers producers and consumers interested in trading with forward contracts.

Forward price should reflect the consensus expectation of the spot price.

Future contracts and futures markets

Secondary markets where producers and consumers of the commodity can buy and sell standardized forward contracts.

Contract not backed by physical delivery $\Rightarrow$ they are called future rather than forward contracts.

As the date of delivery approaches, the speculators must balance their position because they cannot produce, consume or store the commodity.

May help produce and consumers to manage other risks than the price risk. Increase also the liquidity of the market.

Options

Future and forward contracts are *firm contracts*. If the seller is unable to deliver the quantity agreed or the buyer cannot take the full delivery $\rightarrow$ must buy/sell it on the spot market.

Options: Contracts with conditional delivery.

Call option: gives the holder the right to buy a given amount of a commodity at a price called the exercise price.

Put option: gives the holder the right to sell a given amount of a commodity at the exercice price.

Contracts for difference

Producers and consumers may be obliged to trade solely through a centralized market where no bilateral agreements are possible $\rightarrow$ they cannot use forward, future and option contracts to reduce exposure to risk $\Rightarrow$ Contracts for difference.

Parties agree on a strike price and an amount of commodity.

Contract for difference is settled in a way that the difference between the strike price and the market price times the amount agreed in the contract is paid by the buyer.

Markets with imperfect competitions

Up to now: we have assumed that no participants had the ability to influence market price through its own actions.

Supplier who asks more than the market price or consumers who offers less than the market price $\Rightarrow$ ignored because they can be replaced.

All participants price takers = perfect competition

But for many goods, producers or consumers control a share of the market large enough to enable them to exert market power.

Models of imperfect competition

Perfect competition: each firm should increase its production to the point where its marginal cost is equal to the market price.

Is it still the case with imperfect competition?

We will use Cournot models to demonstrate that not.

Cournot model = the firms use their production level as strategic variable.

Case of duopoly

Let us assume that firm 1 estimates the production of firm 2 will be equal to y_e^2. Firm 1 sets its production at a level y_1 that maximizes its expected profit: $\max_{y_1}(\pi(y_1 + y_2^e)y_1 - c(y_1))$.

Reaction function : $y_1 = f_1(y_2^e)$.

Similarly, if firm 2 follows a similar process : $y_2 = f_2(y_1^e)$.

Leads to a dynamics which, if it converges, will necessarily converge to a Cournot equilibrium.

$$y_1^* = f_1(y_2^*) \quad (1)$$
$$y_2^* = f_2(y_1^*) \quad (2)$$

Neither firm would find it profitable to change its output while being in this equilibrium.

Let us consider the case of n firms.

Total output $Y = y_1 + \ldots + y_n$ where for each y_i is equal to $\max_{y_i}\{y_i\pi(Y) - c(y_i)\}$.

If Y is a Cournot equilibrium, then we have: $\frac{d}{dy_i}\{y_i\pi(Y) - c(y_i)\} = 0$ $\Rightarrow \pi(Y) + y_i\frac{d\pi(Y)}{dy_i} = \frac{dc(y_i)}{dy_i}$.

We have: $\pi(Y)\{1 + \frac{y_i}{Y}\frac{Y}{dy_i}\frac{d\pi(Y)}{\pi(Y)}\} = \frac{dc(y_i)}{dy_i}$.

From there :

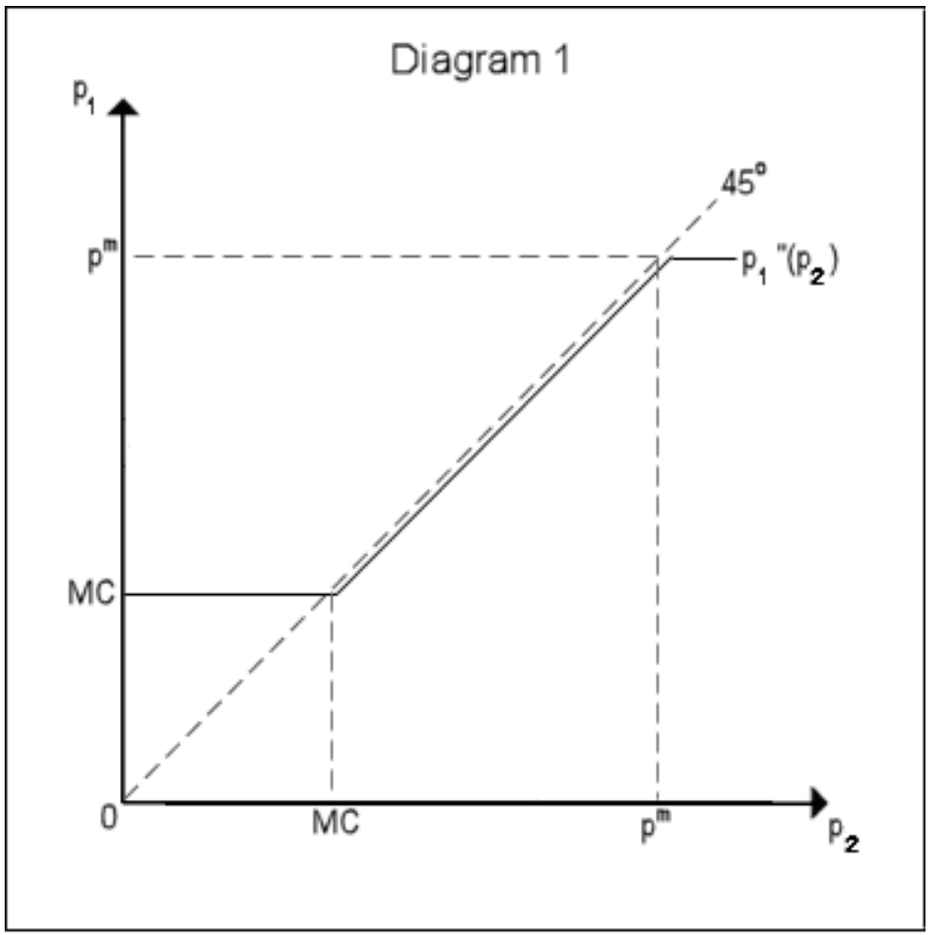
$\pi(Y)\{1 - \frac{s_i}{|\epsilon(Y)|}\} = \frac{dc(y_i)}{dy_i}$ where s_i is the market share of firm y_i and $\epsilon(Y)$ is the elasticity of the demand.

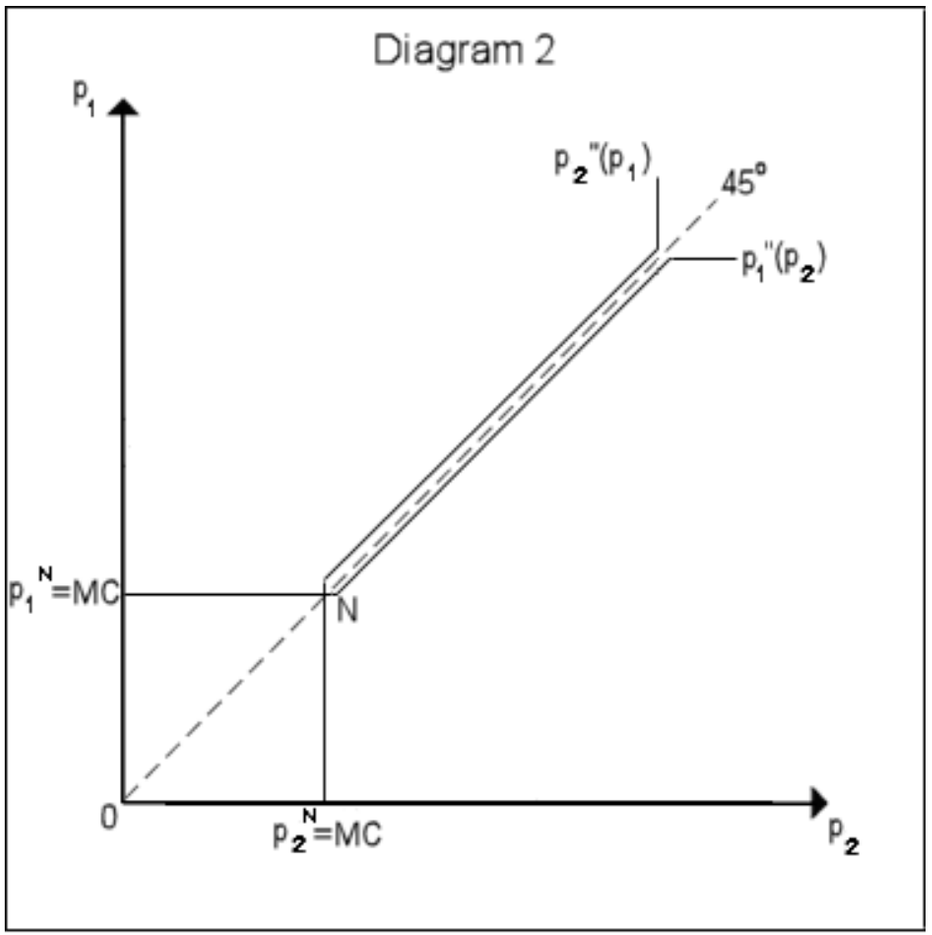
Low elasticity and/or high market share $\Rightarrow$ firms produce a a level where their marginal cost is below the market price!

Bertrand model

Firms use as strategic variable price.

Let us consider two identical firms. If firm 1 decides to set its price below the price of firm 2, it will capture all the market share. Sustainable equilibrium can only be reached when the price matches the marginal cost of production.



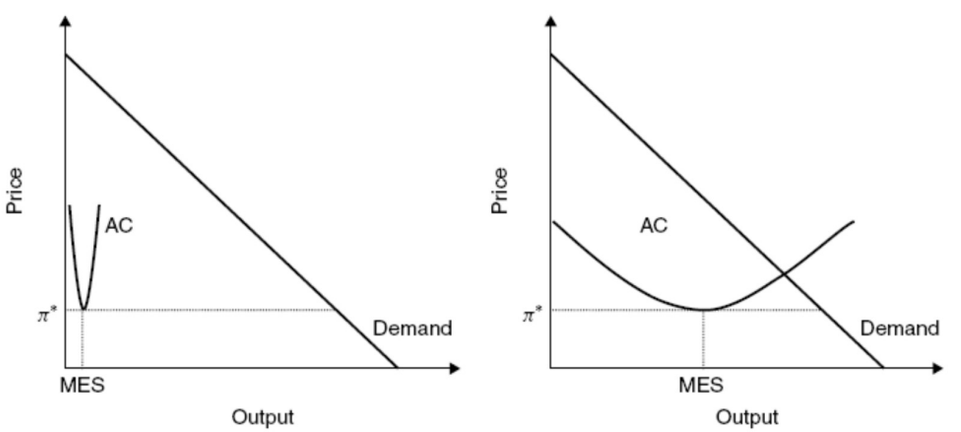


In practice, collusion occurs. Firms form a cartel to set prices and outputs in a way that maximizes profits of the industry as a whole. Regulator should act !

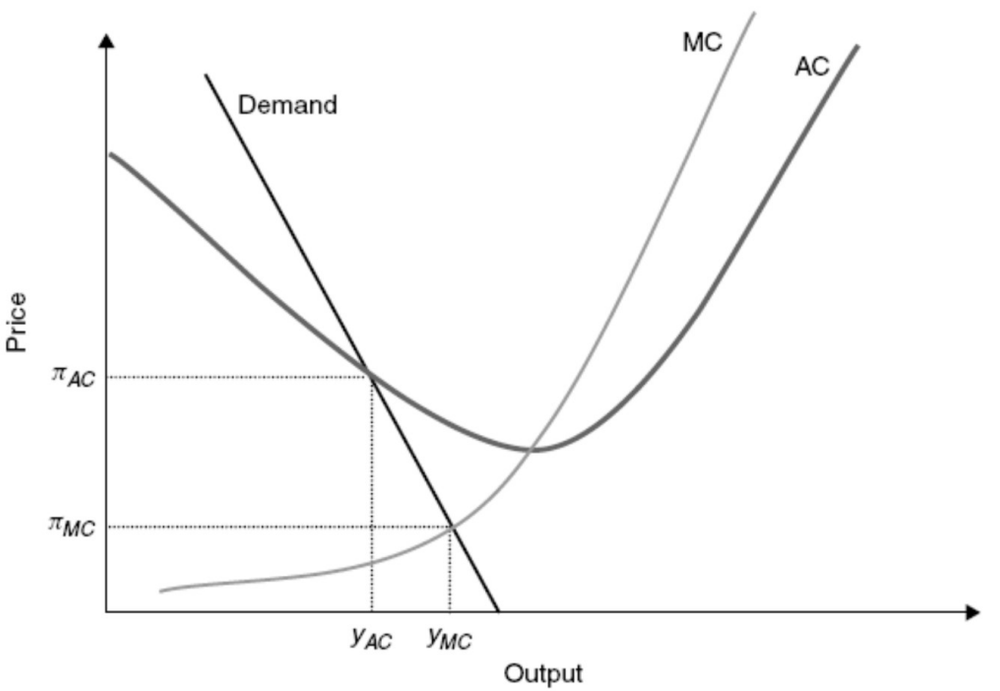
Monopoly

Minimum efficiency size: level of output that minimizes the average cost for a typical firm of the industry.

If MES comparable to demand $\Rightarrow$ monopoly situation is likely to develop.



Regulator should act if monopoly. But setting the right market price may be difficult. For example, if it sets the market price equal to the marginal cost of the firm, it may put it out business.



Homework

For a group of two to three students: prepare a 20 minutes long presentation about agent-based computational economics (ACE). Emphasize the pros and cons of ACE with respect to 'classical' microeconomics.

For a group of two to three students: prepare a 20 minutes long presentation about John Nash, his life and his main scientific achievement. Make the connection between a central result of his career and the Cournot equilibrium presented in this lesson.