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Economics of Natural Gas Transportation

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SUMMARY:

This report demonstrates that the existence of significant economies of scale and scope in the European gas industry make many transmission and local distribution companies natural monopolies in the markets in which they operate. Often, this gives them a strong market power and little competitive pressure. Substantial parts of the rent in the gas chain are accrued in the transportation segment rather than in production and/or to the benefit of consumers. This gives reason for public interventions into the functioning of the market, as seen under the initiatives taken by the European Commission, such as the "Gas Directive".

The report also discusses gas transport regulations; arrangements that goes far beyond the present EU initiatives. No schedule seems to secure any first-best outcome. However, different types of multipart tariffs and price discrimination under Ramsey principles may bring about social acceptable second-best results. The complexity of regulations and the huge interests at stake make it doubtful that such regulations are attainable throughout Europe in the coming decade. The report discusses a game between the public authority and the transporters where various level of conflict and cooperation will influence how far regulations will go and how they will be designed. Changing property rights (nationalization) and the use of market forces is discussed as alternatives to regulation.

Key words: European gas, natural monopolies, regulation, transmission.

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Introduction

To understand the behavior of natural gas markets, one has to understand the economics of gas transportation. Gas production look a lot like oil production, and gas competes with oil and other fuels in end-user markets. Transportation costs for gas, however, is much higher than for oil. When investments in transmission, distribution and storage facilities are made, most costs of transportation are fixed. Variable costs for operation and maintenance, are usually relatively low compared to capital costs. Thus, the use of the pipeline, or the *load factor*[1], does not influence total cost of transportation much.[2] When capital (investment) is fixed, and, within certain limits, even operational costs remains unchanged when volume transported changes, a higher or lower load factor change per unit transportation cost, but not total cost.

Often, the benefits of large-scale operations and vertical integration in gas transportation effectively make barrier to entry for newcomers prohibitive. This contributes in making markets for natural gas transportation highly concentrated with few actors involved.[3] Often, operations in the industry are either taken hand of by firms owned by, or they are private firms facing strong regulations from, governments.

The argument behind various forms for public intervention in the operation of natural monopoly transport utilities is that if they are allowed to behave as profit maximizers, without constraints, consumers and overall economic efficiency will suffer. By intervening into the functioning of the market, governments wish to repair for market failures created by dominating private enterprises. Inefficient operation and possible opportunistic behavior among monopolistic firms, together with externalities in the use of gas as an important source of energy, the environment, concerns over economic activity, rent distribution, reduced dependency on Middle East oil and lack of information throughout the gas chain, have justified government intervention.

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[1] The percentage use of capacity, relative to maximum, or peak, capacity.

[2] The IEA (1994), page 49, argues that "operation and maintenance cost of pipelines, excluding compressors are fixed costs; estimates for them as an annual proportion of construction costs are in the region of 2 % onshore and 1 % offshore". They estimate maintenance costs for compressor stations to "run about 3-6 % of investment cost per year of operation at a relatively high load factor".

[3] Among additional factors determining the routing, choice of dimension, installment of compressor stations of pipelines and building of storage facilities, are distance between producing and consuming areas, seasonal and daily variations in demand, Europe's physical and political geography, and various commercial and political actors' strategies.

This report discusses why public intervention into the behavior of natural gas transportation may be needed also in Europe and analyses techniques for how it could be done. Chapter 1 recalls some basic characteristics of competitive and monopoly markets. Then, it defines a natural monopoly as a firm that inhibits significant economies of scale and/or scope in relation to market size. The chapter also discusses where natural monopolies typically are found in the European gas market, as well as limits to natural monopoly gas firms' overall market power. Chapter 2 discusses reasons for public intervention into these types of imperfect markets, what criteria should be used in order to maximize social welfare and the instruments at hand for policy-makers.

Chapter 3 discusses some of the most commonly used techniques for regulating the behavior of natural monopolies, such as rate-of-return regulation, price discrimination, the use of subsides and the multipart tariffs. How optimal capacity and prices in a transmission system should be determined when demand varies is discussed, as well. Chapter 4 presents a game between the regulator and a transporter under the threat of being regulated. The question is whether and/or when the (potentially) regulated firm benefit from an interplay with the regulator and when it benefits from just opposing any intervention from public authorities. Finally, in chapter 5, changing property rights (nationalization) and the use of market forces is discussed as alternatives to regulation.

1 Natural Monopoly

Competitive and Monopoly Equilibrium's

As demonstrated in any microeconomic textbook, for competition to work, many profits maximizing companies must offer a good or service on the supply side. No firm should hold a dominant market position, everyone should be free to establish or close down a business and no externalities should be present. Correspondingly, on the demand side, there must be many consumers, each maximizing utility. Producers' and consumers' goals are attained if the good or service is priced at the point where the marginal willingness to pay (WTP) equals marginal cost of production. This also gives the largest social surplus.

Under perfect competition, equilibrium is determined by the intersection of market demand and supply curves. At demand D_0 and supply S_0, this intersection determines market price p_o and output q_o, as shown in graph A in figure 1. Each seller is assumed to have marginal cost (MC) and average cost (AC) curves defined for all possible outputs. Prices must be equal to or above average total cost (ATC) (the sum of average variable cost, AVC, and average fixed cost, AFC), to make the firm stay in business (normal profit is included in cost curves as an opportunity cost).[4] In graph B in figure 1, a single firm produces output q_0^* at market prices p_0 at minimum ATC (assuming identical cost curves for all firms). This is the long run equilibrium under perfect competition where each firm is earning normal profit, but no economic profit. If AVC < p < ATC firms will stay in business but only in the short run. In the long run, prices must cover fixed costs, as well.

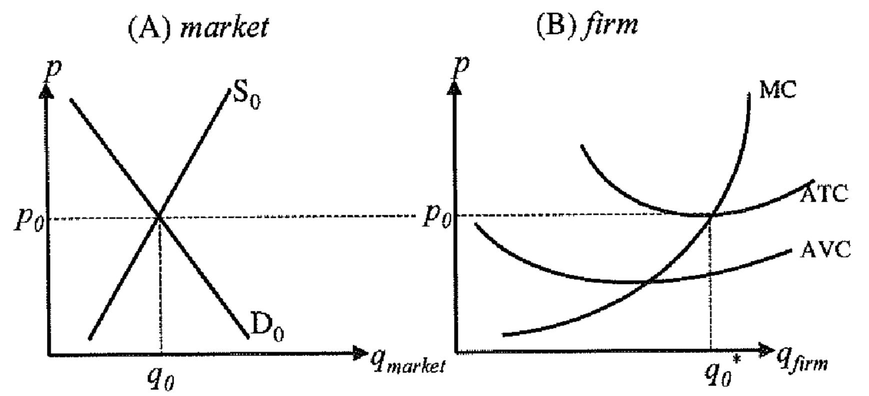

Figure 1: Short and long run equilibrium under perfect competition

If market demand increases, price increases, as well, and each firm will earn an economic profit. This economic profit will attract more firms into the business, which over time will push market supply curve to the right and prices back down to p_0. Without any change in cost curves, each firm will remain at producing output q_0^* in the long run, but the number of firms has increased as the size of the market has grown. Similarly, a negative shift in demand will decrease market prices and force those firms not able to cut costs out of business. In perfectly competitive markets, no firm will earn economic profit in the long run, only normal profit. Supply and

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[4] *Normal profit* is the opportunity cost of being in business, or what you could have earned in your next best alternative activity. This is the minimum return to the owners of the capital employed, for them not to close down the business and move to another activity or simply putting the money into the bank. It is a cost, just as wages, rent et.c., because it has to be covered if the firm shall continue producing. Therefore, normal profit is usually included in the cost curves. *Economic profit*, or rent, is, on the other hand, the excess of profit over normal profit. It is known under several alternative names: supernormal profit, pure profit, abnormal profit, positive profit, producer's surplus and sometimes simply profit. The reasons for earning economic profit can be many, and have led to more names to be employed for the same: 'Quasi rent' may be earned when supply is rather inelastic so that firms being in business earn a rent over some time until other firms manage to enter the market. This is the normal situation in most markets; 'Monopoly rent' may be earned if there is a strong consentration of market power on the supply side; 'Resource rent' may be earned if the product is an exhaustible resource such as oil and gas et.c.

demand conditions will dynamically change output, prices and the number of firms in a way, which is optimal also for society.

The other extreme market situation is monopoly, with only one active seller. There may be 'inactive' sellers willing to enter the market, for example before a monopoly are constructed as a cartel. If a firm has a higher ATC than the cartel members at the possible level of output, this firm is not producing at competitive prices. But as soon as the cartel is established and prices are raised, possibly to a level above this firm's ATC, it can enter the business as a 'free rider'. In this case, the cartel must take such companies' behavior into account, just as sellers in an oligopoly market must consider the behavior of other active and inactive sellers in their strategy. Without inactive sellers in the market, the monopolist is free to determine price and output in a way that profits is maximized. This happens when marginal costs equal marginal revenue (MR) as shown in figure 2.

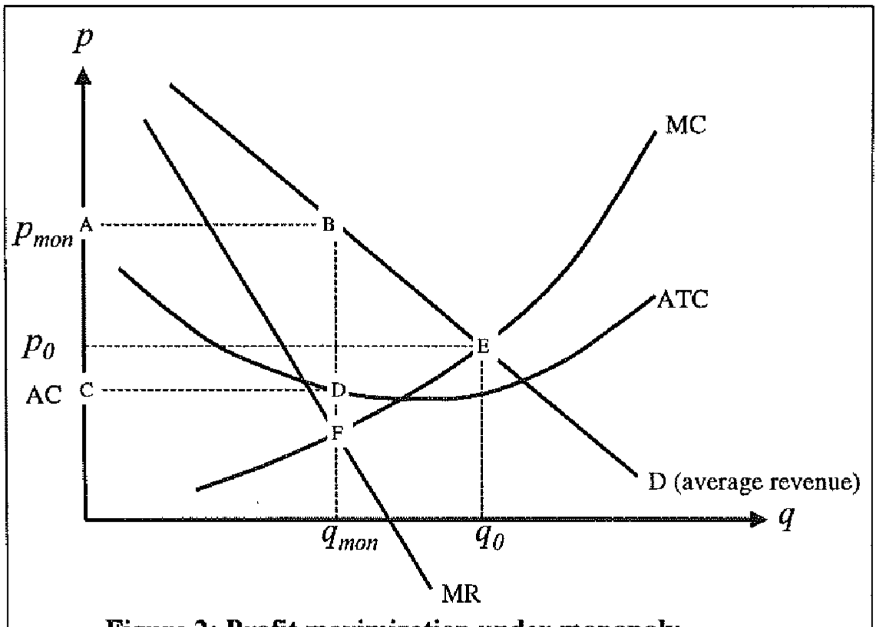


Figure 2: Profit maximization under monopoly

For a price taking firm marginal revenue equals price determined in the market (MR=p_0). Profit is maximized where the firm's marginal cost equals marginal revenue (MC=MR=p_0). For a monopolistic "price making" firm, marginal revenue declines with output. The monopolist is only constrained by the demand curve, as a higher price lower quantity demanded. For this firm, profit is also maximized when the firm's marginal revenue equals marginal cost, which now happens at a lower volume (MC=MR<p_0), at point F in figure 2. Profit is maximized at output

q_{mon} and prices set to p_{mon}. The area ABDC represents the economic profit gained by the monopoly. As consumers' marginal willingness to pay is higher than producers' marginal cost of production at $q_0 < q < q_{mon}$, there is a welfare loss represented by the area BEF.

In addition to the efficiency loss due to monopolistic pricing, monopolies may also incur X- inefficiency or allocative inefficiency: When there is no competitive pressure on profit margins, cost control may become lax. The result may be overstaffing and spending on prestige buildings and equipment, as well as less effort to introduce new technology, scrap old plants, develop new products and markets. The more comfortable the situation, the less may be the effort expended to improve it. The effect is that cost-curves are pushed higher and low quality products are provided at increasingly higher prices. Because of the excessive pricing practice and inferior efficiency, governments generally prohibit cartels, stimulate competition and intervene into the behavior of monopolies in order to repair for the welfare losses.

Natural Monopoly

A natural monopoly is a type of monopoly that exists when it is less costly to satisfy demand with only one company operating in the market than for two or more firms. The monopoly is in this sense 'natural'. However, it is not necessarily optimal if the firm abuses it's monopolistic market power and/or allocate inefficiency. Without public intervention, such firms may behave as monopolists without much fear of competitors entering the market, rise prices excessively and serve increasingly more inferior products with inefficient use of resources. Natural monopolies can arise when there are economies of scale and/or scope in the production of goods or services. Economies of scale exist when it is less costly for one firm to produce a single commodity than it is for two or more firms. Economies of scope exist when one firm can produce two goods or services at a lower total cost than if independent firms produced each of them.

-Economies of Scale

In the very long run, all costs can be considered variable and fixed costs are zero. In most cases, however, depending on what is considered to be short and long run, some costs are fixed, and total costs of production consist of fixed plus variable costs. Whenever there are fixed costs, average cost must be falling for output levels close to zero and rising with larger quantities of output. Large fixed costs are the most prevalent source of economies of scale. The fixed costs must be incurred no matter how many units of output are produced. In figure 3, average costs are falling up to output q_0 and rising thereafter. This plant has economies of scale at $q < q_0$ and diseconomies of scale at $q > q_0$.

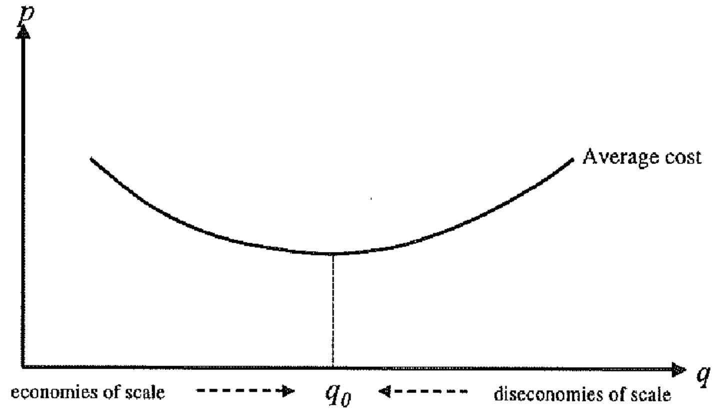


Figure 3: Average costs and economies of scale

This is the general form of an ATC curve. The difference between a plant usually said to be having economies of scale and a competitive firm is that q_0, or cost minimum, occurs at high output levels *compared to market demand.* When there are economies of scale for a sufficient part of the production compared to demand the firm becomes a natural monopoly in producing this product. Thus, for two transmissions companies having identical cost functions, one of them can operate as a natural monopoly, while the other may face some degree of competition. The difference is that demand in the second market is larger than in the first, and large enough so that the economies of scale are exhausted. Figure 4 illustrates this in more detail.

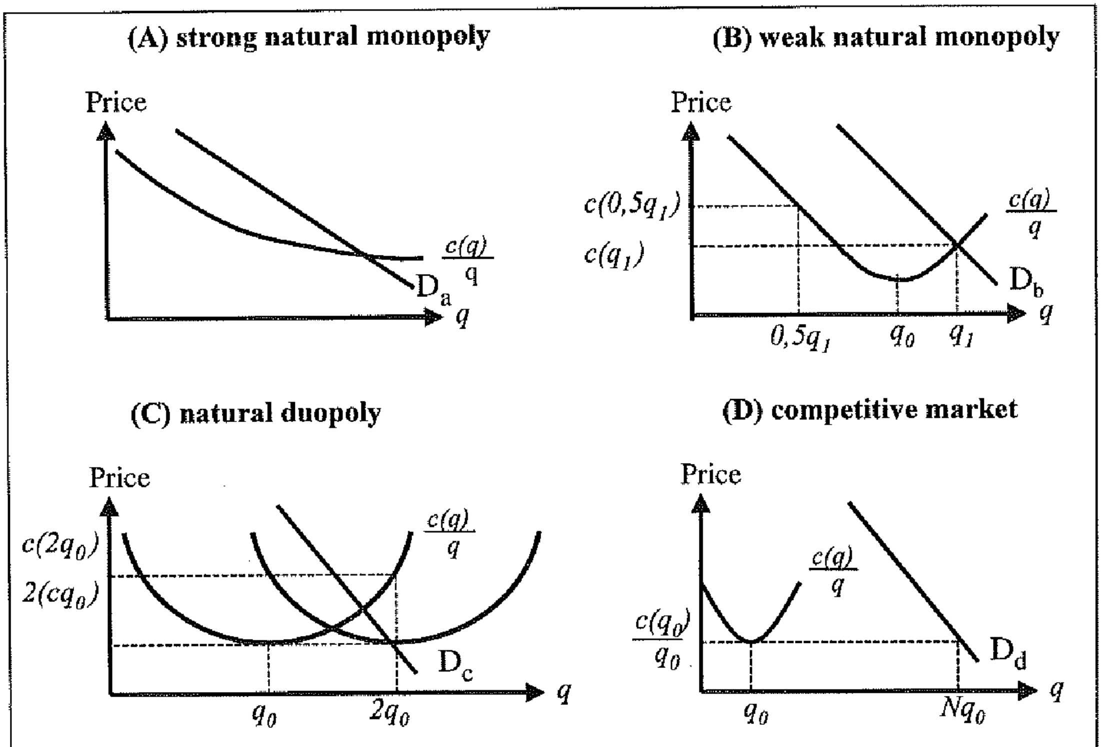


Figure 4: Relation of average cost to demand

Graph A shows a situation where average cost decreases over the entire scale of operation to the left of the demand curve, D_a. Let the average cost of producing output q be expressed by the function $c(q)$. Decreasing average costs can be expressed as:

(i) $c(q_i)/q_i > c(q_j)/q_j$ *(where* $q_j > q_i$*)*

This is the most usual expression for economies of scale and secures that one firm can produce the good at the lowest cost. However, this is not a necessary condition for economies of scale to exist.

In graph B, the demand curve D_b intersects the average cost curve within the area of diseconomies of scale at $q=q_1>q_0$. Average cost are falling at outputs $q<q_0$, but are increasing for $q>q_0$. Let average cost of producing q_1 be $c(q_1)$. If two firms share the market equal, so that each produces $0.5q_1$, average cost for each will be $c(0.5q_1) > c(q_1)$ (assuming identical cost functions for both firms). An uneven division of the market would give different average costs, but the sum of costs would still be larger than $c(q_1)$ and the firm would operate as a natural monopoly due to economies of scale.

The fact that the firm is a natural monopoly also for outputs $q_0<q<q_1$ is explained by the term *subadditivity*. A cost function is subadditive at q if and only if:

$$\textit{(ii)} \quad c\left(\sum_{i=1}^{m} q_i\right) \leq \sum_{i=1}^{m} c(q_i) \text{ for all quantities of } q_1, q_2, \ldots, q_m \text{ where } \sum_{i=1}^{m} q_i = q.$$

This condition is necessary and sufficient for costs to be lowest when one firm operate the market. In a more compact form, the condition for subadditivity for output q_1 can be written as:

$$\textit{(iii)} \quad c(q_1) < c(q) + c(q_1 - q) \text{ for } 0 < q < q_1$$

If q_1 is the largest possible demand in the industry (where demand curve intersect the ATC curve) and inequality (ii) or (iii) holds, then $c(q_1)$ is strictly subadditive and the industry is a natural monopoly. Thus, a cost function can be subadditive even if there are substantial diseconomies of scale at the actual level of output. A firm that has decreasing average costs across the scale is called a *strong* natural monopoly and satisfies function (i). If it only satisfies function (ii) or (iii), it is called a *weak* natural monopoly (Berg & Tschirhart, 1988: 24).

If demand compared to cost should be as high as D_c in figure C, two companies can produce $2q_0$ at a lower cost than one firm. If one firm should produce all output, it would to so at a higher average cost, as $c(2q_0) > 2*c(q_0)$. The market turns into a natural duopoly (or perhaps oligopoly, if demand is even larger). If demand is really large as compared to the efficient scale of operation, as illustrated by D_d in figure 4 graph D, firms are facing a competitive market. Then, we are back to the situation with a number of firms (N) all producing q_0, as illustrated in figure 1.

Sunk cost is closely related to fixed cost. Sunk cost can be defined as the difference between the ex ante opportunity cost and the value that could be recovered ex post after a commitment to a given project has been made. Thus, the larger part of a project's fixed costs that are sunk cost the stronger the natural monopoly.

-Economies of Scope

Costs can also be saved when one firm is producing more than one service. Even though each segment of an industry produces a unique type of output, companies may "bundle" services in order to save cost. When efficient bundling of services takes place, within each segment and across the gas chain, it is due to economies of scope. For example, a producer can search for gas, drill and run a gas field. The transmission company can, next to transporting the gas, also function as a broker and wholesaler and offer storage for its customers. Production and transmission may more efficiently be organized when planned together than independently. Local distribution companies can, besides distributing gas to households and businesses, offer storage, equipment for end-users and advice.

The existence of scope economies indicates that gas companies' bundling services may have competitive advantages over companies operating unbundled. Teece (1990) argues that benefits from joint operation of successive operations may occur if there are:

- *Informational efficiencies*, where one firm may better know the bottle-necks in transportation, producers' opportunities and limitations, customers demand situation etc. than if operations are split to more firms.
- *Operating efficiencies* including pressure controls, rerouting of gas during maintenance work etc. Since gas leaves and enters many stages on the way from producer to end-user, (many of) these operations may better be dealt with under one management rather than many.
- *Aggregation economies* that is achieved if one supplier, better than two, can match demand from different customers. The economic and political costs of failing to supply or purchase are great.

By bringing the decision processes under the management of a single firm or under coordination between firms, greater security and stability of supplies to the market can be provided, when short-term supply disruptions are costly and rapid access to alternative supplies is inhibited or impossible. With one management, or explicit coordination between two or more managements, gas firms such as a transmission company may become more credible if they have aggregated customers and suppliers to match changes. By integrating vertically a firm may also avoid opportunistic behavior from parties earlier or later in the gas chain. Centralized managements may handle vertically linked processes more easily than through market transactions. Signing contracts may be time-consuming and costly and hamper a firm's ability to produce efficiently. If overall profit is the goal, rather than maximum profit in each segment, one firm may easier give an efficient solution than two may or more firms may.

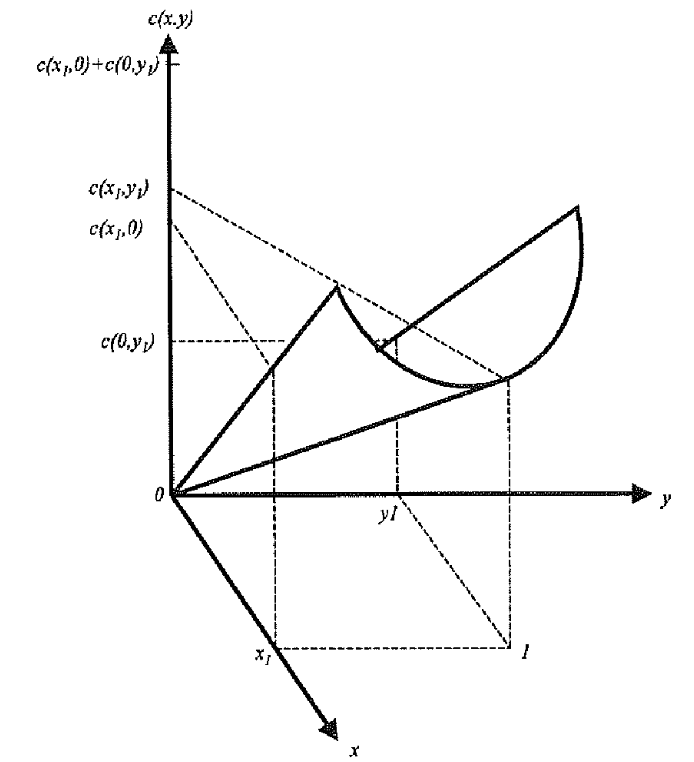


Figure 5: Economies of scope

When economies of scope exist, the factors of production will be used in a way that two or more services can be produced at lower costs than when produced separately. Let's assume that the average unit cost of producing two goods or services, *x* and *y*, can be expressed by the function $c(x,y)$. In figure 5, $c(x,y)$ is drawn by the U-shaped area showing the cost of production at every combination of x and y. At point 1, quantities x_1 and y_1, are produced at total cost of $c(x_1,y_1)$. If one company produces only x and none of good y, the costs for this single product would be $c(x_1,0)$. Similarly, if a company where to produce only y and none of x, it's cost function would be $c(0,y_1)$. The total cost of producing x and y separately would be $c(x_1,0) + c(0,y_1) > c(x_1,y_1)$. Thus, it costs less if one company instead of dividing the production between two or more produces x1 and y1. Economies of scope exist if $c(x,y) < c(x,0) + c(0,y)$ and minimum costs for combinations of x and y are incurred along the u-shaped curve.

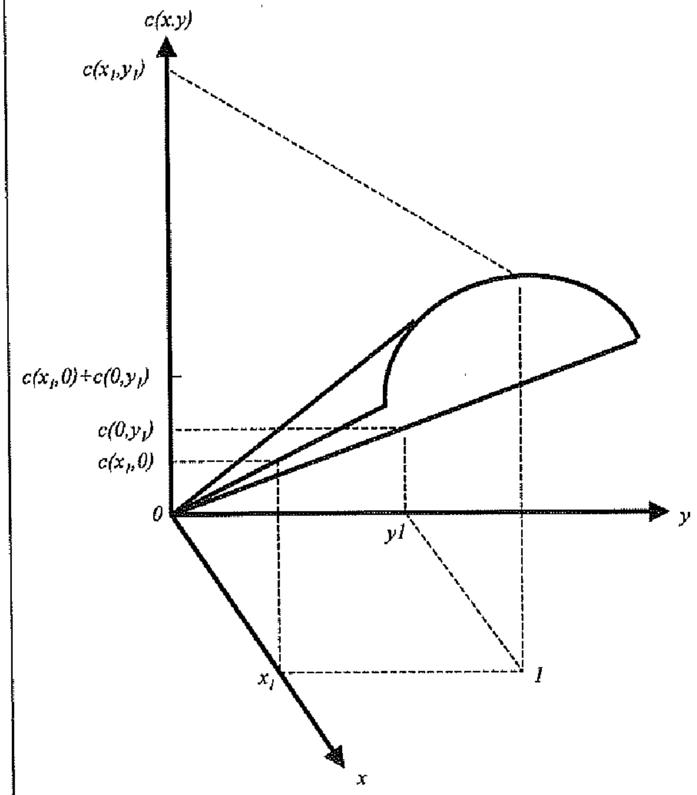


Figure 6: Diseconomies of scope

Figure 6 illustrates, on the other hand, a situation with *diseconomies of scope.* In this situation, any co-production of x and y will lead to higher costs than if production were separated and executed by independent companies; $c(x,y) > c(x,0) + c(0,y)$.

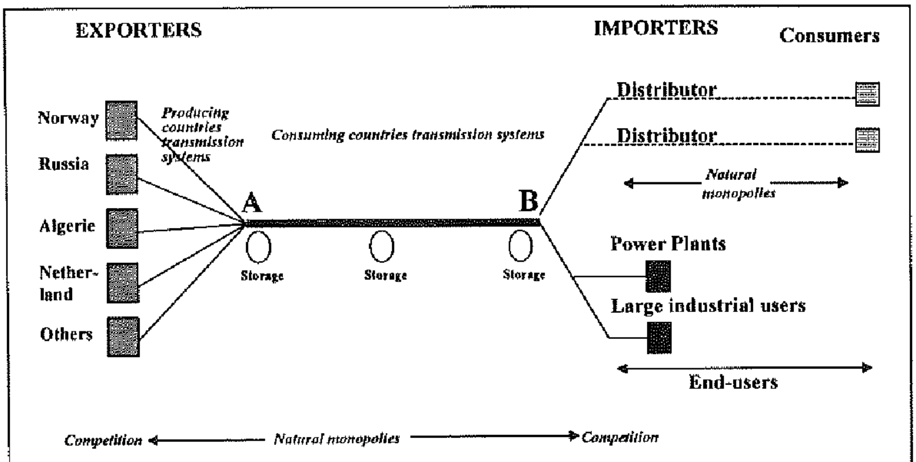
If a natural monopoly bundles services due to scope economics, many combinations of x and y can make it earn an economic profit. A gas producer may i.e. run a normal profit, or even a loss, on a petro-chemical plant, but obtain economic profit in the transmission system they operate. Then, prices are *cross-subsidizing* each other. Equivalently, a transmission company could run a broker- and wholesaler function with normal profits, while the transportation function is run with an economic profit, and vice versa.

Economies or diseconomies of scope may occur with or without economies of scale. Cost may be saved for one firm by producing both services at small volumes, but not at large volumes even if the economies of scale are present all the time and vice versa. For the company, the optimal mix of production will also be determined by how economies and diseconomies of scale and scope are distributed compared to demand. This will also determine whether a single plant and/or a firm producing more than one output is a natural monopoly or not.

Natural Monopolies in the European Gas Market

The existence of economies of scale is a pressure to create firms that are relatively large compared to the markets in which they operate. Smaller firms may integrate horizontally and merge together into larger and more efficient firms. The situation for the European gas market is illustrated in figure 7.

The four main supplying countries (Norway, Russia, Algeria and the Netherlands) compete in selling gas. Often, producers have advantage of large-scale operations. However, even if each gas field may produce most cheaply with one plant, and some of them are very large, there are many independent fields both on- and offshore supplying the European market. Generally, in today's market, gas is sold from producers to the purchasing transmission companies at the border in point A, and resold from them after transmission to the local buyers in point B. In each of the exporting countries, gas sales are done by one body or are orchestrated together (see discussion in Marbro & Wybrew Bond, 1999). This concentrated sales organization does not represent a by-nature wellhead monopoly across fields due to economies of scale. Producers supplying the European gas market have a greater potential for operating under some degree of competition than the transportation segment does. Different fields of production could from a large-scale-benefit point-of-view, compete with each other within and across countries. On the other hand, there may be scope benefits between production, storage and transmission within the exporting countries that gives argument in favor of coordination. The question is whether the scope benefits are so large that bundling services gives the lowest overall costs in providing the services.



Figur 7: Competition and monopolies in the European Gas market

The transmission systems, in producing as well as in the consuming countries, inhibit on the other hand, strong elements of natural monopoly. The purchasing monopsony that transmission networks in consuming countries to a large extent have obtained in Europe is created on the basis of by-nature natural monopolies. The position is reinforced in gas negations with producers through collaboration between the transmission networks. This by-nature strong position and cartelization towards the producers is reflected in the fact that the purchasing transmission companies generally have attained a monopolistic position towards their customers at the city-gate and towards power plants and large industrial users.

Each of the buyers of gas at the end of a transmission line is so small and geographically spread that they usually are unable to construct alternative routes for supply. Power plants and large industrial users are gas consumers themselves. The LDCs are, on the other hand, often monopolists in serving local consumers in households and businesses at its exit due to scale economies. In addition, they may have scope benefits in providing equipment for gas use etc. reinforcing their strong position in these end-user markets. On the other hand, integration between LDCs and pipelines seem to happen to a lesser extent. Probably, this is due to greater dissimilarities between the transmission and retailing business, than between production and transmission. Perhaps, integration between these is restrained by diseconomies of scope, reinforcing the more competitive structure across customers.

Thus, a public authority that wants to liberalize the market at all levels of the gas chain must, generally, seek to

- establish competition between exporters,
- regulate terms for access to producing and consuming countries transmission networks and storage,
- enhance competition between the buyers (LDCs, power plants and the industry), and
- regulate the behavior of the LDCs.

This should all be done without destroying the benefits of bundling of services where scope economies exist.

Obviously, the "Gas directive" (EU, 1998) is not introducing a fully liberalized market per se (Austvik, 2000). Even though the directive addresses the transportation issue through the suggested Third Part Access (TPA) obligations, it does not address the entire gas chain from the gas field to the burner-tip, nor does it require specific terms for how transmission should operate. However, this report will not discuss this directive explicitly. Rather, our discussion will concentrate on how the transportation segment should be dealt with in a completely liberalized market for gas in Europe, beyond the present directive.

Limits to Market Power

With significant economies of scale (and scope), transmission companies tend to become powerful towards producers as monopsonists, and towards customers as monopolists. As profit maximizers they have the potential of negotiating low prices to the producers/exporters and charge high prices and exploit any possible inelasticity of demand from their customers. An invoice from the transmission company to shippers (being producers or customers) can incur the cost of transportation, as common carriers, or implicitly as the difference between sales price to customers and the purchase price from producers, as private carriers.

Private Carriage is transportation where the pipeline buys the gas from the producer for resale to local distribution companies, power plants or large industrial users. *Contract Carriage*, on the other hand, is transport of gas owned by others. Let the tariff (per unit price of transportation) for a private carrier of natural gas be denoted s_t. The difference between the price it pays for the gas from the producer (p_p) and the price it receives from the distribution company (p_d), is then $s_t = p_d - p_p$, which, disregarding all operational and investment costs and physical losses, equals its profit. A monopsonistic pipeline towards suppliers operating as merchant faces a price function that will increase with quantity (q) purchased from the producer. If the transmission company is the only purchaser, it will bid up the price paid to producers when increasing throughput, expressed as:

(i) $$p_p = p_p(q), \text{ where } dp_p(q)/dq = p' > 0$$

On the other hand, being a monopolist towards its customers, the price the transmission company receives from them will decrease with increases in quantity sold:

(ii) $$p_d = p_d(q), \text{ where } dp_d(q)/dq = d' < 0$$

The pipeline's profit (Π) will be:

(iii) $$\pi = s_t * q = p_d(q) * q - p_p(q) * q$$

Setting the derivative of (iii) with respect to quantity to zero yields:

$$d\pi/dq = q * d' + p_d - p_p - q * p' = 0$$

$$\textit{(iv)} \qquad \Rightarrow \quad p_p + q * p' = p_d + q * d'$$

The left side of (iv) expresses the marginal cost of buying gas from the producers. The element q * p' tells us how much the price of gas to producers will increase if the pipeline buys an incremental unit. The right side of the equation expresses the marginal revenue of selling one additional unit of gas. The element q * d' tells us how much the price of gas to customers will decrease if it sells one more unit of gas. Not surprisingly, the equation shows that at maximum profit, marginal revenue from selling an additional unit of gas shall equal its marginal cost. The special in this case is that the transmission company, by restricting quantity traded towards producers and distributors, power plants and large industrial users in this optimal manner, can simultaneously exploit inelasticities of demand and supply in order to maximize its own advantage. It is possible, but not likely, that such a situation, that in a stylistic way describes how the present European gas market is working, is socially efficient or maximizing public welfare.

However, several factors determine the transmission companies' market power in addition to scale and scope economies. One such factor is the power of producers and customers, respectively, that the transporter meets at it end. By concentrating sellers and buyers power, a counterforce to mitigate pipelines' market power is created. In the European gas market, this is, to some extent, done at the supply side, which today better can be characterized as oligopolistic than competitive. There are only a few exporting nations, and within each of these nations gas sales are orchestrated through one body. At the customer's side, however, it is more difficult to concentrate purchasing power. Customers are placed in several consuming countries and there are many LDCs, power plants and industrial users within each of them. Thus, on the customers' side, the European and U.S. gas market is, from an economic point of view, more similar than on the supply side, where in the U.S. there are thousands of producers.

In order to exploit economies of scope, producers have good reasons to integrate wholly or partially with transmission activities. In the Norwegian North Sea, producing firms' in most cases has property rights in offshore pipelines. In Russia and Algeria, it is (so far) done by centralized firm(s) in Moscow and Alger, planning production and transmission to the respective countries' borders. In the Netherlands, Gasunie buys all gas, transports it to the border and sells it. This product extension contributes in realizing the oligopolistic market structure on the supply side. In the market, the long-term contracts between producers and consuming countries' transmission companies may also be considered as an approach to optimizing the advantages of joint management of transmission and production.

The market power of the transmission companies is also limited if there is an alternative route or method of transportation. Often, the building of another pipeline may incur too high costs to represent any credible threat to the existing one. LNG as an alternative to pipeline transportation, may, in some cases, put a limit on how high pipeline fees can be (intermodal competition). Investment costs for LNG transportation are largely connected with liquefaction of gas (in producing countries) and regasification and storage (in consuming countries). Shipping costs between producing and consuming nations are some 50 % higher than for oil, but represent a much lower share of overall costs in bringing gas from producer to consumers than do gas pipelines. The distance of transportation plays a much smaller role in LNG transportation and there is no technical fixed relationship between producer and customers. "As a result, pipeline transportation costs for onshore distances over 4000 km and offshore distances over 2000 km generally exceed those of LNG where an offshore route of similar length is available" (IEA, 1994: 55). Within the European continent, often pipelines provide the only feasible link to customers. However, gas from he Middle East, Nigeria and the Barents Sea, may prove to be more cost effectively transported to the European market as LNG than through pipelines. Transporting gas on lorries and trains, are not economically feasible with today's technology.

In end-user markets, competition from other fuels, in particular oil products, but also coal and nuclear electricity, provide a price cap on gas. To the degree that customers can switch quickly and cheaply between fuels when gas prices changes, LDCs monopoly power towards end-users are restricted by this interfuel competition. The prices of alternative energies represent the limit on total market turnover, and on how much rent the various segments of the gas chain can "fight over". Competition from substitute products (in the case of gas: electricity, coal and oil), makes demand more sensitive to price changes and, thus, restrict the degree of market power by sellers, but it usually does not eliminate it.

Taken together, with some modifications, the barriers to entry is significant in pipeline transportation and transmission companies have great potential of exercising market power both towards producers and towards customers. The potential for and benefits of market power, may lead to "over-bundling" of services and over-investment in capacity in order to deter newcomers.[5] Even if it is not cost-saving advantages in bundling all kind of services, firms may nevertheless profit by doing so due to the benefits of increased market power. For a transmitter, for example, there may be economies of scale in transportation of gas but not necessarily economies of scope in the role as a wholesaler. The broker role may in some cases inhibit elements of economies of scope with the transmission service and in other situations independent firms could do it more efficiently. By having the exclusive rights (natural monopoly) in the transmission function, the pipeline company has the power to prohibit other companies wanting to act as brokers, take over their potential profit and obtain a monopoly in providing merchant services, as well. This will contain the contact between producers and end-users and decrease market efficiency. While the pipeline gains, there may be a net loss for society.

2 Public Interests

The problem for policy makers wanting to liberalize the market is that it's concentrated structure may also be the socially most efficient one, in spite of its inferiority. Because of scale economies, more firms operating in the market may incur higher transportation costs unless the market grows sufficiently in each geographic segment. This argument goes for product extension through vertical (or horizontal) integration and the exploitation of economies of scope, as well. Thus, the challenge for governments is to intervene in a way that preserve a market structure that have the potential to minimize cost, and at the same time change its behavior in order to avoid possible lax cost control and exploitation of market power.

One important question is how large the benefits of vertical integration and coordination is. The existence of scope advantages indicates that liberalization of the market should open for the possibility to bundle services in competition with provision of unbundled services. The smaller the market and fewer the number of players, the less cost arguments seem to be in favor of unbundling operations. If operations are unbundled and there exist economies of scope, the gain from increased competition should be weighed against the losses of less efficient operations

[5] See Broadman (1986) for a discussion of market power in the U.S. natural gas pipeline industry.

of each firm. Thus, with the growth in the European market, gradually more arguments support the idea of unbundling.

Maximizing Social Welfare

The significant scale economy in trunk pipelines, sunk investments and capital immobility, possible economies of scope in vertical integration and companies' bundling of services influences vertical and horizontal ownership relations and contractual terms in the European gas market. In specific segments of the markets, these relationships may promote efficient investments and pricing without public interference, but the strong concentration of market power indicates that this is rather the exception than the rule. Possibly high and rigid prices paid for transportation may lead to under-investment in production, as an overly large part of the market price ultimately paid for natural gas is accrued in the transportation sector rather than by producers. Similarly, high or rigid prices to distribution companies may lead them to exploit their strong position towards consumers (over time restrained by the price of the alternatives to gas), making consumption of natural gas sub-optimal. Gas is fairly non-polluting and, thus, inhibits a positive externality for the environment relative to the use of other fossil fuels. The view from the EU (EU, 1988) is that a too rigid market structure may be harmful for the economies involved, both from an environmental, efficiency and security-of-supply point of view.

The transmission systems are integrated parts of the gas market that should balance in competing demand for transportation services, optimal resource management and risk evaluations. From a social point of view, it is important that the economies of scale and scope is exploited, but at the same time that market inequities caused by extensive pipeline concentration and excessive bundling by transmission companies are neutralized. An optimal gas grid should enhance security of supply for consumers as well as security of demand for producers. The system should secure flexibility both in a static and dynamic sense. Statically by creating a variety of arrangements suiting each actor. Dynamically, by permitting arrangements to evolve gradually based upon market trends rather than through radical change every few years. These goals are sometimes complementary and sometimes conflicting. Ideally, the grid should barely figure into the producers' production decisions and the consumers' choice of energies.

A regulatory regime that aims at optimizing the transporters' behavior should look for arrangements that do not primarily place this judgement upon public policy makers. If one could find self-regulative arrangements, the chances that the system contains the necessary dynamics when market conditions alter are better. This is also important in order to impose minimal administrative costs. Even if a possible regulation may yield a socially efficient outcome, the costs of the enforcement process need to be subtracted from the benefits achieved by regulation, and compared to the costs of operating the existing system, in order to appraise the net social benefits. In the U.S., conditions under which gas could be produced and transported have repeatedly led to undesired results. After some time, some of the regulations was removed and new regulations introduced, but only after having incurred considerable judicial and regulatory costs, loss of efficiency and social welfare (Austvik, 2000: chapter 6).

An additional argument in favor of self-regulative arrangements is that the regulator over time need not necessarily seek to maximize social wealth only. A regulatory agency may begin its existence with public interest in mind, but end up as an agency to protect producers and/or pipeline companies. The persons employed in the regulatory agency may be influenced by his or hers career opportunities, political motives, self-assertion, power, etc. The regulated companies can gain control over the regulator and trap or capture the regulator to act in their interest and influence the goals that the regulator sets and the way he/she seeks to attain them. Such "capturing" can be encouraged by the movement of personnel between regulatory agencies and the firms, which may increase the desire for cooperation and making close ties between them.

Regulatory policy that involves transfer of huge sums from a large group to a small group is often lobbied for more easily by members of the small group. The small group has a lot at stake per capita, and easier to organize than a large group. Therefore, small groups are usually more successful in satisfying their demands towards public policy makers than large and often more diffuse groups. With huge interests at stake, producers, consumers, pipelines and distribution networks have good reasons to vociferously pursue their interests. Some countries and companies may be better off by exploiting a possible monopoly power in the market, even if it is not a zero-sum game in total. Usually consumers are associated with large groups and companies with small groups. Stiegler (1971) argues that public regulation therefore often leads to producer-protectionist results. Each party may also be too small to influence the situation and therefore does not consider the optimal situation even if they would be better off if it prevailed, and may stick to an existing sub-optimal situation.

Maximizing social welfare may, therefore, be an intriguing challenge. How to avoid inefficient bundling in the natural gas industry and keep, or even create, efficient bundling and exploitation of economies of scale and scope? How to prevent firms from taking unacceptable advantage of a possible strong positions in segments of the market? The correct answers to these questions will easily be viewed differently by competing parties, and these groups may pressure regulators. In order to design an efficient and welfare-maximizing way of regulating the market one needs a closer identification of the actual goal of the regulation.

Microeconomic theory is often used for this purpose, i.e. that the ideal situation exists in the market when price equals marginal cost (corrected for externalities). In perfectly competitive markets, there should be no need for public intervention (the *first best* solution). If one market failure arises, such as the existence of a cartel or of pollution, marginal social cost no longer equal marginal social benefit. In order to correct for this market failure, government should intervene to restore the first-best situation, where social benefits equal social costs. A first-best economy operates under conditions of social efficiency (Pareto optimality) and the policies introduced correct the market distortions that occur.

However, in the real world, this is rarely possible. In a *second-best* economy, compromises between theoretical first-best solutions and the real market are adopted. The application of a second-best policy means to minimize the distortionary effects of the market. Policy measures, other than nationalization, generally aims at second-best solutions. In fact, one could argue that nationalization also is a second-best solution (at best), as it over time often does not satisfy social efficiency goals even if it's intended to do so.

Of course, effective public intervention needs to consider political, psychological, cultural, practical and other issues, in addition to the knowledge of economics. Seeking to practice a pure economic model within the real world, i.e. in constructing tariffs for gas transportation, may lead to other results than what should be expected. Economics may first of all give insight into the processes around and the purpose of regulation, describing important forces operating towards optimality. By understanding these forces, the regulator can use this insight together with other aspects to be taken into consideration, to improve welfare and market efficiency and move towards optimality, although not necessarily reaching it.

To illustrate the situation we will start with a strong simplification of the position of a transmission company. Figure 8 considers a strong natural monopoly, due to economies of scale, with low (and constant) marginal costs compared to fixed costs. The position and shape of the demand curve (assumed linear and falling) determines which output-price combinations that are possible in this market. We will discuss three possible outcomes. In point A, the firm acts as a monopolist choosing a high price/low output combination. In point B, the firm acts as a 'cost-plus' company where price is set equal to average cost. In point C, the firm produces an output so large that price must equal marginal cost in order to make consumers absorb the entire output.

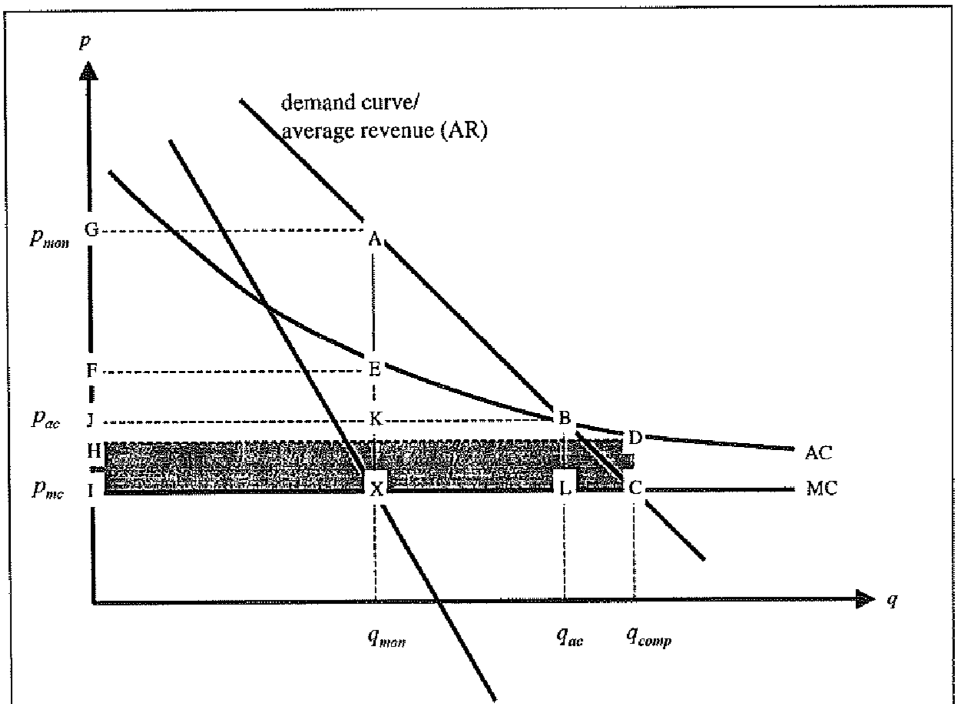


Figure 8: Decreasing average cost in a pipeline; Monopoly vs. competition

Point A: A monopolist would choose to produce where marginal revenue equals marginal cost, which happens at point X. The production (or the amount of transported gas) will be q_{mon}. For this quantity, consumers are willing to pay the price, or tariff, denoted earlier as the share to transmission company, p_{mon}. The company's economic profit will be GAEF, which results from the difference between market price and average costs at output q_{mon}. If the company increased production beyond this point, marginal cost would be higher than marginal revenue and it would loose money on the margin.

Point C: If output increases beyond q_{mon}, this would be more optimal from a social point of view. The willingness to pay is larger than the marginal cost all the way up to point C. Thus, point C is considered to be the socially most efficient way of production. The problem is that the price for transmission at point C, p_{mc} is below average cost and the company looses money unless someone is willing to pay the deficit. The loss is represented by area HDCI, which is the difference between the market price and average costs times output q_{mc}. The net advantage for society in moving production and prices from point A to point C is represented by area ACX.

Point B: If the company should break even, price must equal average cost. At point B an output of q_{ac} is produced at price p_{ac}, and the company earns normal profit but no economic profit. This point is also more optimal for society than the monopoly solution in point A. The gain for consumers (GABJ) is obviously larger than the loss for the producers (GAEF). Society's net gain equals area ABLX, while the deadweight loss is BCL compared to the first-best solution in C. Point B is a second-best-solution from a social point of view compared to point C.

Historically, *nationalization* (point C) has been widely applied in Europe after Word War II. Under nationalization, the government replaces the market by providing the service or good itself. When nationalized, the governmental owned company, usually, sets price equal to marginal cost. As long as average costs often exceed marginal cost for natural monopolies, public budgets must transfer funds to the firm to cover the deficit (HDCI). However, marginal cost pricing is a necessary, but not sufficient, criterion for maximizing social welfare, as it ignores the question of the 'best' or 'fairest' distribution of income. It may be possible to reach a higher level of welfare with an 'inefficient' way of production than with an efficient one. This could happen if the income distribution is 'sufficiently wrong' or if it is difficult to reach the most efficient way of producing. Then, it could be better to look for second-best solutions for how the goods or service should be provided.

Regulation (point B) is such a second-best solution and has been the American way of intervening into such markets. Public regulation may be made through force, or by incentives, inducing the firm to act in its self-interest, which at the same time is compatible with social goals. Under regulation, the goal is to make the firm decrease price/tariff, increase output and to produce this output efficiently at minimum cost. The firm must earn normal profits on its investments in order to remain in business, but no economic profit. However, this simple goal is not that simple to reach.

Often *laws* about market structure and firms behavior are parts of a liberalization of a market. Laws may prohibit or regulate the behavior of firms that are imposing external costs. For example, a firm can be banned or restricted to perform polluting activities. In the case of monopolies and oligopolies, laws can be used to change the structure of the industry or the behavior of the firms within it. When affecting market structure, laws can make mergers (horizontal integration) illegal. Even though there may be a large number of firms in the market, one or a few may control the major part of it and, thus, behave as monopolist/oligopolists. Thus, market concentration can be measured in terms of how many firms control a certain market share. The government could make a merger illegal if the degree of concentration rises above a certain amount. If firms already control more than this percentage, they could be split into smaller firms. Whether this is efficient or not, depend on cost structure of the activity compared to size of market and the behavior of the firm. Competition laws in the EU, therefore, studies the actual performance of the firms rather than market share to assess whether or not, for example, a merger should be considered illegal or not.

Taxes and subsidies are often favored by economists to repair for market failures. These are used both to improve social efficiency and to redistribute income. To improve efficiency, taxes can be used to reduce the social costs of (negative) externalities, monopoly power, imperfect knowledge and irrational behavior. In some simplistic cases, taxes can be used to achieve first-best solutions. However, because it usually is infeasible to use different tax and subsidy rates towards different firms, and because the government lack detailed knowledge about markets, taxes and subsidies seldom achieves more than second-best solutions.

Under regulation, a "visible hand" is introduced in the absence of the market's "invisible hand". By regulating the framework and conditions for how the firm may operate, public authorities seek to achieve what is considered optimal for the society. The incentives and disincentives given for pricing and production should create mechanisms leading to an efficient allocation of resources and "acceptable" distribution of income. As part of intervening into firms' behavior, regulation may be introduced to direct the firm to behave in certain ways. The framework and regulatory mechanisms for the market must then be constructed in a way that companies voluntarily produce an amount at a price that gives maximal profits and simultaneously satisfies social goals. The regulations should lead to consistency between the company's desire to maximize profits and the society's desire for maximizing welfare, as in a perfectly competitive market. This is the core of regulatory economics.

3 Schedules for Regulatory Regimes

Rate-of-Return (ROR) Regulation - the "A-J-Effect".

Averch-Johnson (1962) is considered one of the most influential investigations into regulations' effects on firm's behavior. They showed that a regulation of return on capital not necessarily mitigate the aspects of monopoly control that the regulation addresses. They even concluded that such regulation could make the situation worse.

Consider a monopolist producing a single output q and using two factors of production, labor (*L*) and capital (*K*). The (market) price of capital and labor is denoted *r* and *w*, respectively. Let $q = q(L,K)$ denote the (neo-classical) production function, and the price of q as the inverse demand function $p = p(q)$. The firm's (economic) profit (π) will be:

(i) $$\pi = p(q) * q(L,K) - w*L - r*K$$

Unregulated, the firm will chose its capital-labor ratio in a way that costs be minimized. This happens when the marginal rate of substitution between the two inputs q'_K/q'_L, are equal to the ratio of input prices, r/w. When regulated, assume that the regulator allows a rate of return on capital equal to m. Return on capital is defined as net revenues, which is gross revenues ($p*q$) minus costs of labor ($w*L$) and other possible non-capital input factors (here: zero) divided on amount of capital invested (*K*). The firm is otherwise unconstrained and can choose its price/tariff, level of output and input as long as profit does not exceed this "fair" rate. The rate of return constraint can be expressed as:

$$(ii) \qquad m \geq \frac{p(q) * q(L,K) - w*L}{K}$$

The behavior of the firm will vary a lot with which level of m is chosen. If the regulator sets $m < r$, the firm will make more profit by closing down the business and selling it's capital than continuing it's service (assuming no sunk cost and that it legally can do so).

If $m = r$, the firm makes zero economic profit which yields an indeterminate situation. The firm would earn the same profit per unit whether it increases or decreases output, whether it uses resources efficiently or inefficiently, or whether the input mix is optimal or not. The firm would, in fact, make the same money if it closed down and sold off it's capital (assuming no sunk cost). Thus, as the firm can chose many different outcomes, a ROR regulation that set $r = m$ cannot be relied upon as a device to make it act in any particular way.

If the regulator set $m \geq r^{mon}$, where r^{mon} is the return of an unregulated firm, the constraint is higher than what it possibly could make in the market. This will not change its behavior. In such a case there is essentially no regulation.

If the regulator set $r^{mon} > m > r$, the rate of return is higher than the cost of capital but less than it would earn as unregulated monopolist, the firm will still earn an economic profit on it's investment. If we subtract the (market) price of capital from both sides of inequality (ii) and rearrange:

$$m - r \geq (p*q - w*L) / K - r$$

$$m - r \geq (p*q - w*L - r*K) / K$$

$$m - r \geq \pi / K$$

$$(iii) \qquad \pi \leq (m - r) / K$$

The maximum economic profit the firm can earn on it's investment is $(m - r) / K$.[6] The problem with this approach is that if the firm is allowed to increase it's (economic) profit by

[6] If m = 0.12 (12 per cent), and r = 0.09 (9 per cent), the company's economic profit should not exceed 3 per cent.

increasing it's amount of capital. The rate of return (with an economic profit up to $(m\text{-}r)$) will remain the same, but in absolute terms profit becomes higher.

The discussion above showed that the only way the regulator can set the return constraint is by letting $r^{mon} > m > r$. Whether it is feasible or not for the firm to earn an economic profit on its investment under the constraint of an allowed profit ceiling depends on its technology and demand for service. Some combinations of K and L could exactly yield a rate of return $r = m$. If the firm can manage to find this set of K and L combinations, it chooses the one among them that uses the greatest amount of capital. This gives the highest absolute profit. If the capital stock is not increased, feasible profit will be lower $(\pi < (m-r)K)$, and thus, inferior to the cost minimizing point with the maximum use of capital. Other cost minimizing combinations of K and L, yields the same economic profit but on a smaller amount of capital, and thus, less total profit.

In essence, the A-J analysis shows that the firm adopts an inefficient production plan, as it's marginal rate of transformation between capital and labor exceeds it's cost-minimizing level when the regulator set $m > r$:

$$q'_K/q'_L < r/w$$

This implies that it over-invests and accumulates capital in order to relax the rate of return constraint. This is called the *A-J effect.* The regulated uses more capital than the unregulated; $(K/L)_{reg} > (K/L)_{mon}$, which will be an inefficient way of production. Thus, the output produced by the regulated firm can efficiently be produced with less capital and more labor at a lower cost.

Some modifications have been proposed to this type of regulation (Train, 1991: 20-67, 94-113 and Berg & Tschirhart, 1989: 324-333). Rather than constraining the rate-of-return on capital, a constraint can be put on the return on output, revenue or cost. These modifications may induce the firm to behave more optimal than when return on capital is regulated.

Regulating return on output: In this case, the firm is allowed to make a profit on each unit of output. Now, the firm will expand output as long as consumers' willingness to pay is above total production cost (including allowed profit). If allowed return on output is set sufficiently low, the firm may end up close to where price equals average cost, or the second best solution in figure 8 (point B).

Regulating return on revenue: If the firm is allowed to make a certain profit on each unit of revenue, the firm will expand output in the same way as under a return-on-output regulation as long as marginal revenue is positive. When marginal revenue becomes negative, expanded output decreases revenue. Thus, the firm will produce at the point where total revenue is greatest, or when MR=0. Therefore, a return-on-revenue regulation will only approach the second-best-solution if MR≥0 to this point. In figure 8 the volume produced will be quite far from the volumes representing point B.

Regulating return on cost: If the firm is allowed to make a certain profit on each unit of cost, it increases its allowed profit by increasing its cost. Maximum cost is accrued when output is maximized. However, increasing output, decreases revenues when MR < 0. Therefore, when MR < 0 the firm wishes to increase cost rather than output. The firms start to waste at outputs at this point. In the same way as under return-on-revenue regulation, although of a different reason, a return-on-cost regulation will only approach the second-best-solution if MR≥ 0.

Thus, regulating either the return on capital, revenue or cost yields inefficiencies by the firms' behavior. Regulation of return on each output that is produced is the one form of regulation that has the greatest chance of achieving a solution that in some sense may optimize social welfare, disregarding the problem of actually setting this rate with weak insight in firms cost curves.

Price Discrimination – "Ramsey Pricing"

Under the regulations discussed above, we assumed that the firm charges the same price to all its customers. Price discrimination is, on the other hand, a situation where the firm charges prices for each unit of output equivalently to consumers' willingness to pay. Such price discrimination can be performed towards different type of customers, at different levels of output, seasons etc.

A firm that can charge prices equal to each consumer's WTP performs a perfect price discrimination. By doing so, the firm receives an extra profit that is represented by the entire area under the demand curve and above the price equal to consumer's surplus. Referring to figure 8, a firm can expand output beyond q_{ac} under price discrimination, as long as $p \geq MC$, because it's fixed costs are covered by already charging higher prices to customers with a high WTP (to the left of point B). Under price discrimination, as the firm increases output it has to decrease price all the way *on the margin*, but it does not have to lower the price taken from customers that are willing to pay a higher price. The firm wishes to sell more units as long as the price it receives from selling extra units exceeds the extra costs incurred by producing this unit (the marginal cost) without reducing the price for volumes already sold.

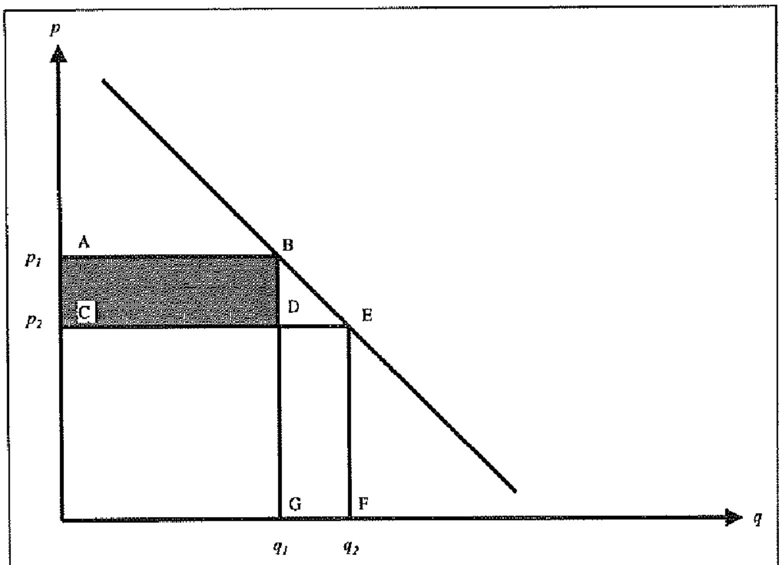


Figure 9: Effects of quantity changes on price and revenue

In figure 9, let's first assume that all customers buying the volume q_1 are charged the same price p_1. If output is expanded from q_1 to q_2, without price discrimination, price must be reduced for all customers from p_1 to p_2. Gain in total revenue due to higher volumes is represented by the area DEFG and the loss in revenue due to lower prices is represented by the area ABCD. If DEFG > ABCD, there is a net gain and MR>0. Otherwise there will be a loss of revenue due to increased production. Let's then assume that increasing output from q_1 to q_2 do not lower prices customers are willing to pay for q_1 only. In this case, when the firms take one price p_1 for volumes q_1, and another price p_2 for volume q_2-q_1, the loss in revenues ABCD equals zero. Net gain will now be DEFG.

Either selling for the same price or under price discrimination, the firm sells an extra unit of output as long as its marginal revenue is above its marginal cost. When the firm must charge the same price to all customers, this happens where MR=MC (< AR as in point X in figure 8). Under perfect price discrimination, the firm chooses optimal output where p = MC = MR = AR, as in point C in figure 8. Thus, under perfect price discrimination, the demand curve becomes the marginal revenue curve. Under perfect price discrimination, the firm extracts all surpluses and none is left to consumers.

Price discrimination could bring the firm to the first best solution rather than to the second best solution and allows the firm to produce more output than under a regulatory mechanism that requires the same price for all outputs. The social success of such discrimination depend, inter alia, whether customers with a low WTP are able to resell their volumes to customers with a higher WTP. Normally, the pipeline itself can prevent this when unregulated. When regulated, the regulator must establish and enforce rules against such resale.

If prices on average shall equal average cost (firm breaks even) and prices are set differently to customers, the firm must deviate from marginal cost pricing (at least) for parts of it's sale. This should be done in a way that harms overall welfare as little as possible. At *Ramsey pricing*[7], prices are raised more in markets with less elastic demand than in market were demand is more elastic, in inverse proportion to the values of each market's demand elasticity ("inverse elasticity rule"). This way of discriminating minimizes the welfare losses when prices are increased beyond marginal cost.

Under Ramsey pricing, output should be reduced from the point where p=MC by the same proportion in *each* market. The higher prices obtained by these even output reductions and uneven price reactions, reduces the firm's loss compared to a situation where prices are increased similar in all markets until the (common) price equal marginal cost. Output should continuously be reduced proportionately until the firm eventually breaks even. More revenue can be obtained with less reduction of output (and less disruption in consumption patterns) if prices are raised more in markets with inelastic demand. In this way, total surplus is reduced as little as possible, and the firm can break-even without being subsidized by the government.

[7] After Ramsey (1927). Ramsey showed how governments could set tax rates for various goods and at the same time disturb consumers' surplus as little as possible. Baumol and Bradford (1970) uses this principle for setting second-best pricing for multiproduct natural monopolies.

In figure 10, the product is sold in two markets, market 1 and market 2. At p=MC, each market wants to consume equal amounts, q^*, of the product (marginal cost is assumed constant). The only difference between the markets is that demand in market 1 is more inelastic than demand in market 2. If output is reduced by the same amount in each market, down to q^{**}, price in market 1 increases to p_1 while price in market 2 increases to p_2, where $p_1 > p_2$.

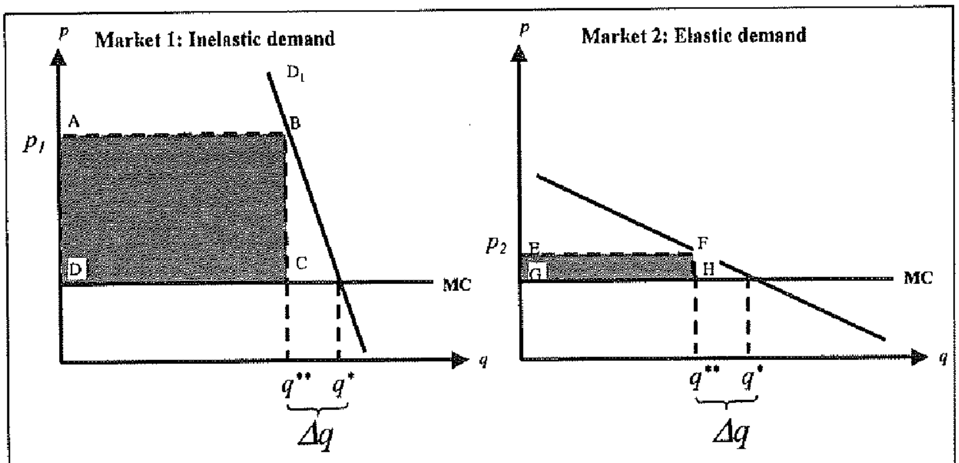


Figure 10: Price changes depend on price elasticities; Ramsey pricing

By doing this, market 1 contributes with a profit to the firm represented by area ABCD and market 2 to a profit represented by area EFGH. Total profit contribution from the two markets would be ABCD + EFGH = $(p_1\text{-}MC) + (p_2\text{-}MC) * q^{**}$. Output should be reduced in this way until total profit contribution from the two markets makes the firm brakes even.

In a more general form, denoting the sale of q in the two markets as q_1 and q_2, the Ramsey rule tells that the relative quantity change shall be the same in each market in order to make consumers behave very much as they would have without the price increase:

(i) $$\Delta q_1/q_1 = \Delta q_2/q_2.$$

(i) is the "inverse elasticity rule" in volume terms. Expressed in price terms, prices should be raised inversely related to elasticity of demand in each market:

(ii) $$(p_1-MC)/p_1) * \varepsilon_1 = ((p_2-MC)/p_2) * \varepsilon_2$$

where ε_i is the price elasticity of demand in market i (i=1,2): $\varepsilon_i = dq_i/dp_i * p_i/q_i$.

Ramsey pricing is already applied in the European gas market, for example when *peak-load pricing* formulas are used. Under this system, the price that consumers pay varies, in order for the firm to cover average costs, including normal profit. This principle would set prices higher when demand in general is more inelastic (especially in winter months). Under this type of price setting, parts of consumers' surplus are transferred to transmission companies when demand is inelastic and from transmission companies when demand is more elastic. Such pricing satisfy efficiency considerations quite well, as they distort consumption patterns as little as possible, and much less than if the same price were charges in both periods (for example in winter and summer).

Subsidizing to Marginal Cost Pricing

If a regulator possesses all information on cost and demand curves, he could simply require prices to be set at marginal cost and give the firm a subsidy, equal to area HDCI in figure 8, in order to let it make a normal profit. Together with nationalization, this has been an important principle for how natural monopolies have been dealt with in many European countries after WW2. However, the regulator rarely has all this information. The company has also incentives to misreport costs in order to increase profits. If reported correctly, incurred cost may not be minimum cost of production, for example due to inefficiencies or sub-optimal capacity choice. Thus, making the firm produce in the firs-best-option is not an easy challenge. Our question here is whether it possible to design some subsidizing mechanisms that induces the firm to produce at marginal cost without a public ownership and regulator's knowledge of the position and shape of cost curves?

Let's assume that the regulator knows that the firm will not charge prices higher than p_a in figure 11. This price could for example be the monopolistic price of an unregulated natural monopoly. The regulator subsidizes the firm for the portion of consumer surplus *between* p_a and the price the firm actually charges. Thus, the lower price the firm charges, the higher the subsidy. If the firm sets prices equal to p_b = MC, the firm maximizes the transfer of subsidy and at the same time behaves in an optimal manner.

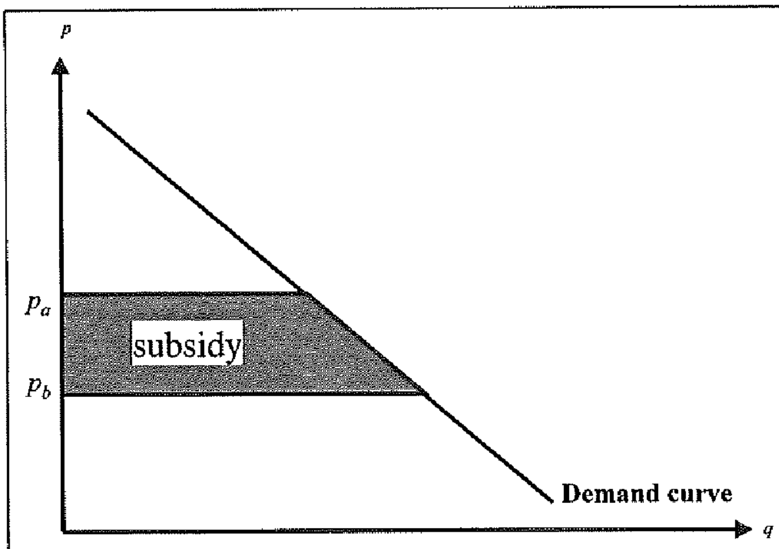


Figure 11: Subsidizing firm to marginal cost pricing

Loeb and Magat (1979) showed that, in general, if the regulator subsidizes the firm by the entire consumer surplus (CS) generated at the price existing in the market, the firm would choose to produce at p=MC. In order to do this, the regulator must have information on the demand curve and the firm's price, and no information on cost is needed. Firm's profit would equal total social surplus, or the sum of producers' (PS) and consumers' surplus. Because this surplus is the greatest when p=MC, the firm maximizes profit (the sum of PS and the subsidy = CS) at this point.

This will be true even if many products exist. By setting all prices equal to marginal cost, profit is maximized in all markets and market segments when receiving such a subsidy. Any decrease in cost results in an increase in profits and firms have an incentive to produce efficiently. As the government pays the subsidy, consumers' surplus is also maximized by this rule, if we disregard that the funding for the subsidy must be collected from many (but not necessarily all) of these consumers.

Such a transfer from the public to the firm may be considered inequitable. One way of reducing it, but maintaining the main principle, is to subsidize only a portion of CS. As the firm could never charge prices higher than p_a in figure 11, it could not receive the CS accrued above p_a. By subsidizing only the portion accrued below p_a, the same result is obtained as if transfers should equal the entire area under the demand curve. This type of transfer should cost less for the public, and thus, be of a less intolerable size from equity considerations. If we refer these results to figure 8, unsubsidized profit for p_{mon}(=pa in figure 11) is represented by area GAEF. Subsidy when p_{mc} (=p_b in figure 11) is represented by the area GACI > GAEF.

By moving p (=pa in figure 11) down from p_{mon} along the demand curve, the firm's economic profit will decrease as will total subsidy. The difficulty is to set p sufficiently high, but not higher than what is necessary, in order to make the firm brake even. But the inequality GACI > GAEF holds all the way until the firm earns only normal profit. At this point, the subsidy will equal the firm's loss when producing at prices equal to marginal cost. Train (1991: 182-190) discusses some regulatory mechanisms that have been proposed in order to find these optimal prices. He suggests a multiperiod marginal cost approaches, where prices, revenues and expenditures in one period determine the subsidy of the firm in the next period with or without full information about the position and shape of the demand curve.[8] Another alternative is to use multipart tariffs.

Multipart Tariffs

A multipart tariff consists of several billing components. There are two main types of multipart tariffs: access/usage tariffs and block rates.

Access/usage tariffs consist of an access charge, which is a fixed fee for having the right to use a system, and a usage charge, which is a per-unit tariff for actually using it. For example, telephone companies often use access/usage tariffs, billing one fee for access to the network, and one (per unit) fee for each call made. This system makes consumers' marginal cost for each call constant, but their average cost (the average price for consumption of telephone use over a period) declines with the number of calls.

Block rate tariffs changes when total level of consumption reaches certain *thresholds*. For example, electricity companies often charges one price for consumption of a certain number of kilowatt-hours and another charge (higher or lower) for additional kilowatt-hours. This system makes consumers' marginal cost of using electricity change with the level of consumption, while

[8] See also Sappington and Sibley (1988) and Vogelsang and Finsinger (1979).

the average cost (the average price for using one kilowatt hour) is the weighed average of the price of all units consumed and may increase or decrease depending on the tariff structure.

-Access / Usage Tariffs – "the Coase Argument"

Coase (1946) argued that the first-best solution for a natural monopoly (price equal marginal cost) could be reached if demand for usage is fixed and an access/usage pricing system is used. The access fee should be set to cover the natural monopoly's fixed costs and the usage fee to cover marginal cost of usage. In this situation, the aggregated access fees are considered a transfer of funds from consumers to producers as if the firm received a subsidy from government. The access fee will not affect consumption of service as long as the access fee covers fixed costs. The firm will benefit by supplying more output as long as price is equal to or higher than marginal cost. When demand for access is fixed and the fixed cost are covered by the "subsidy", the firm will gain by reducing usage fees down to marginal cost of production. Up to this point consumer's willingness to pay is greater than firms marginal cost of providing the service. Any other price or if the firm starts to waste, will incur a loss and, accordingly, the firm will serve in an efficient manner.

However, demand for access is not always fixed, but may vary with the access charge. When demand for access is price-sensitive, any rise in the access fee will, to some extent, lower demand for access. Low access charges may, for example, increase the number of households installing pipes and equipment for use of gas. In a situation with price-sensitive access demand, the access fee influences demand for access and indirectly the demand for usage. The access fee can no longer be considered only to be a transfer from customers to the firm.

Consider the access and the usage of the firm's services as two different goods with separate but interrelated demand, each with a separate marginal cost. For example, there is one demand for installing a new pipe and equipment into a house and another for the actual use of gas when equipment is already installed. With price-sensitive demand for access, optimality can be reached if access fees are set equal to marginal cost of access and usage fees equal to marginal cost of usage. The problem is that with access fees set at marginal cost of access a loss is often incurred to the firm, as average cost of access if often higher than it's marginal cost.

If the firm runs a loss, somehow access must be reduced in order to rise access fees for the firm to brake even. From an efficiency point of view, the reduction in access should be allocated in a way that consumption pattern is distorted as little as possible. Ramsey access and usage fees for the two goods may achieve this. Each customer or group of customers should then reduce consumption by the same proportion, and prices raised for each of them according to their inverse price elasticity of demand. If demand for access is totally inelastic (zero), then the Ramsey rule applied in this situation reduces to the result presented by Coase. This may be true if access fees are relatively low. If not, access fees should be raised to whatever level is necessary for the firm to break even and usage charges reduced to cover usage (marginal) costs of usage. This will generate a second-best solution, as Ramsey pricing does in general.[9]

Figure 12 depicts a situation where consumers take into consideration both the access and usage charge. Let's assume that the usage fee is fixed equal to p_{usage} and that the line AE, given that the customer has access to the system, represents the demand curve for usage. The area ADF then represents consumers' surplus. If the usage fee is raised, consumers' surplus is reduced accordingly. At some level of the usage fee, consumer surplus is not greater than the access fee anymore. This is assumed to happen at p^*, where the area ABC the size of the access fee. At usage fees $p_{usage} < p^*$, the consumer will demand usage depending only on the usage fee, independently of the access fee.

[9] In a situation when usage demand is fixed, but not access demand, the access fee should be set equal to the marginal cost of access, while the usage fee is set sufficiently high in order to make the firm break even. That is, natural monopolies that does not use access fees, but only usage fees, can do so only if usage demand is less elastic than access demand. However, this is very rarely the case for a natural monopoly as fixed compared to variable costs are usually very high.

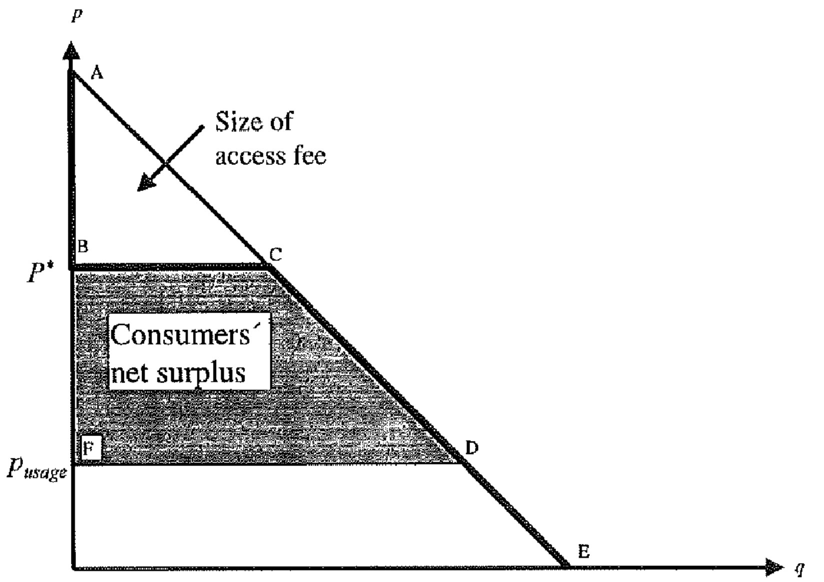


Figure 12: Ex ante and ex post demand curves

Obviously, ex ante, the size of the access fee must be taken into consumer's consideration as well. Consumers know that the surplus they get will be the consumers surplus generated at the usage fee charged minus the access fee (ADF-ABC). Therefore, at $p_{usage} > p^*$, the consumer will choose not to acquire access. In this case the benefit of usage will be less than the cost of getting access. If $p_{usage}<p^*$, consumers get a net surplus equal to area BCDF. The lower the usage fees the greater the surplus. This means that the consumer will have no demand for service at usage fees above p^*. Therefore, ex ante, the kinked line ABCE represents demand for service. Ex post, when the customer has paid the access fee, the line AE will be the demand curve. If consumers net surplus is sufficiently large, which happens when (relative) changes in access and usage fees within 'reason' does not induce consumers to forego service, access demand can be considered fixed. Then access fees can be raised to the point where fixed costs are covered (the Coase result). However, demand for access is fixed only if the surplus from usage is so much greater than the access fee, that "relevant" changes in access *and* usage fees does not imply that consumers forego service.

-Block Rates

The term 'block' rates have arisen from the particular form of its graphical presentation, as the pricing algorithm looks like series of blocks. Consumption of service under each of the prices is called a 'block'. In a declining block rate tariff, as shown in figure 13, price (p) for each unit consumed declines with the level of consumption (q). In the figure the following rates exist:

$$p_1 \text{ for } 0 < q < q_1$$
$$p_2 \text{ for } q_1 \leq q < q_2$$
$$p_3 \text{ for } q_2 \leq q$$

In this case, there exists three blocks: $0 < q < q_1$, $q_1 \leq q < q_2$ and $q_2 \leq q$. The price the consumer pays for an additional unit of consumption is called the *marginal price* and the prices that applies for lower levels of consumption the *inframarginal price.* In figure 13, a customer that *consumes* $q_1<q<q_2$ faces a marginal price of $p=p_2$ and an inframarginal price of $p=p_1>p_2$. At consumption $q>q_2$, the marginal price would have been $p=p_3<p_2$ and two inframarginal prices would exist, p_1 and p_2.

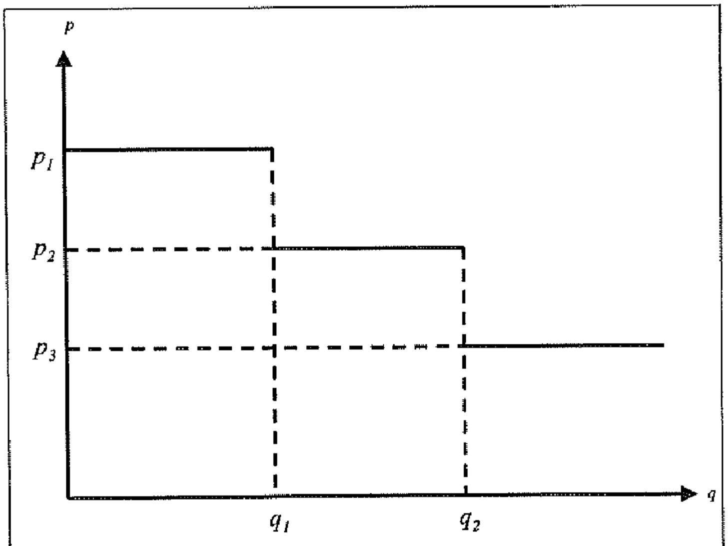


Figure 13: Declining block rate tariff

Block rates can, of course, also be 'inverted', as opposed to declining. Inverted block rates consist of blocks with higher, instead of declining, prices with higher level of consumption. Beyond the first block marginal price is below average price under declining block rates and above average price under inverted block rates. Usage charges under a system with access/usage tariffs can, of course, also consist of block rates, making a combination of the two pricing systems possible.

With a block-tariff system the question arises how to determine the optimal threshold(s) and price(s) in each block. Optimality is reached when consumers' surplus is the greatest given that the firm should break even. This may sometimes yield a first-best outcome and sometimes a second-best outcome.

Let p_1 in figure 14 represent the (uniform) price before a block-tariff system is introduced. This yields consumption of q_1. Marginal cost (MC) is assumed constant. Then the uniform system is replaced by a two-block tariff system, which set the threshold for consumption at which tariff changes equal to q_1 and the price for the second block to $p_2<p_1$ above marginal cost. With this two-block pricing system, the price for output up to q_1 is maintained. By increasing consumption up to q_2 at the lower price p_2, consumers get an extra surplus of ABF and the firm an extra profit of FBDE. No party is worse off compared to the system with a uniform price, in fact in our example both consumers and the firm is better off. Thus, such a block-tariff system is Pareto dominating the uniform tariff system.

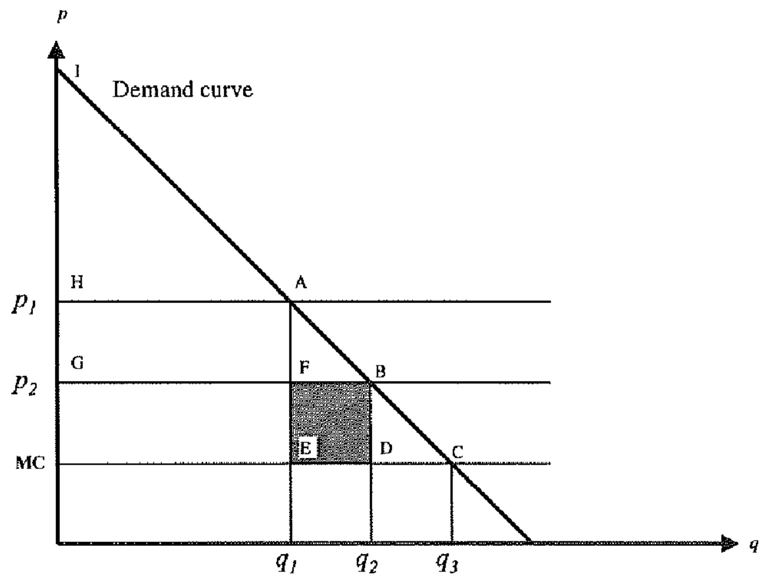


Figure 14: Ex ante and ex post demand curves

If this is the situation for a single customer consuming more than q_1, the area FGHA can be considered similar to an access fee under an access/usage tariff system. The usage tariff will equal to p_2 for all quantities demanded, as the "access fee" FGHA must be paid "first" in order to consume more than q_1. The consumer faces the same total bill under both systems. The bill under a block rate tariff system will be $q_1*p_1 + (q_2-q_1)*p_2$. The bill under an access/usage tariff system will be $q_1*(p_1-p_2) + q_2 * p_2$. Producers face the same marginal price (p_2) under both systems and receive the same total revenue as consumers pay the same total amount.[10]

By replacing a "one-block" tariff (or a uniform price) by a two-block tariff, the deadweight loss is reduced to from ACE to DCB. It is easy to see from the figure that introducing a third block at outputs with a threshold $q_2<q<q_3$ at any price $MC<p<p_2$, reduces the deadweight loss further to the benefit of consumers' surplus and firm's profit. Thus, surplus is improved by increasing the number of blocks, and, in principle, until the first-best outcome is reached ($p=MC$ for the last unit). If number of blocks are N, an optimal N+1 tariff provides greater surplus than the optimal N block tariff as long as the tariff of block number N is greater than marginal cost of service.

At a given $q=q_1$, the optimal prices for each block, p_1 and p_2, should be set in a way that it distort consumption as little as possible (given that the firm shall break even). One good is consider the output within one block. By using the inverse elasticity rule of Ramsey pricing, the price is raised more for the good with the lower elasticity. For consumers in the second block, the inframarginal price in block one does not affect their consumption. At increasingly higher quantities of output, however, in particular in the second block, demand becomes more price sensitive. Thus, prices in the first block should be higher than in the second if consumer surplus should be distorted as little as possible. This is the reason why the optimal block-rate tariff usually consists of declining blocks, rather than inverted block-rates with prices rising at each successive threshold.[11]

In the example above, the threshold was set in a way that consumers demand exactly q_1 at price p_1. Under a uniform price system this will be the customer's demand. The introduction of a declining block rate tariff will be to the benefit for each consumer, as it makes it possible to consume more. The two-block system will increase consumption to q_2, and surplus is increased

[10] This is true if there is no (positive or negative) externalities or transactions costs and the consumer knows its demand. However, if these assumptions does not hold there is a difference between them as consumers could in certain situation desire access without having any charged usage.

[11] However, from an equity consideration, inverted block rates may be preferable. Inverted block rates are lower for smaller quantities of output. Consumers face the lowest rates at low levels of consumption. This benefit low-income consumers, while declining rates benefit larger and high-income consumers.

by the area AFB in figure 14. Now, assume that the threshold for block 1 is set higher than q_1 $(q_1<q=q^*<q_2)$, as shown in figure 15. Because the first block is larger than consumer's willingness to pay, there is a loss of consuming more than q_1 as illustrated by the area AJK. The gain by increasing consumption to q_2 is reduced from AFB to KLB. If KBL>AJK it is a net gain of continue consuming q_2 at the new threshold $q=q^*$. However, the closer q^* approaches q_2, the smaller the gain and eventually it becomes a net loss.

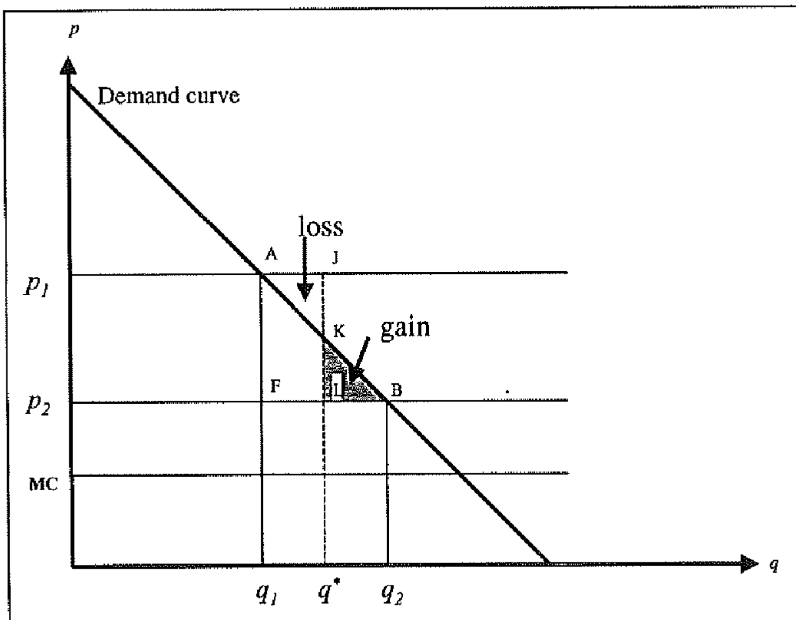


Figure 15: Loss and gains by determining the block threshold

As long as consumers continue to consume in the second block, their elasticity of demand is zero in the first block. The inverse elasticity rule suggests that the price in the second block should be set equal to firm's marginal cost and the price in the first block sufficiently high for revenues to cover total cost. By using Ramsey pricing to determine p_2 and p_1, where p_2=MC and $(p_1\text{-}MC)*q_1$ equal the revenues needed for the firm to brake even (mainly fixed costs), first best optimality can be achieved.

Thus, the optimal threshold in a two-block tariff system depends on which price-output combination make the firm breaks even. A reduction in the threshold gives more consumption in the second block, which benefits consumers, but simultaneously less revenue to the firm (assuming p_1 constant). Usually a reduction in the threshold will also increase the number of customers. At the optimal threshold, the gains and losses for consumers and firms are equal when the threshold is changed in either direction. Even if this is rather unprecise from a practical perspective, it may nevertheless give some assistance in determining the threshold.

Determining Optimal Capacity

In the long run, all costs for the firm can be considered variable. However, in periods from when an investment decision is made until a pipeline actually operates, capacity must be considered fixed. Ex post, capacity is determined by the investment done in a pipeline. Ex ante, capacity can be adjusted. The question is how to determine the size of capacity.

Corrected for uncertainty, a new pipeline project should give a positive net present value of the investment at an appropriate discount rate. One way of considering this investment is in terms of flow of expenditures, rather than as a one-time payment. This flow of expenditures may include mortgage payments on the loans taken to finance the project and varies in particular with the repayment period and the interest rate.[12]

The annual flow of expenditures *per unit of capacity* (a) represents the cost of increasing capacity from K to K+1, at all capacity uses at a given capacity. The short run marginal cost (SRMC) for output $q \leq K$ is denoted b. Both a and b are assumed constant of reasons of simplicity. Then, long run marginal cost (LRMC) of producing one output is the sum of the costs of expanding capacity by one unit and the cost of producing it at this capacity; LRMC=$a+b$ as shown in figure 16.

At output q_1, consumers are willing to pay the price p_1. Their WTP exceed both variable and average fixed costs. The difference between price p_1 and SRMC is p_1-b and represent the amount consumers are willing to pay more than variable cost for capacity to be expanded in order to get one additional unit of output.

[12] With societies' lower discount rates compared to the private ones, caused by a usually longer time perspective and an overall view on the gas business and the economy, a project may be right to realize for the society but not for the private company. On the other hand, governments are normally risk averse, i.e. the numerical cost of the possibility of losing one dollar is often viewed as larger than the benefit of gaining one. Private businesses may be more risk neutral (the numerical cost of the possibility of losing one dollar equals the benefit of one). Some may even be risk lovers (the numerical cost of losing one dollar is smaller than the benefit of gaining one). If private industries are less risk averse than governments, they may tend to invest sooner than governments. The assessment of the uncertainty, at a given discount rate, will depend on factors as the resources at hand, market possibilities, the presence of alternative energies, time horizon etc. The advantages of the government's longer and more general view, may be of particular importance for huge and strategically important pipelines due to reasons of security of supply, overall economic considerations et.c.

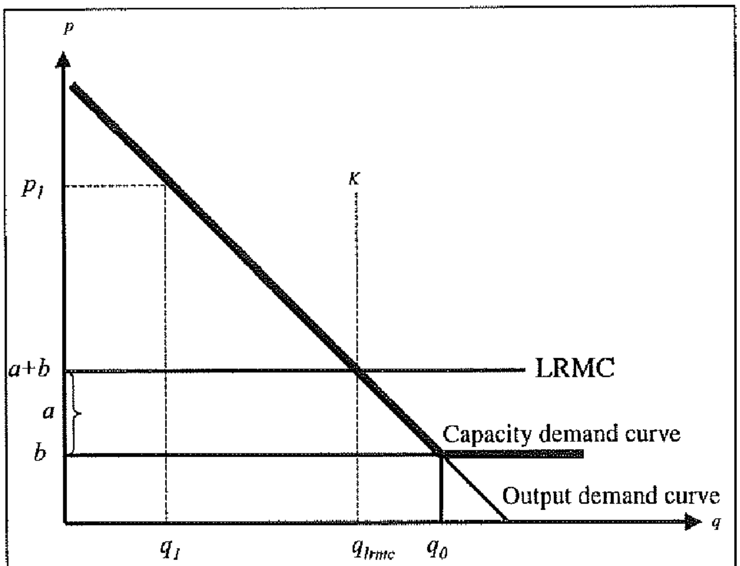


Figure 16: Optimal capacity determined at prices equal to long run marginal costs

At all levels of output $q<q_0$ (where q_0 is the amount demanded at $p=b$), consumers are willing to pay for additional capacity. Thus, the demand curve for capacity is the bolded line in figure 16 with a kink at $q=q_0$. Demand for extra capacity at $q\geq q_0$ equals zero. However at $q_{lrmc}<q<q_0$ prices does not cover more than a part of a pipelines' fixed cost. Only if consumers' WTP for extra capacity exceed the cost of building extra capacity, it contributes with a net surplus. The optimal level of capacity and capital investment is where the demand curve intersects the LRMC-curve at $K=q_{lrmc}$ (where q_{lrmc} is the amount demanded at $p=a+b$).

Social optimum is achieved if prices are set equal to marginal cost of production (at given production capacity). In figure 16, short run marginal cost is constant equal to b for outputs $q\leq K$. If demand exceed K at $p=b$, no more output can be provided (in the short run), and marginal cost increases infinitely. Thus, the (short run) marginal cost curve for providing q is horizontal for $0<q\leq K$ and kinked at $q=q_{lrmc}$ to a vertical position for $q>K$ at a given capacity (se figure 19). Using a marginal cost pricing principle in this situation yield prices at or above b depending on where the demand curve intersect the (short run) marginal cost curve (b).

A problem in determining demand is that it varies over the year. Figure 17 shows atypical pattern over seasons for the consumption of natural gas in Europe. Consumption in summer months is only one-third of winter peak consumption.

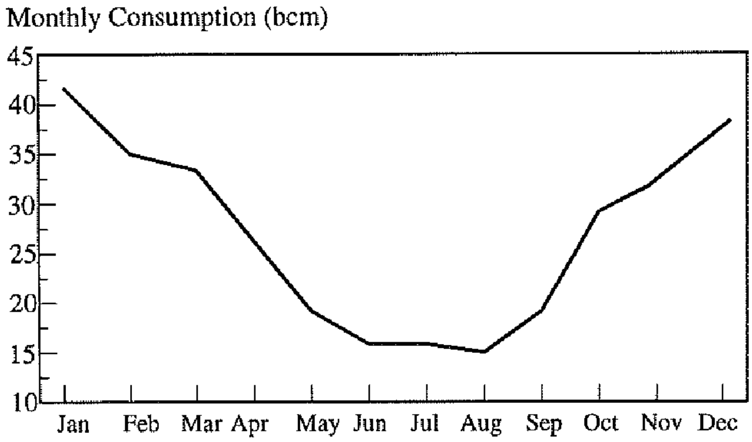


Figure 17. Seasonal consumption of natural gas in OECD-Europe.
Source: (IEA (1994), page 35

Let's denote the cost of adding capacity *a* in *each* period (summer and winter). Customers in high and low demand periods are considered of equal importance. Thus, total cost over both periods is $2a$. If consumers' WTP for capacity on average over high and low demand periods exceed the cost per period, or a, capacity should be added. That is $WTP_{summer} + WTP_{winter} \geq 2a$.

Combinations of high and low demand situations (peak and off-peak periods) with consumers' average WTP greater than the cost of adding capacity can exist if one or both of them are willing to pay more than the cost of increasing capacity. In figure 18 we have drawn one off-peak demand curve (D_{off}) and one peak demand curve (D_{peak}) as one possible combination of the two. q_{off} is the amount off-peak consumers are demanding and q_{peak} is the amount peak consumers are willing to consume at price $p=b$ (SRMC). We assume that the two "groups" of customers consume only in their respective periods and each of them are willing to pay for additional capacity as long as $q<q_{off}$ for off-peak consumers and $q<q_{peak}$ for peak consumers.

As the two groups of consumers are weighed equal, the average willingness to pay can be determined in the middle between peak and off-peak demand curves. For example at output q_1, off-peak consumers are willing to pay CE and peak consumers AE for additional outputs, where AE>CE. The average willingness to pay will be in the middle between CE and AE, which is BE (where AB=BC). Thus, B is one point on a new curve showing average demand over the two periods.

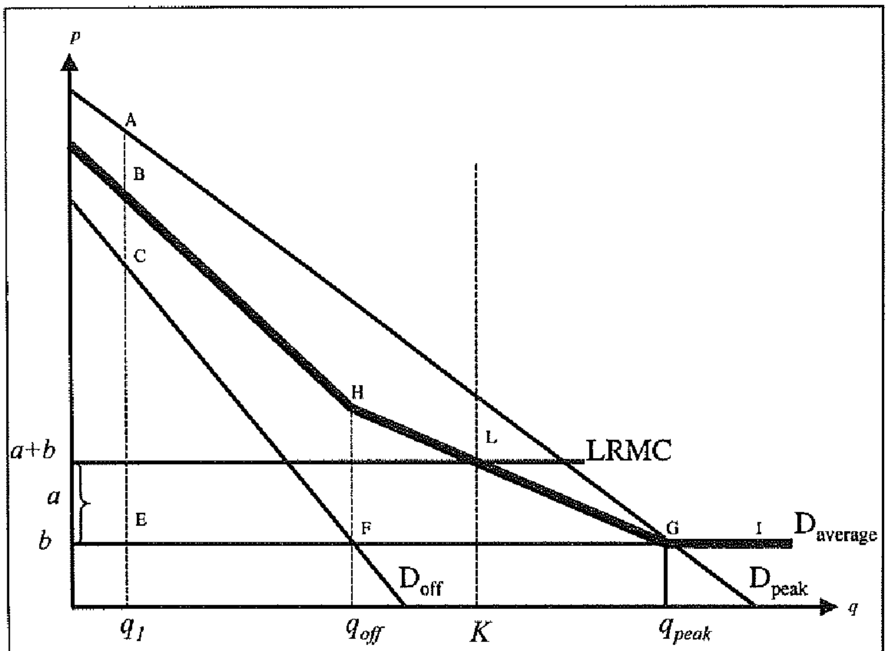


Figure 18: Optimal capacity with two period demand

Up to q_{off}, off-peak consumers are willing to pay for extra capacity while peak consumers are willing to pay for additional capacity up to q_{peak}. At output levels $q_{off}<q<q_{peak}$, off-peak consumers are not willing to pay for adding new capacity to the system. Thus, demand for new off-peak capacity is zero a $q>q_{off}$ and off-peak consumers' demand curve will be a curve kinked at F, running through the points CFI. Capacity demand for peak consumers (AG) will be zero at $q>q_{peak}$ and will be kinked at G, running through point AGI. The average demand curve can be drawn in the middle between these two kinked curves, shown as $D_{average}$ running through points BHGI. The distance between this new curve and b, expresses consumers' average WTP for extra capacity. Optimal capacity is determined where average willingness to pay in the two periods equal long run marginal cost, equivalent to the one-period example above. This happens at point L, with capacity K at LRMC prices $a+b$. At point L, average willingness to pay for extra capacity equals the cost of adding it.

Pricing in Peak and Off-Peak Periods – "Riordan Regulation"

A situation of high and low demand (peak and off-peak demand) compared to capacity is shown in figure 19. Marginal cost curves at fixed capacity (K) is shown as kinked bolded lines. Graph A shows a situation with low demand ($\leq K$) and graph B a situation with high demand ($>K$), both at prices equal to short run marginal cost (b).

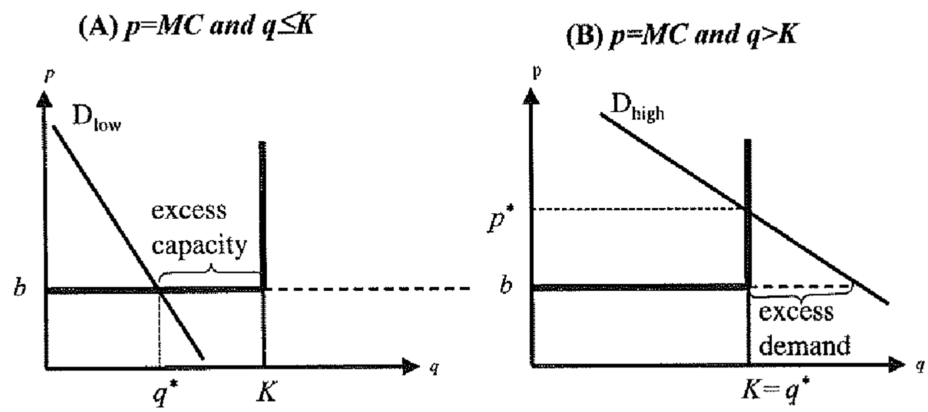


Figure 19: Optimal marginal cost pricing at high and low demand

In graph A, quantity $q^*<K$ is demanded at $p=b$. There is no way capacity K-q^* can be used as long as consumers' WTP < SRMC at these levels of output. In graph B, quantity demanded at $p=b$ is greater than capacity, which is impossible in the short run. In this situation, somehow $q=K$ must be rationed among consumers. Economist usually argue that the most efficient way of rationing is to raise prices high enough to exhaust demand, that is setting $p=p^*>b$. Other methods of rationing may lead to a situation where a consumer that is willing to pay a price above marginal costs (at $q\leq K$) may not get the product. A consumer that is not willing to pay such a price, for example by queuing, a draw, use of force or size, may get it. Thus, if demand for transportation in winter months exceeds capacity and is lower than capacity during summer months, transportation tariffs should be higher during winter than in summer.

However, the firm obviously looses money in summer months with such a pricing principle, as it earns no profit to contribute to investment costs. On the other hand, in winter months the firm makes a profit $(p^*-b)*q^*$. On total, it will not be possible from this information to determine whether the firm runs a loss or a surplus. There are mainly two ways the firm can cover the difference between total revenues and total costs. Government can give the amount to the firm as subsidy or an access charge can be added without affecting the usage charge. The access charge can be evenly distributed on consumers if demand is fixed (the Coase result) or be allocated by resorting to Ramsey prices, depending on the degree of price responsiveness to access charges.

Riordan (1984) discusses how such fixed capacity pricing can be achieved through a regulatory mechanism. The idea is that the firm receives a subsidy from the government or charges an access fee that amounts to the fixed costs of capacity minus the amount prices exceed marginal cost times capacity. In order to do this, the regulator need to know the price charged in the market, the actual capacity of the firm and it's variable and fixed costs, but he does not need information about the demand curve. The information needed is usually accessible, at least as proximate, even in natural gas markets.

In figure 20 the two situations with demand $\leq K$ (graph A) and demand $>K$ (graph B) is redrawn. In graph A, the price for service is set at $p=b$ and the firm receives a subsidy/access fee to cover fixed costs, amounting to $a*K$. If the firm attempts to raise the price from b to p_1, his (economic) profit would increase with the area ABEF = $(p_1-b)*q_1$. But, an amount equal to the price increase *times capacity* is withdrawn from his subsidy/access fee, represented by area ACDF = $(p_1-b)*K$. Obviously, ACDF>ABEF, and the firm suffers a loss by increasing price beyond b. The main point is that while the price increase raises profit on the basis of actual output, the subsidy/access fee is reduced on the basis of capacity.

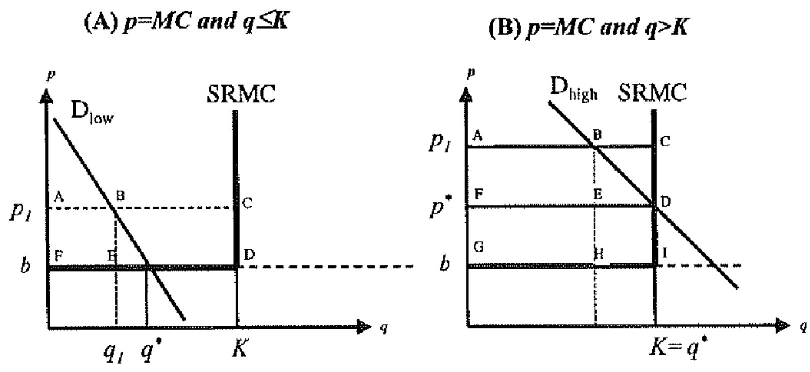


Figure 20: Optimal behavior under Riordan regulation

In graph B, prices are set equal to p^*, equal to marginal cost at the given demand and capacity $K=q^*$. The firm earns a profit over variable costs equal to area FDIG to cover fixed costs. If the subsidy/access fee is set equal to it's fixed cost minus the area FDIG the firm breaks even. If prices are raised from p^* to p_1, it's profit would increase by the area ABEF-EDIH. The subsidy/access fee will be reduced with the area ACDF. Again, because the subsidy/access fee is calculated on the basis of capacity, while profit is calculated on the basis of actual output, net profit suffer a loss. The firm must choose between earning either normal profit or less than normal profit.

Obviously, in "low demand periods", a p=SRMC-principle could yield $p \geq b$ as well as in high demand periods and vise versa. In general, over both the high and low demand periods (over the year) the firms profit will, when a subsidy/access fee = S is included, be:

$$(i) \qquad \pi = (p_{low}-b)*q_{low} - a*K + S_{low} + (p_{high}-b)*q_{high} - a*K + S_{high}$$

The footscripts 'high' and 'low' indicates that the values of the variables refer to high and low demand periods, for example winter and summer. $a*K$, represent the (flow of) capacity costs over each period. For simplicity reasons we have assumed that the year is divided into two equal parts, such that K is half-of-the year per unit fixed cost. The size of the subsidy/access fee in each period must equal:

$$(ii) \qquad S_i = a*k - (p_i-b)*K \ \ at \ \ p_i \geq b, \ \ where \ i = high, low$$

Substituting (ii) into (i) and rearranging yields a profit expressed as:

$$(iii) \qquad \pi = \sum_{i=low}^{high} (p_i-b)(q_i-K)$$

Pricing at $p_i=b$ and producing an amount of output equal to capacity ($q_i=K$) yields zero (economic) profit. Because the firm must set $p_i \geq b$ (to cover variable costs) and $q_i \leq K$ (output cannot exceed capacity), the term (p_i-b) is greater or equal to zero and the term (q_i-K) less or equal to zero. If the firm sets $p_i>b$, which it is allowed to do, and output is below capacity ($q_i<K$), profit will be negative. As long as actual output must be lower than capacity at $p>b$, the firm will loose money by raising prices above marginal cost. In all other situation the firm will make normal profit. Riordan argues that these mechanisms induce the firm to price service in all markets and periods equal to its marginal cost, and thus the first best solution can be achieved.

One problem using such a pricing principle is that LRMC for a new pipeline is often above the average cost of the existing pipeline. One way of covering the costs of new construction is to roll them into the charge for all transportation services. A new average cost level would be established including costs in both old and new pipelines. This may involve new subsidy/access charges in old pipelines when capacity is expanded. The price paid for transportation will under this arrangement not reflect the true costs in each pipeline, as some costs will lie above and some below the average tariff. Another way is to consider each pipeline project separately. Under this arrangement, the newer pipeline will operate with higher costs and the users will have to pay a higher tariff using this pipeline as opposed to using the old ones.

A tariff structure that sets different rates for each pipeline meets the efficiency criterion that prices should equal marginal costs better than when the costs of a new pipeline is rolled into the charges for all transportation services. However, such a price structure may lead to competition between different shippers attempting to gain access to the oldest, and thus the cheapest, pipeline. Market structure and the ability to bundle services will influence the evolution of this allocation. But even if new and old gas are reallocated between pipelines, the marginal quantities will still have to pay the new pipeline's higher marginal cost which serves to equilibrate the market for transmission services over time.

By giving subsidies or regulating the access fee, Riordan suggests that the regulator can induce the firm to install the optimal level of capacity, as well. Because the firm will be indifferent to which capacity level to choose, as long as it earns no more than normal profit in any situation, he suggest that the regulator should actually know the level of capacity by his/hers own evaluation. Then, by subsidizing or regulating the access charges according to which capacity level is optimal, the firm will actually choose this level. Any other choices will result in less than normal profit.

The problem of excess demand allocation has been particularly debated within the natural gas industry. The Ramsey pricing principle may cause intolerable distribution of income, as the most needing may the most. One alternative has been to use a pro rata system. In this system all customers shall be allocated access in proportion to the volume of their shipment. Existing customers' volume is reduced in order to allow incremental customers' access. In the U.S., which has been using this system, downstream customers can choose between buying a good bundled - both the gas and it's transportation fee - from a pipeline or paying the unbundled transportation charge. All shippers according to their nominated volumes share the burden of excess demand.[13] A problem with this approach is that an allocation on the size of volume need not be economically efficient, which can lead to gaming to determine the size of the nominated quantities.

Another alternative has been to take "high-priority" customers before those with "low-priority". In the United States, FERC defines "high" and "low" priority. Schools, hospitals and small commercial users have high priority, while large industrial direct users have low priority. Of course, other priority rankings are possible, such as first-come first-served, bidding and auctioning etc.[14]

In the U.S., an arrangement that is called mandatory contract carriage has been considered. Under this schedule, a customer can contract for "firm" transportation service and get a higher priority than "interruptible" service. Interruptible service can be delayed in order to fulfill firm transportation commitments.[15]

4 When Regulation Threatens; Conflict or Cooperation?

Generally, transmission companies and LDCs will receive lower margins when regulated as compared to an unregulated situation. The drop in profit will be distributed to producers, customers, final consumers or to producing or consuming countries' treasuries through taxation depending on *how* the system is liberalized (Austvik, 1997). Even though transmission companies' and LDCs' margins are rather stable under both systems, their economic profit will be lost or, at least, reduced. In addition, competition between transporters may be established, at least on some distances, which could make more variations in throughput. In a liberalized market

[13] In order to give access to new customers, the initial volumes cannot be used as an allocation device. Such a pro rata system is used in a Common Carriage arrangement (as in the U.S.).

[14] See e.g. Hogan (1989).

[15] Broadman (1987) discusses alternative ways of allocating excess demand in more depth.

system, transporters may face both lower margins and increased volatility and risk regarding volume. Thus, they have every reason to oppose almost any type of liberalization, as compared to today's system. The question here is: Will they be better off by going into conflict with the regulator or is it better to cooperate and try to "trap" him/her in order to make the regulator do what they want?

Conflict With the Regulator

Let's first consider the interest of the regulator (for example represented by the EU Commission) in a liberalization process simplified to a desire to unconditionally take away the transporters' economic profit and give it to consumers. The interest of the transporter is assumed unconditionally to maintain as much profit as possible. Thus, the interests of the regulator and the consumers are assumed identical and conflicting. Under the assumption set up, the game is not zero-sum for society, as regulation is assumed to yield a greater surplus for consumers than the loss incurred on transporters. This binary situation (the choice between regulation and no regulation) is illustrated in figure 21.

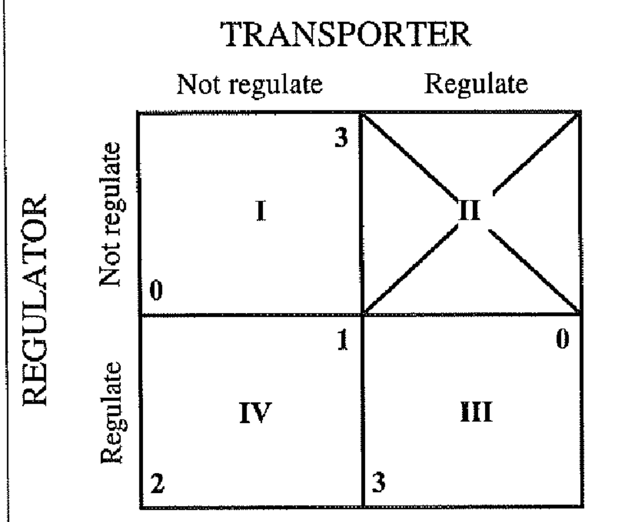


Figure 21: Regulation through force

Both the regulator and the (potentially) regulated can chose between favoring a process that introduce regulation and a process where no regulation takes place. The outcome for the transporter is depicted in the upper right corner in each cell, and the outcome for the regulator is depicted in the lower left. Best possible outcome for each party is value 3 and worst possible outcome value 0 (zero). All utility is considered ordinal, which means that each party may rank the outcomes, but do not know how much better or worse it is compared to another outcome.[16]

[16] Under cardinal utility, utility can be measured and it is possible to say how much better or worse one outcome is compared to another.

If the regulator does not regulate, consumers get no extra surplus, which represents their and the regulator's worst possible outcome, equal to the value 0 (zero). At the same time, no regulatory initiative is the best possible outcome for the transporter, achieving maximum profit, with the value of 3, as depicted in cell I. On the other extreme, if the market should be perfectly liberalized, and the transporter fully accepts the regulator's terms for operations on a normal profit basis, consumers' surplus is maximized. This outcome would be the worst possible for transporters, value 0 (zero), but the best possible for the regulator, value 3. The outcome when both parties favor regulation is depicted in cell III.

If the transporter opposes regulation and the regulator nevertheless chose to regulate, the outcome for the regulator (and consumers) must be assumed to be less than if the transporters just accept new terms for operation. Now, transporters fight against intervention, making as much difficulties as possible for the regulator, and tries to postpone and destroy regulator's initiatives. In spite of this resistance, the regulatory efforts can be expected to yield a better outcome for consumers than no regulation at all, but less than if the transporter adheres. This outcome for the regulator is depicted with the value 2 in cell IV. At the same time, transporters will gain compared to a strategy just following regulator's desires, but less than if no regulation was introduced, depicted with the value 1. Cell II represents a situation where transporters want to be regulated and the regulator don't and are, under our assumptions, considered an impossible combination of strategies.

Even if the outcome for each depends on the choice of the other, both the transporter and the regulator have dominant strategies independent of the other's choice. The transporter will gain 0 (nothing) if regulation is supported, and 3 or 1 if regulation is opposed. Thus, opposing regulation will be a dominant strategy for the transporter. The regulator will gain 0 (nothing) if it does not regulate and 2 or 3 if it does. Thus, favoring regulation will be a dominant strategy for the regulator. Outcome from cell I (status quo) will result if regulator does *not* have the ability to force regulation on transporters without their acceptance. Outcome from cell IV will result if it can do so. This is a situation of direct confrontation between the parties. The relative political strength of the regulator and the transporters will be the main variable in determining the final outcome.

Cooperation With the Regulator

Let's now assume that the transporter knows that it cannot prevent regulation to be introduced. Now, the option "not regulate" does not exist anymore. Then, the question arises for the transporter whether it is best served by continuing making a maximum amount of difficulties for the regulator or if it is better to make an interplay with the authorities in order to design a regulatory regime that is favorable. This is known as a principal/agent problem, in which the agent tries to take control of his/hers principal and traps the regulator to act according to it's desires (Binmore 1992: 526-530). In this situation, when the transporter continues to resist and the regulator nevertheless intervene, the outcome are the same as in the previous game, as depicted in cell IV in figure 22.

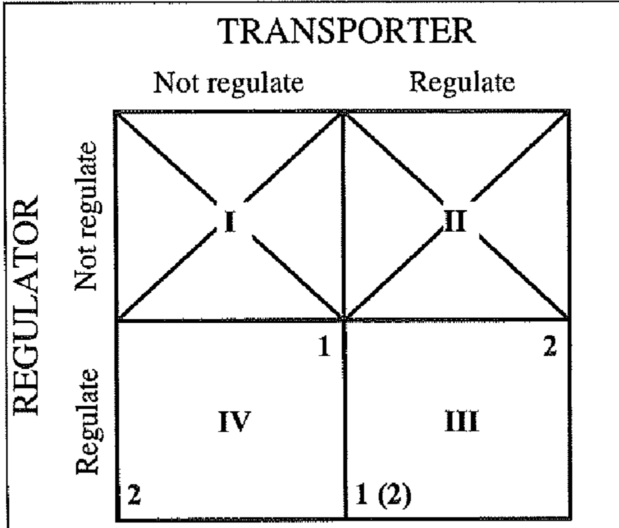


Figure 22: Regulation through interplay

The transporter knows that the best result he can expect by opposing a new system is of value 1 (cell IV), because the regulator certainly will now introduce regulation (cell I will not be possible). However, by participating in the regulatory process, in stead of only opposing it, the transporter might succeed in achieving a value at least as high as when opposing regulation, even though it will still be lower than if no regulation is introduced, set to value 2 in cell III. By doing this, the outcome for the regulator (consumers) may simultaneously be reduced to less than if the transporter only adheres to regulator initiatives set to value 1. (On the other hand, when transporters participate in the regulatory process, better solutions can be found than if the regulator shall figure out all details and the outcome for consumers *may* not necessarily be reduced compared to cell IV, value closer to 2).

In this situation, regulator's dominant strategy will still be to regulate, as regulation would yield a better outcome for consumers no matter what the transporter does (2 or 1). The transporter, however, will change strategy towards collaboration, because it knows that regulation cannot be avoided. By participating in the formulation of regulatory mechanisms the situation can be improved (value 2 in cell III) compared to opposing it (value 1 in cell IV). However, if the transporter considers that regulator will not get such authority, or it can be prevented by some means, it will still choose to oppose any intervention, as shown in cell I in figure 21.

Pay-off-matrixes for Transporters and the Regulator

Transporters may have diverging views on the possibility of introducing a strong (enough) regulatory authority in Europe. However, the greater the number of transporters that think the regulator (will) get such an authority, the more of these transporters will start to influence regulatory design and, accordingly, increasingly set the premises for each transporter resisting. Thus, transporters should form coalitions in order to prevent "too many" others to participate in regulatory processes. In this multifirm dilemma, there may be a critical mass of firms (weighed with their quantity transported, sunk capital, strategic significance, political influence etc) that are needed to do so.

If we, for simplicity reasons consider transporters acting as one firm towards the regulatory authority, the game-theoretic results from this regulatory process can be illustrated in a "Schelling-diagram" (Schelling, 1978). On the vertical axis to the left, the utility for the transporter, U(T), is measured (by it's profit) while on the vertical axis to the right utility for the regulator, U(R), is measured (by consumers' surplus). The horizontal axis between the two vertical axes measures the "level of liberalization". To the left, at point A, no liberalization is introduced; to the right at point B, the market is completely and perfectly liberalized. This is an unmeasurable continuum, but can be thought of as the number of regulatory initiatives; the more liberalized, the more interventions by government must take place such as increased competition and introduction of increasingly more regulatory details.

Maximum utility for the transporter is achieved if no regulation is introduced, as illustrated in point C. In this situation, minimum utility for the regulator is attained, as illustrated in point A. If regulation is established, and the transporter just follows passively regulator's initiatives, maximum utility for consumers is achieved, illustrated in point D. In this situation, minimum utility for the transporter is achieved, as illustrated in point B. Thus, the utility possibility curve goes from C to B for the transporters and from A to D for the regulator when the market is increasingly more liberalized. The curves' down- and upward directions illustrate that more (and efficient) regulation takes increasingly more profit from the transporters and gives it to consumers. Maximum regulatory utility (point D) is drawn as greater than the maximum utility for transporters (point C). Point D is higher on the right axis than point C is on the left axis, because the gain for consumers should be greater than the loss for producers under regulation.

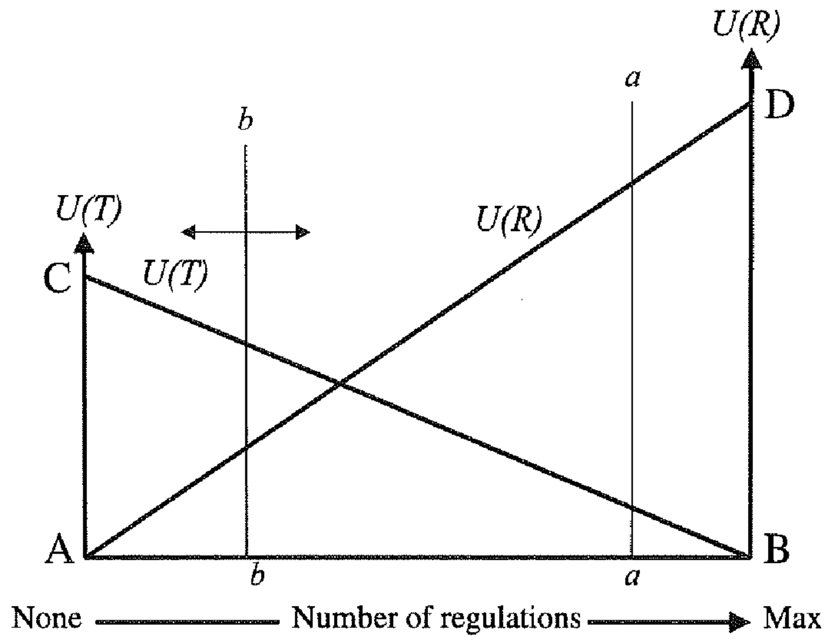


Figure 23: Pay-off matrix for a regulatory process

The outcomes in figure 23 can be traced back to the games illustrated in figures 21 and 22. In figure 21, point C (value 3 for transporter) and point A (value 0 for regulator) represents cell I, where no regulation takes place. Cell III is represented by point D (value 3 for regulator) and point B (value 0 for transporter). Cell IV yields outcomes somewhere between C and B for transporters (value 1) and A and D for consumers (value 2). By opposing regulation, the transporter may succeed in either preventing it from being established, or to maintain some of it's profit. This will simultaneously reduce the effect for consumers and is illustrated by the vertical line *aa*. Thus, under our assumptions, the line *aa* represent the worst outcome for transporters (value 1) when conflict with the regulator is chosen, and the best possible outcome for consumers (value 2).

If the transporter knows that regulation will be established, it may start to interact with the regulator to design the system in a best possible manner for themselves, as discussed under figure 22. By doing so, transporter's utility will at least measure value 1. If it really succeeds in capturing the regulator, real profit may be increased almost back to a monopoly level (point C). The vertical line *bb* illustrates a situation where the transporter has managed to regain most of its profit, but not all, through this interplay. Transporter's outcome is somewhere between 1 and 3, or value 2, while regulator's outcome simultaneously is reduced from value 2 to 1.

However, if the transporters could influence regulation in a way that improves efficiency as compared to a situation with no interplay with the regulator, there may be Pareto improvements in the process. This may happen because regulator's insight into the industry's complexity may be limited and partly be depending on transporter's information. Such examples can be found in the U.S. regulatory history, where regulator has made inadequate decisions for the industry with huge losses in efficiency and resulting stop-and-go-policies. In this case, the utility curve for the transporter will not be a straight line. In figure 24, *U(T)* is dropping when some regulation is introduced. When the transporter starts to interact with the regulator in the formulation of new governmental interventions, with a number of market interventions from the regulator it manages to maintain its profit without reducing the benefit for the regulator/consumers.

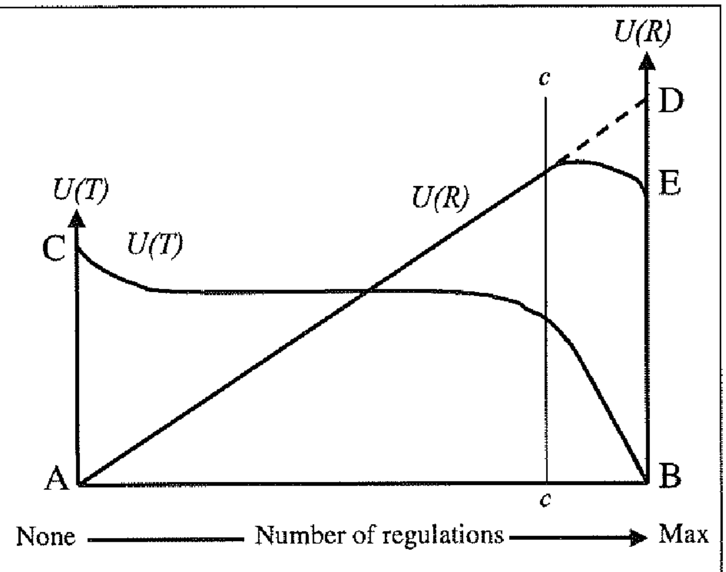


Figure 24: Pay-off matrix if the pipeline can improve regulatory efficiency

This is due to the fact that it can suggest arrangements that are more efficient than the regulator could do itself. Overall surplus in the market is increased compared to the more static first strategy. At some level of liberalization, illustrated by the line *cc*, transporters may start to suffer again, regulatory interventions are so comprehensive that transporter's utility curve drops more steeply down to point B. The transporter would loose so much by passing cc, that it starts to oppose regulation again. In this situation, it is possible that the best point for the regulator could never be reached, because he lacks the ability to liberalize the market perfectly in an efficient manner and, thus, needs the collaboration from the transporter. By trying to move the transporter all the way to point B, the outcome for consumers may be worse than if stopped at *cc*. Thus, utility for regulator may drop if more regulation is introduced.

The two ways the utility curves are drawn are just examples on their many possible natures. They may be bowed in various ways or even be discrete. The most important information we can get about transporter strategy from this analysis, independent of the shape of the curves, is that it depends heavily on whether a regulatory authority gets the power and have ability to liberalize the market or not. The transporters should adopt a dual strategy opposing any initiatives taken by authorities on market intervention and simultaneously prepare for interplay in designing optimal regulatory regimes, if or when they come. Transporters will be best served if they succeed in delaying or destroying political decisions giving such power to regulatory authorities, pointing out the complexity of regulations, security issues, risk or any other arguments that work. But when or if a decision about actual regulation is made, nevertheless, transporters should shift partly to a collaborative strategy. The regulator should try to penetrate a possible collaboration between transporters by starting to design regulatory regimes with only one or a few of them. If a critical mass of transporters interact, the rest must follow, as well.

In the dynamics of this decision making process, the strategies may shift from conflict to elements of cooperation, and back. When and how the parties should or would collaborate and when they confront each other, depends on the shape of the curves. The shape depends on market complexity, competence among each party, ability to intervene etc. If one accepts that it is difficult to reach a fully and perfectly liberalized market, one should rather discuss what would be the optimal degree and form for regulation, not only in the sense of economic efficiency, but also in terms of political feasibility (*cc*)

Of course, the highly stylized description of a completely liberalized market and possible intermediates misses a lot of other information that may be important. Nevertheless, it is interesting to identify segments where competition may be introduced and in which segments regulation is necessary in order to assess liberalization. This also identifies why and where economic rent is collected in today's gas market. This may be of interest for each party in the market if liberalization actually should take place. Firms may have an interest in liberalization, if they can be assured that it is confined to those areas that serve their interests. Ceteris paribus, transporters may be interested in more competition among producers and customers, producers may be interested in lower tariffs to transporters, LDCs may be interested in more competition among producers and free access and low tariffs to transporters and so on.

5 Alternatives to Regulation

Public Ownership / Changing Property Rights

An unregulated transmission company is behaving monopolistically because its owner has an interest in maximizing profit. By changing it's property rights, the new owners may have other goals. If the owner has, for example, overall efficiency in society, or maximum profit in the distribution or production sector, as a goal, profit maximum in the pipeline may not be in the owners' interest.

One way to change property rights is to socialize the firm by changing its ownership from private to public. In Europe, this has, until recently, been a quite usual way of approaching the problem for a wide range of branches, such as coal, electricity, railroads, post, telecommunication, defense industries, steel, shipbuilding, buses, airports, water and gas. The idea has been that the problems of monopoly power, externalities, inequality etc. can be dealt with directly if they are run with social welfare as goal rather than private profit.

Nationalization has been argued for both on ideological grounds and because of the market failures natural monopolies create. In Europe, labor parties have mostly favored nationalization, advocating that ownership of means of production; distribution and exchange should be common. The early advocates of nationalization in the 1930s and 1940s hoped that the old class antagonism between workers and owners of businesses should be broken down. Nationalization should be one means of rectifying the injustice in income distribution between consumers and producers and across classes, when huge firms exploit their monopoly power. However, there has been considerable debate through the twentieth century on how much of a nation's industry should be under public ownership and how much should be managed trough market mechanisms (as the "Austrian school"). As we have discussed, "untouched" natural monopolies often do create inefficiencies in markets, restrain economic growth and lead to an unfair distribution of rent, between producers and consumers and throughout the gas chain. The question arises whether nationalization is superior to regulation or whether some other means should be used to repair for the deficiencies.

One major argument for the privatization of publicly owned enterprises over the past 20 years, has been their relatively poor economic performance. Obviously, that these run a deficit, and not a profit, is a non-valid argument. The nationalized industry *should* in many cases run a loss if prices are set equal to marginal costs and average costs are falling, as discussed for example in figure 8). Therefore, the assessment of nationalized industries should rather be done on the basis of its costs and quality of service than on it's profit. Because such comparisons are rather difficult[17], especially for natural monopolies without competitors, it will not be possible to observe such differences with certainty before they become rather significant.

Another argument in favor of privatization has been that private firms will be more exposed to market forces than the publicly owned own one. Privatization should improve efficiency, reduce costs, and improve quality and lead to greater responsiveness to the wishes of the consumer. However, if a national firm is privatized in a non-competitive market or some other regulatory mechanism are introduced, a private monopolist should not have much more reason to behave more efficiently than the public one.[18] Thus, in most such cases, privatization must be followed by some sort of regulation should efficiency be improved. Ownership may be only one determinant for the efficiency in an industry, while the degree of competition is another. Also public enterprises can be more efficient if they face competition.

Whether publicly or privately owned and run, transporters in the (non-competitive) European gas market must be followed closely by public authorities, which under whatever approach will need independent competence and will to take a stand to the number of issues that

[17] See for example Meyer(1975).

[18] The main exception is perhaps that the private firm would not have to frequently adjust their targets for political reasons.

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