

The Regulation of Access to Gas Storage with Capacity Constraints

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Abstract

1. Due to the liberalisation of European gas markets, gas storage has been unbundled from production and transmission and nondiscriminatory third party access to storage capacity has been imposed. We claim that regulated access should be introduced until storage plants are essential facilities and competition is not feasible. However storage is not a natural monopoly and storage services may be partially substituted by alternative flexibility inputs. Moreover, access to storage is at present affected by capacity constraints. We firstly analyse the effects of storage rationing on the productive efficiency of gas suppliers and characterize an efficient allocation rule for storage. As the latter may be hard to implement, because of suppliers adverse incentives due to asymmetric information, we consider storage allocation through market and non-market (administrative) mechanisms. In particular, we compare an administrative and an auction mechanism in a two stage model where firms firstly obtain access to storage capacity and then compete in the gas market. Due to the strategic behavior of the dominant gas supplier, even a market mechanism could be characterized by capacity hoarding. However, this mechanism welfare dominates the administrative distribution of storage capacity, unless the latter assigns more capacity to the competitive follower.

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1 Introduction

Due to the implementation of the directives 98/30/EC and 2003/55/EC, during the last decade natural gas markets have been liberalised in the European

Union. National regulatory reforms have been carried out in order to implement unbundling and non discriminatory third party access to essential facilities. At present each member Country is expected to implement legal unbundling of the transmission and distribution networks from the potentially competitive activities, though the European Commission is now fostering the introduction a third "liberalisation package" in order to strengthen unbundling requirements. In order to let new entrants compete with former integrated utilities on a level playing field, regulated third party access to transmission and distribution networks has also been imposed by the last EC directive.

A particular feature that differentiates natural gas from electricity is the opportunity of storage. Gas consumption is affected by seasonal, weekly and daily fluctuations, both predictable and unpredictable. Utilities need to balance continuously demand and supply (which might be flat). Access to storage gives suppliers the flexibility needed to cope with demand uncertainty. Therefore directive 2003/55/EC also requires unbundling of gas storage and non discriminatory third party access to storage facilities. However, member Countries are just required to implement accountancy unbundling of storage and can opt between negotiated and regulated third party access, according to the features of national storage markets.

Though storage costs are affected by scale economies, storage is not a natural monopoly. Any storage plant can supply storage services in competition with other existing plants as minimum efficient scale is generally far from the amount of total storage demand coming from gas suppliers. However the liberalisation directives did not require divestiture of existing storage owned by former integrated utilities in order to introduce storage to storage competition. At present a competitive market for storage is effective only in the UK, where ownership unbundling has been already implemented and multiple storage firms operate their business independently from gas supply, under the supervision of antitrust authorities. Most continental Countries are characterized either by de facto monopolies or by market power in the storage sector. Moreover, access to storage facilities is still granted by branches of the former integrated gas utilities¹, now operating as dominant gas suppliers in the downstream market.

However storage services are not the unique flexibility source for gas suppliers. Flexible production fields and flexible importing contracts may operate as a substitute for gas storage, as well as interruptible contracts with industrial customers or access to spot market for gas (though not yet liquid enough in Continental Europe). But in practice these storage substitutes can hardly exhaust the demand for flexible gas by any supplier. Moreover the nature of most flexibility inputs is such that a market for flexibility is hard to define. Flexible production fields are available just in gas producing Countries like the UK and the Netherlands. Flexible importing contracts and a sufficient portfolio of interruptible contracts with industrial customers are generally positively corre-

¹When liberalization took place national markets were characterized by just one or a few firms owning multiple storage plants and European directives did not impose any horizontal unbundling aiming to split storage firms by selling part of their plants to new entrants, as was done in the case of electricity generation

lated with market shares and then more available to incumbents than to new entrants. Moreover, even if the duplication of storage plants were considered economically viable by new entrants, it would require suitable sites and a long time span to carry out new investments.

Once we consider existing storage plants as essential facilities to compete in the gas market the need to regulate access prices ex-ante follows, as non-discriminatory third party access (from now onwards TPA) implemented through negotiated tariffs may not be sufficient to control market power. However, the regulatory setting should account for the availability of storage substitutes and their asymmetric distribution among gas suppliers. Standard regulation by cost-reflective storage tariffs reviewed with price-cap mechanisms not necessarily leads to an efficient allocation of the existing storage resources among gas sellers, when the latter differ with respect to the availability of storage substitutes. The need to consider the availability of storage substitutes beyond the degree of concentration in local storage markets has been recently recognized also by the Federal Energy Regulatory Commission (FERC) in the USA (FERC, 2005). Considering also storage substitutes is deemed useful to better assess market power when storage firms ask FERC for exemptions from regulated tariffs, claiming they operate in a competitive storage market.

Furthermore the market for storage is at present affected by capacity constraints in most European Countries. According to an enquiry carried out by Energy Regulators, in 2006 43,5% of total European storage capacity was fully booked. Concerning another 38% of total capacity the enquiry found that less than 5% of technical capacity was available (ERGEG, 2006). The top 15 storage operators state that actual capacity is insufficient with respect to the demand for storage services. Scarcity is even expected to increase in the future². The most recent enquiry carried out by the European Commission (European Commission, 2007) has also found that access to storage is foreclosed by long term reservations and capacity hoarding. In fact, due to the absence of used-it-or-lose-it provisions, booked storage is not fully used³. In some Countries like the Netherlands and Denmark, gas suppliers can overcome bottlenecks by resorting to plants located in Germany.

Due to capacity constraints, the efficiency properties of the allocation of storage resources depends on rationing criteria implemented by regulators or storage firms through congestion management rules. Efficiency could be pursued by allocating scarce storage capacity according to its value for any single gas supplier. We expect these values to be heterogeneous due to the asymmetric availability of storage substitutes. However at present this principle seems not

²Recent forecasts concerning North-Western Europe (Hoffler and Kubler, 2006) recognize that a storage gap is going to affect the whole region in ten years, due also to the expected decrease of national production in the UK and the Netherlands. The Storage gap could even be higher than expected if the increasing import dependency would lead more Countries to devote storage capacity to precautionary inventories.

³The Inquiry has found that most of the storage from the sample which is fully booked has been more than 95% full at the beginning of winter (in the period from January 2003 to mid-2005). In some cases however less than 90% of capacity has been actually used (European Commission, 2007, p.65).

to be respected by access rules implemented in practice. Inefficient allocation rules may in turn produce distortions not only in the storage market but also in the downstream market for gas supplies. The same inquiry quoted above, has highlighted that wholesale and retail markets for gas are still affected by the market power of incumbents, which operate as dominant firms after liberalisation. The availability and distribution of storage resources is considered one of the causes of market foreclosure in Europe.

To the best of our knowledge, regulatory issues concerning gas storage have never been tackled by economic theory. However some recent contributions have analysed the economics of gas storage and the effects of liberalisation policies carried out in Europe. Creti, Chaton and Villeneuve (2005) deal with seasonal gas storage in a competitive gas market where injection and withdrawal decisions react to price fluctuations, taking account the depletion of exhaustible gas resources. Chaton, Creti and Villeneuve (2007) deal with precautionary gas storage as an instrument to face supply disruptions, considering market failures with respect to supply security goals. The strategic nature of storage decisions in an imperfectly competitive gas market is considered by Baranes, Mirabel and Poudou (2005, 2007) and by Durand Viel (2007). According to Baranes, Mirabel and Poudou (2005) TPA to independent storage facilities can reduce welfare because it incites firms that are vertically integrated up-stream to adopt storage decisions that increase wholesale gas prices for downstream competitors (storage may be used to raise rival's cost). Therefore fostering integration of storage facilities with downstream suppliers is considered to be a better solution with respect to TPA, from the point of view of social welfare. Both in Baranes, Mirabel and Poudou (2007) and in Durand Viel (2007) the alternative between carrying inventories or buying the commodity in the spot market is analysed. However the two models differ concerning the assumptions about market structure at the production stage. Assuming oligopoly both at the production and at the supplier (wholesale) stage, Durand Viel considers storage not only as an instrument to preempt future demand but also a strategic tool for suppliers to deter producers market power. Actually storage decisions can avoid the increase of prices in the spot market but, given that all downstream competitors share this benefit, storage by any firm exerts a positive externality on rival suppliers. Strategic storage decisions should therefore take account of this trade-off.

In our contribution we focus on regulatory issues by considering both the existence of storage substitutes and congestion management due to capacity constraints. Moreover the efficiency of rationing rules concerning access to storage will be considered not only per se but with reference to the distortions induced on the downstream market. Most of the previous quoted contributions assume the existence of a liquid spot market, which is not a realistic assumption at the present liberalisation stage in Continental Europe, where most gas exchanges takes place through long term contracts with take or pay clauses. Therefore we assume that the downstream market is characterized by a dominant firm and a competitive fringe of new entrants behaving collectively as followers with respect to the incumbent. In our opinion such an assumption fits better the result of the recent inquiry of the European Commission about competition in

European gas markets (European Commission, 2007).

As gas storage is not a very well known industry, a short introduction to the storage market is presented in section two. In section three we consider to what extent storage plants may be considered as essential facilities, applying a test developed by the antitrust practice. In section four we give a theoretical representation of the technology of gas supply, assuming that flexibility may be obtained by a bundle of inputs that includes access to storage capacity. In this framework we can analyse the effects of storage rationing on the productive efficiency of gas suppliers and distinguish between the cost and the value of storage, the latter being represented as its shadow price. In section five we consider a specification of the gas supply technology and derive an example of optimal rationing rule for the allocation of storage capacity, accounting for the availability of storage substitutes. In section six, through equilibrium analysis, we consider the effects of the rationing rule on competition in the downstream market and compare the allocation of storage implemented by the regulator through administrative rules with the allocation resulting from a market mechanism (storage auctions). In section seven the same comparison is made on welfare grounds. Some conclusions follow in section eight.

2 The Value of Storage

From the supply side the availability of storage plants allows to reduce the investment cost in transmission networks as pipeline load need not correspond to the maximal predictable demand but rather to average gas consumption. In fact resort to gas storage allows suppliers to cover the difference between peaks and average demand even when network capacity corresponds to the latter. The demand for gas storage originates from various aims of gas suppliers but also from producers and network operators. Gas storage helps gas suppliers to face both predictable and unpredictable demand fluctuations in the temperature sensitive market, including the structural summer-winter consumption differential and peak-days requirements exceeding the average winter consumption⁴. Seasonal gas storage satisfies this type of gas demand by allocating storage space, injection and withdrawal capacity to gas suppliers. Daily demand fluctuations can be dealt with storage inside pipelines, known as "linepack" and traditionally provided by the network operator.

Precautionary gas storage is used instead to manage the risk of supply disruptions, due to accidents or geopolitical reasons. The amount of storage devoted to this last scope is also known as "strategic storage" and consists in gas stocks managed by the Government of Countries like Italy or Hungary, whose gas supplies mainly depend on imports from outside the EU. Gas reserves blocked for this purpose reduce the availability of storage capacity for seasonal storage, which is measured by the amount of "working gas" that users can inject in sum-

⁴Due to pressure reasons, the amount of peak capacity warranted by storage firms decreases with the total amount of gas stored underground and is therefore typically greater at the beginning of the winter season and lower towards the end of it, when inventories are lower.

mer and withdraw in winter from a storage plant⁵. Storage may also be used to assist gas production, in order to loosen the geological constraints affecting this activity. Moreover storage represents a supplier of last resort for the transmission system operator, which is in charge of the duty to assure continuously a gas flow consistent with the physical balancing of the network. In a decentralised gas system based on market exchanges, any utility with access to the transmission network (shipper) must satisfy commercial balancing obligations. Then gas storage may also represent a supplier of last resort for utilities aiming to avoid paying penalties for being unbalanced, especially when a liquid spot market for gas is not available yet.

In liberalised gas markets storage is also a tool for price arbitration, be it seasonal (summer-winter price differentials can easily be exploited by resorting to gas storage) or between the electricity and the gas market (if price soars at the power exchange, utilities can obtain rents from gas fired power plants by resorting to gas in storage instead of buying it in the spot market at a higher price, provided that the cost of access to storage is not too high). Therefore due to multiple and rival uses of gas storage, capacity constraints may easily arise, especially at the start of liberalisation and considering that network safety and supply security aims are obviously given priority with respect to the commercial exploitation of storage capacity.

However flexibility resources are not restricted to storage capacity. Countries like the UK dispose of indigenous production fields whose output can fluctuate according to demand ("supply swing"), therefore their need for seasonal gas storage is reduced. Suppliers in importing Countries can profit from flexibility clauses of long term contracts, allowing to maximise imports up to capacity during peak times and to reduce them when demand is weaker. Liquid spot markets provide an additional flexibility source for gas sellers. However these flexibility sources can hardly substitute gas storage completely. According to some estimates (Global Insight 2002) gas storage provided about 50% of seasonal swing all over Europe, with strong differences in single Countries⁶. To the extent that demand fluctuations mainly concern the household market, gas sellers may conclude interruptible supply contracts with industry and power generation, by offering price discounts to customers that either dispose of multifuel appliances or are anyway willing to bear the risk of supply interruptions. Utilities involved in power generation and supply both to the downstream gas market and the electricity market ("dual fuel market") may accordingly switch multifuel power generation plants to fuel oil or coal in order to maximise gas flows devoted to the temperature sensitive market. Interruptions of industrial customers and fuel switching in power generation plants can be considered a substitute for peak deliverability of storage plants. As a market for flexibility does not exist it is hard to define a value for storage substitutes. One way would be to compare the output value of gas suppliers which use a different bundle of storage substitutes.

⁵The amount of gas that must steadily be kept inside the storage field to let it work properly is called "cushion gas"

⁶An extensive analysis of the flexibility sources in European Countries before the implementation of market liberalization is provided in International Energy Agency (2002).

Another way would be to compare the willingness to pay for storage.

Storage tariffs can be negotiated between storage firms and gas sellers (as in most European Countries and in exceptional cases in the US) or regulated by an independent authority (as in Italy, Spain, Belgium and in most US local markets). Negotiated tariffs allow to discover the value of storage through price signals but the market power of storage suppliers distorts market prices, then inducing an inefficient allocation of storage resources except when there is enough competition in the storage market. Regulated tariffs may be cost-reflective and effective in controlling the exercise of market power by the storage firm, however they prevent the value of storage to be signaled by prices. Moreover, with congestion the allocation of storage capacity among gas suppliers depends also on the rationing mechanism included in access rules. Most European Countries adopt "first come first serve" methods and allow long term booking of storage capacity. In Italy storage capacity is rationed among gas suppliers according to their market share in the temperature sensitive market, due to the implementation of public service obligations concerning supplies to households. Auctions are used in a minority of Countries, and for small amounts of storage capacity. To the extent that gas suppliers obtain access to a portion of storage capacity which is not consistent with the value they assign to storage, inefficiency in the allocation of storage capacity results. Moreover competition in the downstream market for gas will be affected by distortions concerning the access to an essential input like storage.

3 Is Gas Storage an *Essential Facility*?

The Essential Facility doctrine deals with the imposition to the owner of an essential input of the "duty to deal" with other firms requiring access to this same input. Granting access to these firms prevents abuses of a dominant position by the owner of the essential input, when it operates in the market as a "bottleneck monopolist". Therefore when an asset is considered an essential facility then its owner cannot oppose a "refusal to deal" on the basis of his property rights. The latter are constrained by the need to protect competition in the market where the services granted by the facility are deemed to be essential.

Gas storage assets are implicitly recognized as essential facilities by the last liberalization directive, to the extent that unbundling and non discriminatory third party access to storage facilities have already been imposed by the European Commission. However leaving member Countries the option between negotiated and regulated TPA may cast some doubts on the nature of gas storage plants in each national gas market⁷. Negotiated storage tariffs in principle should be implemented when there is a sufficient degree of competition in the storage market⁸. If storage facilities are owned and managed by a bottleneck

⁷We do not consider this issue at the European market level to the extent that at the moment a single market for gas is far from being working in the European Union.

⁸It is worth noticing that in the US the decision to exempt storage firms from regulated access is left in the hand of the independent regulator, which must assess by a case by case

monopolist, regulated third party access seems to be necessary in order to avoid the exploitation of market power. Otherwise the abuse of the dominant position excluded by third party access could materialize in the imposition of excessive storage tariffs, to be sanctioned ex-post only on the basis of the non-discrimination criteria. Therefore once it is ascertained that gas storage is an essential facility, the need to implement regulated third party access ex-ante seems to be as a logical consequence.

The essential facility doctrine cannot tell with a sufficient degree of precision and generality which are the features that characterize an asset as an essential facility⁹. However the antitrust practice in the US has developed a test to ascertain the economic justification of refusal to deal opposed by the owner of an asset that potentially could be an essential facility (Pitovsky, Patterson and Hooks, 2002). Such a test could be conveniently extended also to the European experience. Castaldo and Nicita (2007). propose a test in five steps to identify the requirements to be satisfied: 1) Dominant position of the facility owner in downstream markets 2) Unjustified and effective refusal to deal 3) Feasibility of shared access 4) Essentiality of the facility 5) Non-duplicability of the facility. In order to apply the test to storage facilities we examine all five steps that are supposed to be cumulative and, according to Castaldo and Nicita (2007), hierarchically fulfilled.

Dominant position of the facility owner. Dominance should be referred not only to the market where the services of the facility are sold (the storage market in our case) but also to the market position of the facility owner in the downstream markets. This first requirement is fulfilled in the case of storage facilities if the storage firm has a dominant position not only in the storage market, but also in the downstream market for gas supplies. In most European countries storage is actually provided by a branch of the former integrated utility which also operates in the wholesale market as a dominant supplier of gas. If a dominant position is held by the facility owner then either a refusal to deal or the imposition of higher access prices may imply a market foreclosure or a raising rivals' costs strategy.

Unjustified and effective refusal to deal. In the case of gas storage this requirement is apparently overcome by the fact that separated TPA to storage facilities is imposed by the second European directive. However the requirement should be intended more broadly to include also cases where access tariffs are excessive and then such to prevent feasible access for competitors.

Feasibility of shared access. Shared access to the facility should be feasible both from the technical and economic point of view. Concerning this requirement, the degree of rivalry in the use of the facility implied by third party access should be analysed. Once technical feasibility is shown, then economic feasibility

analysis if the degree of market concentration is such to allow market based rates for storage services.

⁹Areeda, while commenting the diffusion of the doctrine, states in that "The essential facility doctrine is less than a doctrine than an epithet, indicating some exceptions to the right to keep one's creations to oneself, but not telling us what those exceptions are" (Arreda, 1989), p....

concerns both the level of access prices and the amount of access that is granted to the facility owner, once the facility is shared with its competitors. Access prices should cover any incremental cost due to sharing, beyond all capital and operating costs. Moreover the owner of the facility should not face any shortage in providing access to its own customers due to the sharing arrangement. In the case of gas storage the technical feasibility of shared access is not an issue. From the economic point of view regulated access can provide for fair access prices to the extent that regulated tariffs are cost-reflective. As to the amount of storage services needed by the supply branch of the dominant firm owning the facility, we can state that in case of storage rationing due to congestion management the final allocation should not impair these needs. However due to the existence of storage substitutes and their concentration in the hands of the dominant supplier, the amount of storage services actually needed by the storage owner should be properly assessed.

Essentiality of the facility. Essentiality means indispensability, i.e. that it is not possible to produce the output for the downstream market without having access to the services provided by the facility. In the case of gas storage the existence of storage substitutes that provide flexibility to gas suppliers may lead to state that the essentiality requirement is not satisfied. However one should also consider that 1) The mix between gas storage and its substitutes to provide flexibility affects the value of gas sales in the downstream market 2) Any mix of flexibility inputs must include gas storage, to the extent that it is hard to think that any gas supplier could completely exhaust his demand for flexibility by just resorting to storage substitutes.3) When liberalisation starts new entrants in the market for gas supplies are generally not equipped with flexibility substitutes.4) In some European Countries public service obligations require that gas suppliers be equipped with a due amount of storage capacity, in order to satisfy household demand which accounts for the greatest part of the temperature sensitive market. While the first point does not concern the "indispensability" of gas storage, the other ones lead to state that the essentiality requirement can be ascertained even in the case of storage facilities.

Non-Duplicability of the Facility. Once the last four conditions are respected one must consider the opportunity to duplicate the asset. Non-duplicability should be assessed both from the technical and the economic point of view. Concerning gas storage limitations to the duplicability of storage plants may arise due to the availability of suitable sites. Moreover once a site is found, the availability of new storage capacity may be hampered by the long times required to complete investments. From the economic point of view one should consider that gas storage is not a natural monopoly. Any storage plant can supply storage services in competition with other existing plants as minimum efficient scale is generally far from the amount of total storage demand coming from gas suppliers. However the exclusion of natural monopoly is not a sufficient condition to exclude non-duplicability. The latter should be assessed considering the returns on investments devoted to create an alternative facility by a representative competitor. Then it is necessary to ascertain whether a new entrant is at least able to break-even by replicating the asset. Actually

in that case entry cannot be strategically preempted by denying access to the facility. Economic feasibility should however be assessed with respect to market structure. A criterion has been offered by the European Court of Justice with the "Bronner case". If, due to free entry, a symmetric duopoly arises both upstream, in the market for the facilities services, and downstream and furthermore both firms obtain non negative profits, then duplication of the facility is economically feasible (Bergman, 2003). With respect to the to the gas market it is more frequent to observe a market structure with a dominant firm and a fringe of smaller competitive firms. Therefore according to the previous criterion duplication of storage assets seems not to be feasible, considering that market structure is asymmetric both upstream and downstream. Investments in new storage facilities are at present planned all over Europe also by new entrants, showing that infrastructures may be duplicated. According to the long times required to complete new plants, storage can *de facto* remain a transitory bottleneck monopoly in most European markets, until new capacity is delivered to the market by new entrants. The incentives to invest in seasonal gas storage are analysed by Codognet and Glachant (2006) with reference to the UK storage market, where regulation has been removed and storage decisions are supposed to react to spot prices. While investments in storage plants which allow fast and multiple cycles of gas injection and withdrawal (salt cavities) have been widespread in the UK, investments in huge gas fields devoted to seasonal gas storage are lacking due to market failures in providing incentives to this kind of investments. Therefore even the market won't deliver an "optimal" amount of investments in storage facilities. Then access to existing plants remains a regulatory issue.

4 The effect of storage rationing on the productive efficiency of gas suppliers

In order to concentrate on the cost of flexibility, we assume that the latter is the unique input needed to provide the service of gas suppliers. For the sake of simplicity, we also assume that flexibility must be acquired in the same amount of the final output, indicated by y (this is equivalent to say that the overall production function is of a Leontief-type with respect to flexibility). We also assume that flexibility can be obtained according to a (well-behaved) sub-production function whose intermediate inputs are indicated by the vector \mathbf{x} , and that each input x_i has a unit price of w_i . Though a true market for flexibility is hard to define we assume that the specificity of flexibility tools available to each firm can be captured assuming that the unit price w_i of any flexibility input is possibly idiosyncratic to each firm.¹⁰ For example the advantage of

¹⁰From an empirical point of view the specificity of flexibility tools should arise as a difference of the value added to the same amount of gas sold to the same type of customers across suppliers. For example, the flexibility of import may be coupled with a different price of the commodity and the availability of interruptible contracts is coupled to discounts offered to the industrial customers subscribing these contracts.

an incumbent can be represented by a lower cost of flexibility with respect to new entrants in the liberalized gas market. Finally, we assume that x_1 is the amount of storage capacity which is procured by the firm in a fixed amount z due to capacity constraints that induce rationing in the storage market. We assume that access to storage is regulated and therefore for all firms the price of storage is fixed and amounts to w_1 , corresponding to the regulated (cost-based) tariff for a unit of storage capacity.¹¹ If there were no restrictions concerning access to storage the total cost of achieving the amount y of flexibility would be represented by the following cost function:

$$c(\mathbf{w}, y) = \text{Min}_{\mathbf{x}} \{ \mathbf{w}'\mathbf{x} \text{ s.t. } f(\mathbf{x}) \geq y \}, \quad (1)$$

where $f(\mathbf{x})$ is the relevant (sub-) production function. Due to the fact that the amount of storage capacity is fixed, the total cost of flexibility can be represented by a "short run" cost function that we define as the restricted total cost function for flexibility $\hat{c}(w, y, z)$:

$$\hat{c}(\mathbf{w}, y, z) = w_1 z + \text{Min}_{\mathbf{x}_{-1}} \{ \mathbf{w}'_{-1}\mathbf{x}_{-1} \text{ s.t. } f(z, \mathbf{x}_{-1}) \geq y \}, \quad (2)$$

where \mathbf{x}_{-1} represents the vector of all flexibility inputs but storage, whose amount is given by $x_1 = z$. Thus, with obvious notation we can also write the restricted total cost function in the following way:

$$\hat{c}(\mathbf{w}, y, z) = w_1 z + \hat{c}_{-1}(\mathbf{w}, y, z). \quad (3)$$

Let $w_1^*(\mathbf{w}_{-1}, y, z)$ be the unit price that would induce the firm to demand (conditionally on the output level y and prices \mathbf{w}_{-1}) an amount $x_1 = z$ of input one (and the same amount of the other inputs implied by (2)) if it were unrestricted, i.e. if there were no rationing of storage but its price were such to lead him to buy exactly the amount obtained when rationing is present. Such implicit price represents the "virtual" *marginal* willingness to pay for that amount of storage and can be defined through the conditional demand function $x(\mathbf{w}, y)$ which solves (1) as follows:

$$x_1(w_1^*(\mathbf{w}_{-1}, y, z), \mathbf{w}_{-1}, y) = z. \quad (4)$$

Since $\hat{c}_{-1}(\mathbf{w}_{-1}, y, z) = c(w_1^*(\mathbf{w}_{-1}, y, z), \mathbf{w}_{-1}, y) - w_1^*(\mathbf{w}_{-1}, y, z)z$, we can rewrite the restricted total cost function (3) in the following way:

$$\hat{c}(\mathbf{w}, y, z) = (w_1 - w_1^*(\mathbf{w}_{-1}, y, z))z + c(w_1^*(\mathbf{w}_{-1}, y, z), \mathbf{w}_{-1}, y). \quad (5)$$

Equation (5) allows a simple computation of the (marginal) value of storage when capacity is rationed and access to storage is regulated. In fact, the impact

¹¹We do not consider here the difference among space, injection capacity and withdrawal capacity. In practice the amount of rationing may be different for the three types of storage capacity offered to customers. Therefore rationing might be overcome concerning space but persist as far as withdrawal capacity is considered.

of the availability of a supplementary unit of storage capacity on the restricted cost function is given by:

$$\partial \hat{c}(\mathbf{w}, y, z) / \partial z = w_1 - w_1^*(\mathbf{w}_{-1}, y, z). \quad (6)$$

Notice that with a virtual willingness to pay for storage greater than the regulated price a marginal increase of storage availability reduces total costs. Therefore $(w_1^*(\mathbf{w}_{-1}, y, z) - w_1)$ represents the shadow price of relaxing the constraint on storage availability. This shadow price will be positive only if the firm is actually rationed at (\mathbf{w}, y) with respect to storage. On the contrary, the shadow price of relaxing the constraint on storage may be negative, meaning that the willingness to pay for storage is less than the regulated price, and implying that alternative flexibility inputs would be more convenient than storage. In this last case a marginal increase in the use of storage would lead to an increase of marginal cost. Therefore we cannot exclude that a gas supplier (if he is allowed to) will prefer to get less storage with respect to the amount he could get on the basis of rationing rules, when the latter allocate storage capacity independently of storage value.

5 The Efficient Rationing Rule: an example

Storage rationing increases total and marginal costs, and induces a sub-optimal demand of the other flexibility inputs. Due to these negative effects on productive efficiency, access to storage might be regulated with the aim to minimize industry distortions in the allocation of this scarce resource. Accordingly we should find an efficient rationing rule, i.e. a rule that would distribute the rationed input z across firms with the aim to minimize the total cost of flexibility overall the gas industry. A rule that would reach this aim implies that the regulator implements the allocation resulting from the equalization of the shadow costs of storage across firms. In this case the final allocation of storage capacity would be such to respect the heterogeneous values of storage for gas suppliers.

In order to illustrate this point, let us consider an example where flexibility is provided by two inputs, storage (x_1) and a substitute (x_2). The sub-production function for flexibility is a two-input Cobb-Douglas with constant return to scale: $y = \sqrt{x_1 x_2}$. Then we have $c(\mathbf{w}, y) = 2y\sqrt{w_1 w_2}$ and $x_i(\mathbf{w}, y) = y\sqrt{w_j/w_i}$. As we did in the previous section we assume that $x_1 = z$ and then compute the restricted total cost function $\hat{c}(\mathbf{w}, y, z) = w_1 z + w_2 y^2/z$, the restricted conditional demand of the storage substitute $\hat{x}_2(w_2, y, z) = y^2/z$ and the restricted marginal cost function $\partial \hat{c}(w_2, y, z) / \partial y = 2w_2 y/z$. Therefore in this case the virtual willingness to pay for storage is given by $w_1^*(w_2, y/z) = w_2(y/z)^2$.

With in mind the analysis of next sections (and without loss of generality for what concerns an illustration of the efficient rationing rule), we assume that in the final market for gas two firms are present: a dominant firm (l), and a single “competitive” follower (f), which can be thought as a competitive fringe of symmetric suppliers. We assume that the price for the rationed input is regulated to be the unit cost of the storage service ($w_1 = c$), while the price

of the unique storage substitute differs across the two firms: $w_{2l} = \alpha w_{2f}$, with $0 < \alpha < 1$, to account for a better access to the storage substitute by the dominant firm. Given the output levels, the efficient rationing rule implies the equalization of the shadow cost of storage of the leader with that of the follower, i.e., $w_{1f}^* = w_{1l}^*$. In the current example this task reduces to the implementation of the following rationing rule:

$$\frac{y_l}{z_l} = \frac{1}{\sqrt{\alpha}} \frac{y_f}{z_f}. \quad (7)$$

It is worthwhile to notice that the resulting allocation of storage capacity across firms differs with respect to the final allocation of output, as $y_l/y_f > z_l/z_f$. In fact efficiency requires that the firm with the worst access to storage substitutes should be "compensated" with the allocation of a greater proportion of storage capacity with respect to her final sales. Therefore in general neither rules that distribute storage capacity in proportion to final market shares¹² nor "first come first served" rules lead to cost minimization, as they neglect the asymmetries across firms concerning the availability of storage substitutes. On the contrary, efficient rules should be expected to discriminate among firms and imply asymmetric regulation of access to storage. More capacity should indeed be allocated to firms characterized by higher costs for the storage substitutes.

However, to the extent that the availability (and cost) of storage substitutes is a private and non verifiable information, efficient allocation rules would be very difficult to implement, due to the asymmetric information of the regulator about the technology of each gas supplier, especially considering the idiosyncratic nature of flexibility costs. Clearly, gas suppliers have no incentive to report to the regulator their amount and/or cost of storage substitutes if such a report would reduce the amount of rationed storage capacity allocated to them. In fact, once the competition for market shares is taken into account, any gas supplier even faces the following trade-off: possibly getting more storage capacity than the amount required by cost minimisation leads to an increase of flexibility costs, but to the extent that such an amount is embezzled to the other supplier it may raise rival's cost and so increase his own market share. For example, the leader may find it optimal to hoard storage capacity in order to increase the follower cost for flexibility¹³. Intuitively, such a strategy should be more profitable to the leader the lower is the regulated price of storage and the higher his cost of storage substitute. The scope for a strategic demand for storage is investigated in next section. Notice that the regulator may adopt a market mechanisms to elicit firms preferences concerning storage capacity. For instance, auctions might be used as a suitable rationing mechanism to the

¹²This kind of rules, satisfying an intuitive fairness criterion, is often used; a possible "equity" justification comes from the practice of it being coupled with public service obligations that require utilities to assure gas sales to households in any event (thus, access rights to storage capacity become proportional to the share of the household market served by each firm).

¹³In practice if a new entrant has no flexibility tools available but storage, then by hoarding storage capacity the leader can prevent the follower from extending its market share.

extent that bids should naturally depend on the willingness to pay for storage capacity. But even resort to storage auctions does not eliminate the incentive to hoard storage capacity in order to raise rival's cost (see next sections). However, with a storage auction the profitability of such a strategy is endogenous to the auction itself as the price paid for storage capacity depends on the bids posted by gas suppliers.

6 The strategic function of storage with imperfect competition in gas markets

In this section (and in section 7) we compare the allocation of storage capacities carried out at a regulated price with rationing by some market mechanism. Though resort to the market is in itself another way to implement third party access to storage by an independent regulator, for simplicity we shall label the first mechanism as "administrative regulation" and the second one as "auction". Then administrative regulation and auction are compared considering their effects on competition in the downstream market and on overall social welfare.

We assume that the storage market is a monopoly and that the gas market is characterized by a dominant firm (the market leader) and a fringe of symmetric competitive producers. This last assumption reflects quite correctly the structure of wholesale gas markets in European Countries, which are still dominated by former integrated utilities sharing the market with multiple small new entrants. Dominant firms in the wholesale markets are frequently also owners of storage plants, as liberalization directives just require accountancy unbundling concerning storage.

6.1 The Basic Model

In this section we introduce some extreme (though not necessarily unrealistic) assumptions concerning technology by assuming not only that flexibility is in principle provided by two inputs (storage (x_1) and a unique storage substitute (x_2)), but also that the latter is completely unavailable to the follower. Then while the price of storage (w_1) is the same for all firms (be it set by the regulator or by an auction mechanism), the price of the other input is w_{2l} to the leader and $w_{2f} = \infty$ to the follower. In addition, the production function is linear: i.e., $y = x_1 + x_2$. Thus the restricted production function of the follower is simply $y_f = z_f$ and his total cost function is given by $\hat{c}_f(w_1, y_f, z_f) = w_1 z_f$ for any $y_f \leq z_f$, while the restricted cost function of the leader is given by $\hat{c}_l(\mathbf{w}_l, z_l, y_l) = w_1 z_l + w_{2l}(y_l - z_l)$ for $y_l \geq z_l$. The leader demands storage either because $w_1 < w_{2l}$ and/or just to raise rival's costs. The main simplification which follows from linearity of the technology is that the restricted *marginal* cost of the leader is unaffected by the amount of storage received (assuming rationing).¹⁴ This simplification has a cost: w_{1f}^* is not well defined (the follower

¹⁴In principle, an increase of z_f given the total amount of available storage has possibly both a pro competitive effect (by increasing the supply function of the competitive fringe) and

is not really rationed *given* his level of output, while he cannot produce more than z_f) and w_{1l}^* is equal to w_{2l} (so the leader is rationed with respect to storage only if $w_1 < w_{2l}$). As a consequence, an efficient *distribution* of storage just coincides with the only feasible allocation $z_f = y_f$ and $z_l = S - z_f$, where S is the total amount of storage available (we assume that the unit cost of storage c is less than w_{2l} , so that it is never socially efficient to waste some storage). Accordingly, what we investigate in this section is just the strategic behaviour of the leader in presenting his demand for storage.

Concerning the final gas market, we assume that demand is linear: $D(P) = a - P$; as the fringe of competitive followers sells all its feasible output in the market, the residual demand of the dominant firm will be given by $d_l(P) = a - z_f - P$. We assume that $a - 2S > w_{2l}$, so that even a monopolist would be rationed with respect to the storage available capacity.

6.2 Equilibrium Analysis with Administrative Regulation of Storage Capacity

In this case we assume that third party access regulation is implemented through an access tariff and administrative rules concerning the allocation of scarce storage capacity. We do not specify the administrative rule chosen by the regulator. It can be one of the rules currently followed in European Countries, which do not consider neither the cost and availability of storage substitutes nor the strategic function that storage may play in order to rise rivals' costs. Therefore in the first period the storage firm distributes storage capacity according to these rules and in the second period firms compete in the gas market on the basis of the amount of storage capacity previously obtained. That is, we assume that the strategic link between the storage market and competition in the downstream market is neglected by the regulator. Be then $w_1^r = c < w_{2l}$ the regulated price of a unit of storage capacity and γ the percentage of storage capacity assigned to the follower, to give $z_f = \gamma S$ and $z_l = (1 - \gamma)S$, ($0 \leq \gamma \leq 1$).

Considering gas market equilibrium, the follower sells in the market an amount of output y_f which is only constrained by storage: therefore $y_f = z_f$. To derive the optimal quantity of gas to be sold by the dominant firm we consider the maximisation of its profit function:

$$Max_{y_l} \Pi = (a - y_l - z_f)y_l - [w_1^r z_l + (y_l - z_l)w_{2l}]. \quad (8)$$

From the F.O.C. we obtain the optimal output sold by the leader:

$$y_l = \frac{a - z_f - w_{2l}}{2}, \quad (9)$$

the equilibrium output of the industry:

$$y = y_l + y_f = \frac{a + z_f - w_{2l}}{2}, \quad (10)$$

a counter competitive effect by raising the leader marginal cost.

and the equilibrium price:

$$P = \frac{a - z_f + w_{2l}}{2}. \quad (11)$$

Equilibrium analysis shows that any increase of storage capacity allocated to the follower reduces both the equilibrium quantity of the leader and the final market price in the downstream market. Actually the increase of his storage capacity allows the follower to expand his output so that the residual demand faced by the leader decreases, affecting the equilibrium price, which also depends on the leader marginal cost w_{2l} . Thus, an increase of storage capacity allocated to the follower has a net positive impact on the expansion of equilibrium output: since $z_f = \gamma S$, we can also notice that any increase of the total amount of storage capacity for a given γ induces the same effects just described. Therefore if a dominant firm is also the owner of storage capacity, then its incentive to invest in storage might be adversely affected by the effects of storage availability on competition in the final gas market. Finally, we can consider what would happen under a "first come first served" rule, if the leader can choose first her amount of storage. Clearly, it is never optimal for the leader to leave any storage capacity to the follower, because at the very least she could choose $z_l = S$, produce the same total output that in the market equilibrium with $z_f > 0$ and get a higher revenue and profit. Thus, in this setting, a leader firm "first served" of storage would completely crowd out the competitive fringe (i.e., it would set $\gamma = 0$).

6.3 Equilibrium Analysis when Storage Capacity is Auctioned

Access to storage capacity may alternatively be implemented by some market mechanism, whose rules must be set by the regulator. In particular, we suppose that storage capacity is rationed through a *multiunit sealed bid uniform price auction*. This auction assigns multiple units of storage capacity to each bidder. For each storage unit, bidders must specify their willingness to pay: thus, firms when bidding for storage present "to the market" a demand function for access to storage capacity. Then the S units of storage are allocated to the S highest bids, but bidders will pay a uniform price p equal to the lowest of the highest bids that are awarded the auctioned units: The storage auction will then establish the unit cost of storage capacity $w_1^a = p$ and this cost can of course exceed the regulated unit tariff for access to storage considered in the previous section $w_1^r = c$. The timing of the model is such that storage capacity is auctioned in the first period and then in the second period firms compete in the gas market. Therefore firms, through their behaviour as bidders may try to influence the final allocation of storage capacity in order to affect the result of competition in the final gas market. We continue to assume that these markets are characterized by a dominant firm and a fringe of competitive followers. Due to our assumptions about technology the leader can obtain flexibility not only through storage but also through a storage substitute, while the output of the follower is constrained by the amount of storage obtained in the auction. Then it is rational for the

leader to behave strategically also as a bidder for storage and try to manipulate the auction mechanism in order to exert market power in the market for gas supplies.

We then look for a sub-game perfect Nash equilibrium and solve the model backwards by considering firstly equilibrium in the gas market (second stage) and then the equilibrium values of the auction mechanism (first stage) given the equilibrium of the second stage. As the second stage concerns competition in the gas market, the equilibrium results already computed in section 6.2 still apply. We can then consider the equilibrium of the auction mechanism. The follower needs storage as an essential input and, given its resulting output and the gas price, demands the amount of storage capacity that maximises his profits:

$$Max_{z_f} \pi = p(z_f) y_f - w_1^a y_f = \left(\frac{a - z_f + w_{2l}}{2}\right) z_f - w_1^a z_f, \quad (12)$$

$$\frac{\partial \pi}{\partial z_f} = \frac{-2z_f + (a + w_{2l} - 2w_1^a)}{2} = 0. \quad (13)$$

From the F.O.C. (13) we can derive the follower's demand of storage:

$$z_f = \frac{a + w_{2l}}{2} - w_1^a \quad (14)$$

(notice that $z_f = S$ if $w_1^a = \frac{a + w_{2l}}{2} - S$). Thus, we can characterize the behaviour of the follower in the storage auction by the following competitive bidding strategy:

$$w_1^a = \frac{a + w_{2l}}{2} - z_f, \quad (15)$$

for $0 \leq z_f \leq S$. On the contrary, the leader takes as given the demand for storage of the follower, anticipating that she will get a certain amount of storage capacity at the uniform price arising from the auction. Assuming that the storage is rationed ($z_l + z_f = S \leq y$), the leader is led to bid strategically in order to establish the equilibrium price of storage w_1^{a*} within the auction, unless she chooses not to get any storage capacity. Therefore the dominant firm firm maximises its profit with respect to this price:

$$\begin{aligned} Max_{w_1^a} \Pi &= p(z_f(w_1^a)) y_l(z_f(w_1^a)) - \\ & [(w_1^a - w_{2l}) z_l(z_f(w_1^a)) + w_{2l} y_l(z_f(w_1^a))] \\ &= \left(\frac{a - z_f(w_1^a) + w_{2l}}{2}\right) \left(\frac{a - z_f(w_1^a) - w_{2l}}{2}\right) - \\ & \left[(w_1^a - w_{2l})(S - z_f(w_1^a)) + w_{2l} \left(\frac{a - z_f(w_1^a) - w_{2l}}{2}\right) \right] \quad (16) \\ &= \frac{(a - z_f(w_1^a))^2 - w_{2l}^2}{4} - \\ & \left[(w_1^a - w_{2l})(S - z_f(w_1^a)) + w_{2l} \left(\frac{a - z_f(w_1^a) - w_{2l}}{2}\right) \right] \end{aligned}$$

Since (given (14)) $\frac{dz_f}{dw_1^a} = -1$, from the F.O.C. we can obtain the optimal value w_1^{a*} from the point of view of the market leader as follows:

$$\frac{\partial \Pi}{\partial w_1^a} = \frac{3(a + w_{2l}) - 6w_1^a}{4} - S = 0, \quad (17)$$

$$w_1^{a*} = \frac{a + w_{2l}}{2} - \frac{2}{3}S \quad (18)$$

(in order to establish this equilibrium price the leader just needs to bid w_1^{a*} for the total amount of storage capacity demanded). Notice that $\frac{\partial \Pi_l}{\partial w_1^a} = -S < 0$ if this derivative is evaluated at $w_1^a = \frac{a+w_{2l}}{2}$: thus, it will never be the case that the leader completely crowds out the competitive fringe if she has to pay a "market" price for storage (this behaviour would be too costly for her in our setting). However, since $w_1^{a*} > \frac{a+w_{2l}}{2} - S$, it will also never be the case that $z_f = S$, i.e., the leader will always engage in some capacity hoarding, irrespective of the value of w_{2l} . Indeed, given (21) the follower and the leader will respectively obtain the following amounts of storage capacity:

$$z_f^* = \frac{a + w_{2l}}{2} - w_1^{a*} = \frac{2}{3}S, \quad (19)$$

$$z_l^* = S - z_f^* = \frac{1}{3}S. \quad (20)$$

Notice that, while one could expect the amount of storage optimally obtained by the leader to depend negatively on the value of w_{2l} , and that accordingly corner solutions with $z_f^* = 0$ or $z_l^* = 0$ could possibly arise, in our setting the effect of an increase in w_{2l} is totally offset by the corresponding increase in the bidding strategy of the follower (which in turn depends on the increase in the equilibrium price in the gas market) and then in the value of w_1^{a*} : see (15) and (18). Then, to get the equilibrium price and quantities in the final gas market the previous amounts of storage capacity must be substituted into the equilibrium results of the second stage of the model to obtain the following sub-game perfect Nash Equilibrium:

$$y_f^* = z_f^* = \frac{2}{3}S, \quad (21)$$

$$y_l^* = \frac{a - z_f^* - w_{2l}}{2} = \frac{a - w_{2l}}{2} - \frac{1}{3}S, \quad (22)$$

$$y^* = y_f^* + y_l^* = \frac{a - w_{2l}}{2} + \frac{1}{3}S, \quad (23)$$

$$P^* = \frac{a + w_{2l}}{2} - \frac{1}{3}S. \quad (24)$$

These results holds given that storage is rationed and the dominant firm obtains flexibility by partially resorting to a storage substitute. Obviously, the

equilibrium output of the industry is increasing with respect to the amount of storage capacity and the equilibrium price is decreasing with respect to the same variable. Moreover, the equilibrium output is increasing (and the equilibrium price is decreasing) with respect to w_{2l} . These results are straightforward, and given the storage allocation results (19)-(20) directly come from the equilibrium values of the gas market stage (the larger the amount of storage allocated to the follower, the better the performance of the gas market at the final stage: see below for the welfare analysis). In particular, the auction allocates a larger amount of storage to the follower than the administrative rule if and only if $\gamma \geq \hat{\gamma} = 2/3$.¹⁵

7 Welfare Analysis

In order to compare the performance of the administrative regulation of access to storage with storage auctions and draw some conclusions about these regulatory options we have to evaluate the welfare values of the equilibrium outcomes. Social welfare includes consumer surplus in the gas market, and the profits obtained by the market leader (Π), the competitive fringe (π) and the storage firm (π_S), i.e.:

$$W = CS + \Pi + \pi + \pi_S. \quad (25)$$

However, assuming that the use of storage is rationed ($S < y$) the only difference between the two allocation mechanisms considered which concerns the storage market comes from the different storage prices $w_1^r = c < w_1^a$. This implies that under the auction mechanism the storage firm gets a higher profit, while the overall profit of gas supplier is less, but this is simply a costless transfer from the point of view of social welfare. In addition, since overall consumer surplus only depends on the amount of total output produced in the gas market, which in turn only depends on the storage allocated to the follower in the first stage, accordingly we can conclude that the welfare will be the largest under the administrative rule if and only if $\gamma \geq \hat{\gamma}$ (notice that there is no question of "cost mix", since the relevant incremental output $y - S$ will in both cases produced by the leader by using x_2). Finally, notice that, under the administrative rule, in our setting an increase of γ certainly decreases the profit of the leader firm, both as a result of lower gas price and smaller own output, and of greater resort to the storage substitute which is more expensive. On the contrary, the competitive fringe will be positively affected by an increase of γ , since the increase of their gas supply will overcome the negative impact of the reduction of gas price.

¹⁵In a more general setting, we might expect that the less costly the alternative flexibility to the leader, the larger the amount of storage allocated to the follower in a market solution, the better the gas market performance at the final stage, with a value of $\hat{\gamma}$ decreasing with respect to w_{2l} .

8 Conclusions

In vertically integrated industries gas storage is an important optimisation tool for gas suppliers. In liberalized gas markets storage not only arises as a potentially independent industrial activity but also plays a strategic role to the extent that storage availability affects competition in the downstream market for gas supplies. In this paper we have tried to provide a first analysis of regulatory issues concerning storage, considering both the productive efficiency of gas suppliers who demand storage as a flexibility tool and the allocative efficiency issues in gas markets which are far from being competitive. Due to the scarcity of storage resources in Europe, we have been led to consider efficient rationing rules as an important part of the current regulatory issues.

We claim that in order to discuss the efficiency of rationing rules storage should be considered together with all inputs that provide flexibility to gas suppliers. The asymmetric distribution of storage substitutes between incumbents and new entrants, together with the long time span required to deliver new capacity to the market leads to recognize storage plants as essential facilities, even if storage is not a natural monopoly and duplication of storage facilities may be viable in principle. The need to regulate storage tariffs then follows. Though charging cost reflective access charges may be effective in controlling the exercise of market power by *de facto* storage monopolists, not necessarily leads to an efficient allocation of storage capacities. Regulated prices do not signal storage scarcity and the final allocation of storage resources depends on the rationing rule arising from congestion management. The efficiency properties of this rule require to allocate storage according to its idiosyncratic value for each gas suppliers. Therefore we find that an efficient rationing rule should equalize the shadow price of storage across gas suppliers. The shadow price accounts both for the quantity of output to be supplied by each firm and the cost of its storage substitutes. Current rules adopted in Continental Europe are then found to be inefficient as they allocate storage either just in proportion to the market shares of gas suppliers in the household market or just according to a "first come first served" criterion. At a first glance market mechanism like auctions should perform better to the extent they are expected to allocate storage according to its value for bidders.

However, ex-ante efficient rules may be difficult to implement due to asymmetric information about the technology of flexibility. To the extent that gas suppliers are rationed they are led to report to the regulator greater storage requirements than those implied by the equalization of shadow prices. Moreover, storage demands should be assessed not only with respect to their effect on the productive efficiency of gas suppliers, considered in isolation from each other, but also taking account of the structure of the final gas market. If we assume imperfect competition in the final gas market, then storage demands may be affected by strategic behavior. Considering a market structure with a leader that controls the final gas price and a competitive follower, we show that the adverse incentives of the dominant firm lead it to demand storage with the aim to exclude the leader from the final market. Then "first come first served"

rules and long term booking of storage capacity can be considered particularly detrimental to competition, as they allow the dominant firm to carry out exclusionary strategies aimed at market monopolization. We then compare a general (non-specified) administrative rules with a market mechanism that allocates storage capacity according to gas suppliers bids. The market mechanism we consider is a *multiunit sealed bid uniform price auction* that raises the price of storage above the regulated cost-reflective price: storage capacity is allocated by charging the market clearing price arising out of the bidding equilibrium. The dominant firm is again assumed to behave strategically, driving the market clearing price towards the level that optimizes from its point of view the quantity of storage assigned to the follower. However, to the extent that the dominant firm is charged the same price to get its portion of storage capacity, then the market mechanism makes the exclusionary behavior more costly and potentially increases the portion of storage capacity left to the follower with respect to an administrative allocation that just charges the cost-reflective access price. Since this market mechanism welfare dominates any administrative distribution of storage capacity except when the latter leads the follower to get more storage capacity, welfare analysis tends to prefer the former mechanism. In fact, in our setting any increase of the portion of storage capacity allocated to the follower is pro-competitive and allows to increase both consumer surplus, social welfare and the follower profits, though it reduces the profits of the dominant firm. Obviously the profits of the storage firm are increased by the adoption of a market mechanism due to the rents that accrue to it through a market price greater than the cost-reflective regulated tariff.

In this paper we do not consider neither the issue of ownership unbundling of storage facilities from gas supply nor the incentives to invest in new storage facilities. However, our conclusions concerning the strategic use of storage by the incumbent are reinforced when the incumbent is also the owner of storage facilities. In that case not only the incumbent can raise rivals' cost by hoarding storage capacity, but it can also prevent an expansion of the follower market share by controlling the pace of storage investments until new entrants have developed their own storage capacity. Without ownership unbundling even the effect of the adoption of a market mechanism on the adverse incentives of the incumbent is diluted. In fact the market clearing price paid by the incumbent gas supplier to the storage firm just becomes a transfer price inside the same holding company. We have also neglected the existence of secondary markets for storage capacity, where suppliers could get rents from selling excess capacity even if market prices may approximate the real values of storage. However, once secondary markets were considered the possibility of strategic behavior should be analysed also within these markets.

A further limitation of our analysis is that it considers the effect of storage rationing on productive efficiency separately from its effect on allocative efficiency, so that when the strategic behavior of the incumbent supplier is analysed its effect on productive efficiency is neglected. If the incumbent gas supplier is also the most efficient one from the point of view of productive efficiency - which is rather likely - any increase of output she supplies would have a positive ef-

fect on welfare through an increase of overall productive efficiency. However this last effect cannot be accounted for in our analysis. Such a limitation is due to our assumptions about the technology of gas supply. At present we do not dispose of empirical evidence about the technology of flexibility and consequently our assumption about a linear production function is just for the sake of simplicity. But considering together the issues of productive efficiency and allocative efficiency would also allow to discuss the question of the efficiency of entry. Such a question has been put aside in the debate about the liberalization of the European gas market, to the extent that the unsatisfactory results about competition probably led to welcome any additional entry or any additional expansion of new entrants. On the contrary, the question of efficient entry has been widely considered in the case of the telecommunication markets, also with reference to the regulation of access prices, and it should deserve some analysis also with reference to the gas market.

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