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Efficient Mechanisms for Access to Storage with Imperfect Competition in Gas Markets

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Abstract

Scarce storage capacity and distortions in access to gas storage are considered causes of market foreclosure in liberalized gas markets. We consider rules currently adopted in Europe for storage rationing and propose efficient rationing mechanism based on the value of storage, when other flexibility inputs are available. Firstly we analyse productive efficiency issues neglecting vertical restraints and strategic behaviour in the final market. Then we assume imperfect competition in the downstream market for gas supplies, given the avaialbility of storage capacity upstream. We consider effciency issues in a two stage model comparing regulated storage tariffs – coupled with a centralizedrationing mechanism – with storage auctions. Finally we consider as an optimal mechanism the allocation of storage arising from welfare maximization by a social planner. We find that it is usually optimal to maximize the amount of storage capacity allocated to new entrants in the gas markets. Storage auctions deviates from the optimal mechanism, but still improve effciency, with respect to current mechanisms, to the extent that they allocate storage according to its value. Furthermore storage allocation appear to be an extremeley powerful mechanism to improve competition and efficiency in gas markets.

Keywords: Liberalization, Auctions, Essential Facilities
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1 Introduction

A particular feature that differentiates natural gas from electricity is the opportunity of storage to cope with demand fluctuactions. Gas consumption is

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affected by predictable and unpredictable fluctuactions. Seasonal fluctuactions are the most important but also weekly and intra-day changes are non negligible. Utilities need to constantly balance demand and supply (which might be flat). Access to storage gives suppliers the flexibility needed to cope with demand fluctuactions and uncertainty. Moreover as storage activities generally imply gas injections when prices are lower (summer) and gas witdrawal when prices are higher (winter), gas suppliers, through storage, can profit from a winter-summer spread. Further spreads may be cashed by using storage as a financial option for short term cycles of injection-withdrawal to speculate on gas prices fluctuactions, provided spot and future markets for the commodity are liquid enough. But storage may also be useful to limit supply shortages in importing Countries exposed to the risk of supply failures from non-EU Countries. Denamrk and Italy for example dispose of huge reserves of gas that are especially locked for this purpose (strategic storage). Seasonal storage is also used by utilities to satisfy public service obligations to the extent that households must be protected by supply shocks and are given priority with respect to other customers. Finally storage is also used by gas producers for supply optimisation and by the transmission system operator to keep physical balancing into the transmission network[1].

Before the liberalization of European gas markets, storage was used by vertically integrated utilities to optimize the size of the transmission network in the long run and to efficiently manage gas flows in the short run[2]. After liberalization new entrants in the gas markets, beyond access to the transmission network, should also gain access to storage capacity in order to supply gas to their customers. In fact any supply failure would become a threat to their reputation as gas sellers. Therefore the lack of storage capacity available to new gas suppliers can be a barrier to entry[3] According to the last enquiry carried out by the European Commision on the energy sector (European Commission, 2006), distortions in access to gas storage represent one of the main cause of market forclosure preventing competition progress in wholesale and retail gas markets.

The European directive 2003/55/EC requires memeber Countries to implement non discriminatory third party access to storage facilities. However, member Countries can opt between negotiated and regulated third party access, according to the features of national storage markets. Such a difference provision, with respect to access to transmission and distribution networks, which should be regulated by independent authorities, can be ascribed to the economic features of storage markets, to the extent that storage is not a natural monopoly.

Though storage costs are affected by scale economies, 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 from gas suppliers. However the liberalisation directives did not require divesture of

[1]Individual gas suppliers, as shippers, may in turn resort to storage for commercial balancing purposes, to prevent being exposed to penalties if they cause unbalances inside the transmission network.

[2]The availability of storage plants avoids to fit the size of the trasmission nework to peak demand, with big savings on investments costs for pipelines. In the meantime any significant expansion of pipeline capacity should be coupled with some increase of storage capacity. In the very short term pipeline capacity could also be used for storage purposes (linepack).

[3]In a recent analysis carried out by the ERGEG (European Regulator Group for Electricity and Gas) most gas suppliers stated that unavailability of storage prevented them from offering some kind of contract in the downstream gas market. (ERGEG, 2010).

existing storage assets owned by former integrated utilities, in order to introduce storage to storage competition[4]. Not even ownweship or legal unbundling was required and nowadays storage is frequently supplied by branches of the former integrated utilities, now operating as dominant gas suppliers in the downstream market. At present a competitive market for storage is effective only in the UK[5]. Most continental Countries are characterized either by de facto monopolies or by market power in the storage sector.

However storage services are not the unique flexibility source for gas suppliers. Flexible production fields (offering "supply swing") and flexible import contracts may operate as a substitute for gas storage, as well as interruptible contracts with industrial customers, access to spot market liquidity or availability of gas fired power plats (considered as "virtual storage")[6]. But in practice these storage substitutes can hardly meet the total demand for flexible gas by any supplier and are generally positively correlated with market shares and therefore more available to incumbents than to new entrants[7]. According to ERGEG (2010) access to seasonal storage is essential for fullfilling public service obligations. 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. Therefore in practice even if storage is not a natural monopoly it stils represents an essential facility[8] for downstream competition in most gas markets all over Europe.

Once we consider existing storage plants as essential facilities 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[9]. However, standard cost reflective tariffs may not give appropriate signals about the scarcity of storage resources. Furthermore the regulatory setting should account for the availability of storage substitutes and their asymmetric distribution among gas suppliers[10]. We sus-

[4]Before liberalisation national markets were characterized by just one or a few companies owning multiple storage plants and European directives did not impose any horizontal unbundling aiming to split storage companies by selling part of their plants to new entrants, as was done in the case of electricity generation. In the UK divesture of existing storage plants owned by the incumbent was requested by the Monopoly and Merger Commission, but opposed by the British Government (Yarow, 2003). Divesture was required only ex-post in some antitrust cases by competition authorities. An example is a Merger Case (Case No COMP/M.3868-DONG/Elsam/Energi E2) whereby the DG Competition approved a Merger by Dong, the state owned Danish gas company, but imposed divesture of two storage plants as a remedy to protect competition in the energy market.

[5]In the UK ownership unbundling has been implemented and multiple storage companies operate their business independently from gas supply, under the supervision of antitrust authorities.

[6]Moreover the nature of most flexibility inputs is such that a market for flexibility is hard to define. See for example Ofgem (2002); Commission of the European Communities (2006).

[7]Flexible production fields are availble just in gas producing Countries like the UK and The Netherlands. An enquiry carried out jointly by the National Competiton Authority and the Italian Energy Regulator has shown the extensive resort of ENI – the dominant firm – to the flexibility available in his import contracts in order to cope with demand fluctuactions. An opportunity not available to new entrants (Autorità Garante della Concorrenza e del Mercato, 2009). An empirical analysis extended to the Italian Market for flexibility has shown that according to the opinion of most gas suppliers regulated storage services represent the less expensive flexibility inputs (Bonacina et al., 2009).

[8]See Cavaliere (2009) for a discussion of an essential facility test applied to storage markets.

[9]At present storage tariffs are regulated just in Hungary, Italy and Spain. Empirical evidence shows that negotiated tariffs are much more higher than regulated tariffs.

[10]The need to consider the availability of storage substitutes beyond the degree of concen-

pect that current tariff regulation and current allocation rules hardly meet this criterion.

In most European Countries – with the exception of the UK, France and Hungary – the market for storage is affected by persisting capacity constraints (ERGEG, 2010) and storage scarcity is even expected to increase in the future[11]. The most recent inquiry carried out by European Commission (2006) 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 in some cases was not even fully utilized[12].

Even if storage scarcity is frequently linked to the absence or slowness of new investments, we think that it may be due also to the inefficient access rules currently adopted all over Europe. Though in some Countries market mechanism like auctions are being used, in many cases rationing rules like "Fist Come First Served" (FCFS), "Pro-quota" and "Capacity Goes with the Customers" (CGWC) are still widespread. Rules like FCFS may easily induce capacity hoarding. "Pro-quota" and "CGWC" allocates storage capacity according the market share of gas suppliers in the downstream market for gas, and then seems to be more fair. However neither of these rules appears to be efficient,.to the extent that storage capacity is not allocated according to its value for single gas suppliers. Market mechanism like auctions should work better in this respect, although their efficiency may be affected by the strategic behaviour of dominanat gas suppliers when bidding for storage capacity.

The resort to storage auctions to replace cost based regulation of storage tariffs has been considered by Yarow (2003) with respect to the UK experience. To the extent that individual demand for storage is characterized by different price elasticities, regulation improvements based on the use of Ramsey Pricing may be suggested. However in the case of the storage market demand information by the regulator is lacking, to the extent that storage is an intermediate input demanded by gas suppliers[13]. Then auctions may work better in this respect to the extent they help information discovery about the willingness to pay for storage. Moreover storage auctions may provide information also about the total amount of storage capacity needed and that can be financed through the market. Storage auction may then facilitate the transition from regulation to competition in the storage market, as actually shown by the UK case.

The economic literature on gas storage traditionally considers the effects of storage decisions on final gas prices, assuming that a competitive and liquid market for the commodity is in place. Extensions to industrial organization

tration in local storage markets has also been recognized by the Federal Energy Regulatory Commission (FERC) in the USA (FERC, 2005), in order to assess market power when storage companies ask for an exemption from regulated tariffs, claiming they operate in a competitive storage market.

[11]Recent forecasts concerning North-Western Europe (Hoffler and Kubler, 2006) show 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 anf the Netherlands. The Storage gap could be even wider than expected if the increasing import dependency led more Countries to devote storage capacity to precautionary inventories.

[12]The 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 actually been used (European Commission, 2006, p. 65).

[13]Ramsey pricing may in fact implemted more easily as far as regulation of final consumer prices is at stake, to the extent that consumer demand elasticities are well known.

and regulatory issues are very recent. One can see Baranes et al. (2011) for a detailed survey. The contributions collected in Cretì (2009) especially focus on the economics of gas storage from a European point of view. More recently Ejarque (2011) has considered the cost of blocking gas reserves for precautionary purposes in order to pursue security of supply. Both blocking inventories for precautionary purposes and limiting access to storage by inefficient rationing rules prevents gas suppliers from exploiting the arbitrage opportunities given by gas storage. Baranes et al. (2009) analyse the strategic use of storage facilities to gain market power. To the best of our knowledge regulatory issues concerning access to storage capacity with imperfect competition in gas market have not been considered so far. In Bertoletti et al. (2008); Cavaliere (2009) we focused on regulatory issues by considering both the existence of storage substitutes and the efficiency of rationing rules not only per sè but also with reference to the distortions induced on the downstream market. In this paper we extend our analysis with alternative assumptions about the the technology of gas supply and assume that not only dominant firms but also new entrants dispose of storage substitutes, whose amount and cost may vary. Moreover we extend welfare analysis in order to compare the results of storage auction with storage allocations that would be chosen by a benevolent dictator as a benchmark (though still assuming imperfect competition in the final gas market).

In section two we consider the effects of storage rationing on productive efficiency both in the case of imperfect and perfect susbstitution between storage and alternative flexibility inputs. In section three we consider allocative efficiency in a two stage model where firstly storage is rationed and then gas suppliers compete in the downstream market. We compare market equilibrium in a dominant firm model assuming both a centralized allocation of storage by generic rationing rules and storage auctions. In section four we carry out welfare analysis by considering as a benchmark the allocation of storage resulting from welfare maximisation by a benevolent dictator, to compared it with storage auctions and pro-quota mechanisms. Some conclusions follow in section five.

2 Rationing, Productive Efficiency and Shadow Price of Storage

In this section we concentrate on the effects of storage rationing on the productive efficiency of gas suppliers, without considering the strategic effects due to imperfect competition in the downstream market for gas supplies. We assume that access to storage is regulated. Regulation concerns both the price of storage and the allocation of storage capacity. We suppose that price regulation consist in setting storage tariffs that reflect storage costs.coupled with a non-specified rationed mechanism. The latter is implemented by the regulator in order to manage capacity constraints. As in Bertoletti et al. (2008), we derive efficient rationing rules in this framework by considering the shadow price of storage.

Concerning the technology of gas supplies, we assume that "supply flexibility" is the unique input needed to sell gas (we then neglect access to the transmission and distribution networks). Flexibility derives from alternative ways to procure the commodity (by flexible production fields or flat import contracts) and to supply the market (flexibility is increased by selling gas trough interruptible contracts). For the sake of simplicity, we assume that flexibility must be acquired in the same amount of the final output, indicated by y 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 in practice 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 (for example the advantage of an incumbent can be represent by a lower cost of flexibility with respect to new entrants in a 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. The price of storage is fixed and amounts to w_1, corresponding to the regulated (cost-based) linear tariff for a unit of storage capacity.[14] 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:

$$c\left(\mathbf{w}, y\right) = Min_{\mathbf{x}} \left\{ \mathbf{w}'\mathbf{x} \; s.t. \; f\left(\mathbf{x}\right) \geq y \right\}, \tag{1}$$

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 $\hat{c}(w, y, z)$:

$$\hat{c}\left(\mathbf{w}, y, z\right) = w_1 z + Min_{\mathbf{x}_{--1}} \left\{ \mathbf{w}_{-1}'\mathbf{x}_{-1} \; s.t. f\left(z, \mathbf{x}_{-1}\right) \geq y \right\}, \tag{2}$$

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

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

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 of storage cpacity $x_1 = z$ of storage capacity (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 occurs. Such implicit price represents the shadow price of storage and can be defined through the conditional demand function $x(\mathbf{w}, y)$ which solves (1) as follows:

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

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) as:

$$\hat{c}\left(\mathbf{w}, y, z\right) = \left(w_1 - w_1^*(\mathbf{w}_{-1}, y, z)\right) z + c\left(w_1^*(\mathbf{w}_{-1}, y, z), \mathbf{w}_{-1}, y\right). \tag{4}$$

Equation (4) allows a simple computation of the (marginal) value of storage when capacity is rationed and access to storage is regulated. In fact, the impact

[14]We 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 might not concern space but still persist as far as withdrawal capacity is considered.

of a marginal increase of the amount of storage on the restricted cost function is given by:

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

Notice that if the shadow price for storage is higher than the regulated price, a marginal increase of storage availability reduces total costs (the marginal value of storage is positive). In that case the gas supplier is actually rationed in storage. On the contrary, if the shadow price of storage is lower than the regulated price, a marginal increase in the use of storage would lead to an increase of marginal cost (the marginal value of storage is negative). In this last case the gas supplier is not really rationed in storage. Therefore, even if storage is rationed among gas suppliers, we cannot exclude that a single gas supplier will prefer to get less storage with respect to the amount assigned to him by the existing rationing rule. Such a rule may in fact be inefficient, to the extent that it does not consider that some suppliers may dispose of alternative flexibility inputs that may be more convenient than storage. Therefore, if we exclude strategic behaviors, these suppliers may then ask for less storage than the existing rule actually allows them[15]. On the contrary assuming that gas suppliers behave strategically then they could take over the entire storage capacity allowed by the existing rule in order to raise the cost of their rivals, whose shadow price is positive and that result to be really rationed in storage.

2.1 The Efficient Rationing Rule: Two Examples

Storage rationing prevents gas suppliers from adopting the optimal flexibility mix, causing then an increase of their costs. Due to these negative effects on productive efficiency, access to storage might be regulated with the aim to minimize distortions in the allocation of this scarce resource to the whole gas industry. If we neglect the vertical effects of rationing rules on the final market for gas supply an efficient rationing rule would distribute storage capacity across firms with the aim to minimize the total cost of flexibility. According to the analysis of last section such a rationing rule could be implemented through the equalization of the shadow price of storage across firms. In fact shadow prices could reflect the heterogeneous values of storage for gas suppliers.

In order to illustrate this point, we consider two examples where flexibility is provided by two inputs, storage (x_1) and a substitute (x_2). Without loss of generality for what concerns the 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 a single 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 unit cost of the storage substitute differs across the two firms: $w_{2l} = \alpha w_{2f}$, with

[15] For example in Italy storage capacity, since liberalization, has been rationed following a pro-quota rule. Then storage requirements by gas suppliers were proportionally reduced according to their market share in the temperature sensisitive market. The existing evidence Autorità Garante della Concorrenza e del Mercato (2009) shows that – until recently – the dominant firm (ENI) has always been requiring less storage capacity than its market share entitled the firm to obtain, disposing in fact of alternative flexibility inputs whose availability was not considered by the rationing criteria. Of course it would be hard to state how much storage capacity the dominat firm really needed and to what extent it could have given up even greater amounts of it.

$0 < \alpha < 1$, to account for a better access to the storage substitute by the dominant firm.

Example 1 *In our first example we assume that 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 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 shadow price of storage is* $w_1^*(w_2, y/z) = w_2(y/z)^2$*. Given the output levels, the efficient rationing rule implies the equalization of the shadow price 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:*

$$\frac{y_l}{z_l} = \frac{1}{\sqrt{\alpha}} \frac{y_f}{z_f}.$$

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 the storage substitute should be "compensated" with the allocation of a greater proportion of storage capacity. Therefore "Pro-quota" (or "CGWC") rules, that distribute storage capacity in proportion to final market shares*[16]*, cannot lead to cost minimization, as they neglect the asymmetries across firms concerning storage substitutes. On the contrary, efficient rules require discrimination among asymmetric firms. More capacity should indeed be allocated to firms characterized by higher costs for the storage substitutes, in order to maximise productive efficiency.*

Example 2 *In the second example we assume that the two inputs are perfect substitutes:* $y = x_1 + x_2$*, then the cost fuction is given by* $c(\mathbf{w},y) = Min\{w_1, w_2\}\, y$*, concerning the price of inputs we keep the same assumptions of the first example. Due to the fact that storage and the other flexibility inputs are perfect substitutes, the shadow price of storage is simply the price of the storage substitues, then* $w_{1l}^* = w_{2l}$ *and* $w_{1f}^* = w_{2f}$*. Given that* $w_{2l} = \alpha w_{2f}$*, with* $0 < \alpha < 1$*, in order to minimize the total cost of gas suppliers storage capacity should firstly be allocated to the follower according to its requirement:* $z_f = y_f$ *(for* $y_f \leq z$*) and with the aim of excluding its resort to the storage substitute, which is more expensive. The cost of the follower will then be* $c(\mathbf{w},y_f) = w_1 y_f$ *Then the leader should get the residual amount of storage* $z_l = z - y_f$ *and its cost function will be* $c(\mathbf{w},y_f, y_l) = w_1(z - y_f) + w_{2l}(y_l - z + y_f)$ *which reduces to:* $c(\mathbf{w},y_f, y) = w_{2l}(y - z) + w_1(z - y_f)$*. As a result only the leader will be rationed in storage. The allocation of storage capacity is efficient to the extent that storage is dstributed with the aim of minimizing the cost of flexibility for the industry. This cost amounts in fact to* $c(\mathbf{w},y) = w_1 z + w_{2l}(y - z)$*.*

[16]This 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).

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. 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 storage capacity allocated to them, when storages is the cheapest input.

The eventual distortions due to asymmetric information may be present even when storage is not the cheapest input but there are differences in the cost of the storage substitute and we consider the strategic effects due to imperfect competition in the downstream market. In fact a dominant firm may fint it profitable to hoard more storage capacity with respect to the amount required by cost minimisation if such a strategy contributes to raise rival's cost[17].

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 extent that bids depend on the willingness to pay for storage capacity. But even resort to storage auctions does not eliminate the incentive to hoard 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.

3 Storage Allocation and Gas Market Equilibrium

We now consider the vertical relationship between storage allocation and the equilibrium in the final market for gas. We continue to assume that flexibility is provided by two inputs: storage (z) and a unique storage substitute (x_2). Access to storage is characterized by capacity constraints. The available storage capacity is given by S and we normalize it to $S = 1$.While the price of storage (w_1) is the same for the two firms, the price of the unique storage substitute is different: w_{2f} is the price for the follower, while w_{2l} is the price for the leader. As before we assume $w_{2l} = \alpha w_{2f}$, with $0 < \alpha < 1$, and for the sake of simplicity we set $w_{2f} = 1$, so that $w_{2l} = \alpha$. In fact new entrants are less efficient than the dominant firm in providing the storage substitute, as the leader was already active as an integrated monopolist in the gas industry, before liberalization.

Concerning the technology of flexibility we think that a linear production function better fits the case of firms involved in gas supply. In fact providing flexibility for gas sales consist in procuring gas from alternative sources. The commodity is an homogeneous good, though gas procured from alternative sources has different costs Then the production function will be:

$$y = z + x_2.$$

Therefore the leader's restricted cost function will be given by $\hat{c}_l(\mathbf{w}_l, z_l, y_l) =$

[17] In 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.

$w_1 z_l + w_{2l}(y_l - z_l) = w_1 z_l + \alpha(y_l - z_l)$ for $y_l \geq z_l$, while the restricted cost function of the follower will be $\hat{c}_f(\mathbf{w}_f, z_f, y_f) = w_1 z_f + w_{2f}(y_f - z_f) = y_f - z_f(1 - w_1)$ The linearity of the technology implies that if z_f increases (given S), not only the follower could potentially increase its output (a pro-competitive effect), but a productive efficiency gain also arises, due to the avoided cost of the flexibility susbstitute by the follower.

For the final gas market we assume that the demand is linear: $D(p) = a - P$. According to the dominant firm model we assume that the follower (which represent the competitive fringe of the market) sells all its feasible output in the down-stream market.at the price set by the leader. Then the residual demand of the leader will be:

$$d_l(P) = a - y_f - P = a - z_f - x_{2f} - P.$$

3.1 Equilibrium analysis when storage tariffs are regulated

In this first case, we assume that third party access regulation is implemented through a cost-reflective access tariff coupled with any centralized allocation rule chosen by the regulator to manage the amount of available storage capacity (be it pro-quota or CGWC or FCFS). At this stage we just assume that any centralized rule adopted neglects both strategic behaviour due to vertical restraints and the eterogeneity of storage value due to the cost and availability of storage substitutes.

We consider a two stages model. In the first period the storage firm assigns storage capacity according to centralized rules set by the regulatory agency, while in the second period firms compete in the final gas market on the basis of the storage capacity previously obtained. Be then w_1^R the regulated price of a unit of storage capacity (we assume $w_1^R < w_{2l} < w_{2f}$) and, being γ the percentage of storage capacity assigned to the follower then $z_f = \gamma$ and $z_l = 1-\gamma$ (with $0 \leq \gamma \leq 1$).

As the follower behaves competitively then it will sell the maximum amount of gas that it will be able to supply: $y_f = z_f + x_{2f}$ at the price chosen by the dominant firm. The optimal quantity of gas sold by the dominant firm, is.the output (y_l) that maximizes its profit function (Π), given the amount of gas supplied by the competitive fringe:

$$Max_{y_l}\Pi = (a - y_l - z_f - x_{2f})y_l - (w_1^R z_l + (y_l - z_l)\alpha)$$

from the F.O.C. we obtain:

$$y_l = \frac{a - z_f - x_{2f} - \alpha}{2}$$

Then the equilibrium output of the industry will be

$$y = \frac{a + z_f + x_{2f} - \alpha}{2}$$

and the equilibrium market price

$$P = \frac{a - z_f - x_{2f} + \alpha}{2}$$

As equilibrium analysis shows, the optimal output of the dominat firm is a decreasing function of both the amount of storage and the storage subsitute available to the follower. On the contrary industry output increases (and the market price decreases) with these amounts. Therefore inefficient allocation rules that distribute storage independently of its value may potentially strengthen dominant positions in the final gas market. Such rules may assign less storage capacity to followers despite the higher value they may attribute to it becuase they lack cheaper storage substitues. Efficiency improvements in allocation rules are then expected to be also pro-conmpetitive.We can also notice that the market price is affected by the cost of the storage substitute available to the leader. This cost also affects the optimal output to be sold by the leader and industry output. Therefore more effcient leaders that are able to procure cheaper storage substitutes can increase their market share, contributing at the same time to reduce the final price of gas and to expand equilibrium output in the market.

3.2 Equilibrium analysis when storage capacity is auctioned

Efficient rationing rules are difficult to implement because of asymmetric information between the regulator and gas suppliers about the value of storage (see section 2). Considering the results of equilibrium analysis carried out above, one can notice that the behaviour of the dominant firm will be affected by adverse incentives. Would the regulator distribute storage according to the reports of gas suppliers about their flexibility mix, then the dominant firm will be lead to distort upwards the cost of its storage substitutes in order to hoard storage capacity. This would be a profitable strategy to the extent that the dominant firm could raise the cost of its rival which should substitute storage capacity with a more expensive flexibility input. The regulator would then face an adverse selection problem.

We do not analyse the problem of regulation with asymmetric information as storage is an intermediate input that could be allocated with a decentralized market mechanism that could potentially provide some information about the shape of storage demand (Yarow, 2003). To the extent that productive effciency requires that storage should be allocated according to its value for each gas suppliers we consider auctions as a way to elicit the wilingness to pay for storage. Non discriminatory third party access could in fact implemented also through storage auctions still controlled by the regulator. Auctioning storage capacity does not eliminate strategic behaviour, as the dominant firm bids could still be distorted by its aim to hoard storage capacity in order to raise rivals'cost. However alternative rationing mechanism (centralized and decentralized ones) could be compared both from the point of view of market equilibrium and on welfare grounds (see next section).

We then assume that storage capacity is rationed through a *multiunit sealed bid uniform price auction*, which assigns multiple units of storage capacity to each bidder. Through this mechanism bidders must reveal they willingness to pay for each unit of storage capacity. Then firms, when bidding for storage, present their demand function for access to storage capacity. Their demand will depend on the availability and costs of storage substitutes. As a result of the auction, the available units of storage are assigned to the highest bids, even though bidders will pay a uniform price (w_1^A, i.e. the unit cost of storage capacity) equal to the lowest among the highest bids that are awarded the available units. This price of storage arising from the auction is then expected to be higher with respect to the regulated tariff, as we suppose that the latter just reflects storage costs, being independent from storage demand[18].

The model develops in two steps: in the first step storage capacity is auctioned and in the second one firms compete in the gas market, given the allocation of storage resulting from the auction. There is a substantial difference in equilibrium analysis with respect to last section. To the extent that storage capacity is no more assigned through a centralized mechanism but rather distributed with a market mecahnism, bidders are able to affect the final allocation of storage capacity. Therefore gas suppliers can bid for storage capacity not only with the aim of procuring an essential input for competition but also with the scope of distorting competition in the downstream market. Therefore we shall solve the model backwards, by finding firstly the equilibrium in the gas market (second stage) and then considering the results of the auction mechanism (first stage), given the equilibrium of the second stage. Then we shall find a sub-game perfect Nash equilibrium for the two stage game.

Concerning the second stage, straight reference can be made to the equilibrium values found in the previous section. Then we look for an equilibrium in the first stage, considering the auction mechanism, and the bidding strategies of the two firms. The follower, given the results of competition in the gas market, will demand the amount of storage that maximizes his profits (π):

$$Max_{yf}\pi = \left(\frac{a - y_f + \alpha}{2}\right) y_f - \left(w_1^A\left(y_f - x_{2f}\right) + x_{2f}\right)$$

from the FOC:

$$\frac{d\pi}{dy_f} = \frac{1}{2}a - w_1^A - y_f + \frac{1}{2}\alpha = 0$$

we can then derive the follower's demand for storage within the auction:

$$z_f^A = \frac{1}{2}\left(a + \alpha\right) - w_1^A - x_{2f}, \text{ with } 0 \leq z_f^A \leq S \tag{5}$$

and then the bidding strategy of the follower

$$w_1^A = \frac{1}{2}\left(a + \alpha\right) - z_f^A - x_{2f}, \tag{6}$$

One can notice that both the demand for storage and the bid of the follower depend on the value of storage, to the extent that the latter depends on the availability of the storage substitute.Then rationing strorage trough auctions can elicit the willingness to pay for storage. Moreover both the demand for storage and the bid of the follower increase with a and α, to the extent that these parameters affect the final price of gas in the downstream market (being

[18]Due to information problems we exclude that the regulator is able to implement Ramsey Pricing for storage capacity (Yarow, 2003). More sophisticated mechanisms concerning regulation with asymmetric information have been derived concerning acccess pricing in the case of networks (Armstrong and Sappington, 2007). However even in the case of networks the existence of rationg problems in congested points has been practically faced by resorting to auctions (Daniel and Neuhoff, 2004).

a the reserve price for gas and α the marginal cost of gas supply for the leader). In fact the higher the price of gas the higher the bid the follower can afford to pay within the auction)

The dominant firm takes as given the bid of the follower, anticipating that it will demand a given storage capacity paying the uniform price resulting from the auction. If we assume that storage is rationed for both firms ($z_f^A + z_l^A = S \leq y$), it is individually rational for the the leader to bid strategically in order to set the equilibrium price of storage at a level that maximizes his profits, given its equilibrium strategy in the downstream market (see section 3.1):

$$\begin{aligned} Max_{w_1^A}\Pi = & \left(\frac{a - z_f(w_1^A) - x_{2f} + \alpha}{2}\right)\left(\frac{a - z_f(w_1^A) - x_{2f} - \alpha}{2}\right) \\ & - \left[\left(w_1^A - \alpha\right)(1 - z_f) + \alpha\left(\frac{a - z_f(w_1^A) - x_{2f} - \alpha}{2}\right)\right]. \end{aligned}$$

As $z_f^A = \frac{1}{2}(a + \alpha) - w_1^A - x_{2f}$, the maximization program reduces to:

$$\begin{aligned} Max_{w_1^A}\Pi = & \, w_1^A\left(\frac{3}{4}a + \frac{3}{4}\alpha - x_{2f} - 1\right) - \frac{3}{4}\left(w_1^A\right)^2 \\ & + \left(\alpha - \frac{7}{8}a\alpha + \frac{1}{16}\alpha^2 + \alpha x_{2f} + \frac{1}{16}a^2\right) \end{aligned}$$

and the FOC will be:

$$\frac{d\Pi}{dw_1^A} = \frac{3}{4}(a + \alpha) - 1 - \frac{3}{2}w_1^A - x_{2f} = 0$$

and then the optimal value of the storage price for the dominant firm is

$$w_1^{A*} = \frac{a + \alpha}{2} - \frac{2}{3}(1 + x_{2f}).$$

Therefore if the leader wants this price to result as the equilibrium price in the auction, he has just to bid w_1^{A*} for the total amount of storage capacity demanded. This equilibrium is such that we can exclude that $\gamma = 1$, (i.e $z_f(w_1^{A*}) = S = 1$) as in this case $w_1^{A*} > w_1^A$ (being w_1^A the bid of the follower) which is out of the equilibrium, given the rules of this auction mechanism. Therefore in equilibrium the leader will always get a positive amount of storage capacity, independently of the value of α, which represents his marginal cost. On the other hand in equilibrium the leader will never crowd out the follower as $\gamma = z_f^A = 0$ implies $\frac{d\Pi}{dw_1^A} = -1$. Therefore the price the leader should pay to exclude the follower from the auction is too high to make complete crowding out profitable strategy for the dominant firm.

Given (5) and (6), the follower and the leader will respectively obtain the following amounts of storage capacity in equilibrium:

$$z_f^{A*} = \frac{1}{3}(2 - x_{2f}), \tag{7}$$

$$z_l^{A*} = 1 - z_f^{A*} = \frac{1}{3}(1 + x_{2f}). \tag{8}$$

We can notice that in equilibrium any increase in the amount of the storage substitute available to the follower positively affects the storage capacity obtained by the leader and reduces the share of capacity obtained by the follower. The equilibrium amounts of storage capacity do not depends on the relative prices of the storage substitute $\left(\frac{w_{2l}}{w_{2f}} = \alpha\right)$ as any increase in α gives rise to a corresponding increase in the value of w_1^{A*} (the price the leader can afford to pay within the auction increases with the price of its storage substitute, representing its marginal cost, that in turn affects the equilbrium price in the gas market), as does any increase of the reserve price a for gas in the final market.

The equilibrium in the final gas market can then be derived by substituting the amounts of storage capacity obtained by the two firms within the auction, into the equilibrium results of the gas market (cfr. 3.1) to obtain the following sub-game perfect Nash Equilibrium:

$$y_l^{A*} = \frac{a - z_f^{A*} - x_{2f} - \alpha}{2} = \frac{1}{2}(a - \alpha) - \frac{1}{3}(1 + x_{2f}),$$

$$y_f^{A*} = z_f^{A*} + x_{2f} = \frac{2}{3}(1 + x_{2f}),$$

$$y^{A*} = \frac{1}{2}(a - \alpha) + \frac{1}{3}(1 + x_{2f}),$$

$$P^{A*} = \frac{1}{2}(a + \alpha) - \frac{1}{3}(1 + x_{2f}).$$

We can notice that the equilibrium output of the industry is still increasing with respect to the amount of storage substitute available to the follower, while the equilibrium price is decreasing with respect to the same variable. If we compare the amount of storage assigned to the follower by the centralized mechanism (by assumption fixed at a level γ) with the value obtained within the auction (z_f^{A*}), we can say that the auction assigns a larger amount of storage to the follower if and only if $\gamma \leq \frac{1}{3}(2 - x_{2f})$.This implies that the less the storage substitute available to the follower, the larger amount of storage will be allocated to him within the auction. From this point of view the auction represents per se a more efficient mechanism to the extent that it allocates storage capacity considering the availability of storage substitutes. One can also notice that, as in last section, equilibrium output negatively depends on α and the equilibrium price positively depends on it. Then, idependently of the allocation of storage, the more the leader is efficient in providing the storage substitute compared with the follower (i.e. $\alpha - > 0$), the more the equilibrium output of the industry increases and the equilibrium price decreases.

4 Welfare analysis: a comparison with an optimal mechanism

In this section we aim to compare alternative mechanism to regulate access to gas storage on welfare grounds. Our approach consist in comparing both centralized allocation rules and storage auctions with an optimal mechanism resulting from the maximisation of social welfare by a benevolent and omniscient dictator. However, such a mechanism represents a second best as we assume that the benevolent dictator distributes storage capacity taking as given the existence of imperfect competition in the gas market. In addition storage auctions are compared with a specific mechanism, which allocates storage capacity in proportion to firms' shares in the down-stream market ("pro-quota"). Due to the existence of a dominant firm we explicitly consider a mechanism that assigns to the the leader 80% of available storage capacity while the residual 20% is assigned to the follower.We can express social welfare as the sum of the consumer surplus in the gas market (CS) and the profits obtained by the dominant firm (Π), the follower (π) and the storage company (π_S), i.e.:

$$W = CS + \Pi + \pi + \pi_S.$$

Let us firstly consider the benchmark of the analysis which is represented by the second best, i.e. the storage capacity allocation (expressed as the share allocated to the follower) that would maximize social welfare, given imperfect competition in the gas market. We consider the expression social welfare when access to storage is allocated by a generic centralized mechanism and storage tariffs reflect storage costs. In that case (given the results of sub-section 3.1) we can derive the espression of consumer surplus as:

$$CS^R = \frac{1}{2}\frac{a + z_f + x_{2f} - \alpha}{2}\frac{a + z_f + x_{2f} - \alpha}{2} = \frac{1}{8}\left(a + \gamma + x_{2f} - \alpha\right)^2$$

and then the profits obtained respectively by the market leader and by the follower:

$$\begin{aligned}
\Pi^R &= \frac{a - z_f - x_{2f} + \alpha}{2}\frac{a - z_f - x_{2f} - \alpha}{2} \\
&\quad - \left(w_1^R\left(1-\gamma\right) + \left(\frac{a - z_f - \gamma - \alpha}{2} - 1 + \gamma\right)\alpha\right) \\
\pi^R &= \left(\gamma + x_{2f}\right)\frac{a - z_f - \gamma + \alpha}{2} - \left(\gamma w_1^R + x_{2f}\right)
\end{aligned}$$

and finally the profits of the storage firm:

$$\pi_S^R = \left(w_1^R - c\right)$$

By adding the previous components and simplifying we obtain the expression of social welfare to be maximised by a benevolent dictator:

$$\begin{aligned}
W_R &= \gamma\left(\frac{a - \alpha - x_{2f}}{4}\right) \\
&\quad + \frac{1}{8}\left(8\alpha - 6a\alpha + 3\alpha^2 - \gamma^2 - x_{2f}^2 - 8x_{2f} + 2ax_{2f} + 6\alpha x_{2f} + 3a^2\right) - c \qquad (9)
\end{aligned}$$

from the FOC, and the concavity of W with respect to γ, we can then obtained the optimal share of storage capacity that should be allocated to the follower γ^* in order to maximise social welfare:

$$\begin{aligned}
\frac{dW}{d\gamma} &= \frac{1}{4}\left[a - \alpha - \gamma - x_{2f}\right] = 0 \\
\gamma^* &= a - \alpha - x_{2f}, \qquad (10)
\end{aligned}$$

However, the value (10) can not always be attained: in fact, γ^* should belong to the interval $[0, 1]$. Therefore, remarking that $\frac{dW}{d\gamma} > (<)\ 0$ for $\gamma < (>)\ \gamma^*$, we can conclude that

$$\gamma^* = \begin{cases} 1 & \text{if } a - \alpha - x_{2f} > 1 \\ 0 & \text{if } a - \alpha - x_{2f} < 0 \\ a - \alpha - x_{2f} & \text{otherwise} \end{cases}$$

We remark that, the second and the third case (i.e. $\gamma^* < 1$) need a wery low value for a and a very large value for x_{2f}; this cases are unlikely when trying to describe an actual economy. Section 5 will show an example and clarify this point.[19]

5 A numerical example

In this section we set the parameters' values to reasonable amounts and present some equilibrium results in terms of storage shares, social welfare and of its components. Table 1 shows the parameter's values, Table 2 presents the resulting equilibrium prices, quantities and welfare components. Figure 1 shows how the social welfare depends, for different values of x_{2f}, on the share γ of storage assigned to the follower. Finally, Figure 2 plots the γ yielding from an auction on the storage market.

Some remarks.

1. First of all, we underline that, from the qualitative point of view, the results keep valid for a fairly large range of the parameters value. We set them to values that aim to mimick a real case.

2. The social welfare is strictly increasing in γ, with $\gamma \in [0, 1]$ (see Figure 1). This behavior depends on the parameters' values, but we note that to obtain a non monotone function we need unreasonable parameters' values, i.e. extremely low demand (a slightly larger than one) resulting in a non rationing role for the storage.

3. Figure 1 shows the negative effect of x_{2f} on the social welfare. This can be explained pointing out that, when $x_{2f} = 0$, the follower uses the storage only and the leader both storage and its substitute. Instead, when $x_{2f} > 0$, the follower uses the substitute input, but in doing so, it is inefficient ($w_{2f} = 1 > w_{1l} = \alpha$).

4. The increase of γ reduces the leader production of an amount smaller than the increase in follower output.

[19]However if we focus on $\gamma^* = a - \alpha - x_{2f}$, it is a local maximum if and only if $a - \alpha \leq x_{2f} \leq a - \alpha + 1$. Then, according to the maximisation of social welfare, the optimal share of storage capacity to be allocated to the follower negatively depends on x_{2f} and on α. That is, the less the storage substitute available to the follower and the greater its cost with respect to the leader then the greater the share of storage capacity to be assigned to the follower in order to maximise social welfare. In the meantime lower values of α positively affects productive efficiency and contribute in turn to increase social welfare. Please notice that x_{2f} is an indirect measure of the price elasticity of the follower demand for storage. Thus the amount of storage capacity assigned to the follower is inversely related to the price elasticity of its demand for storage. A result close to Ramsey Pricing (Yarow, 2003).

Parameter	value	comment
S	1	The gas quantities are normalized such that $S = 1$
w_{2f}	1	The substitute input for the follower is chosen as numéraire
a	20	This demand function's intercept value, toghether with the ones of α, x_{2f} and c below, allows to obtain a regulated cost of storage to gas price ratio $\frac{c}{P}$ around 5%
α	0.75	The leader's cost for the substitute input: this parameter is difficult to measure
c	0.5	The cost of the storage for the storage company
w_1	c	For the regulated case, the storage price equals its cost
x_2f	0.2	The substute input available to the follower is much smaller than the total amount of storage ($S = 1$)

Table 1: Calibration of parameters' values. We underline that quantities and values are normalized in terms of S and w_{1f} respectively.

	Regulation ($\gamma = 0.2$)	**Auction**	**Second best** ($\gamma = 1$)
P	10.1750	9.9750	9.7750
y	9.8250	10.0250	10.2250
y_l	9.4250	9.2250	9.0250
y_f	0.4	0.8	1.2
w_1	0.5	9.5750	0.5
γ	0.2	0.6	1
x_{2l}	8.6250	8.8250	9.0250
x_{2f}	0.2	0.2	0.2
CS	48.2653	50.2503	52.2753
Π	89.0306	81.5706	81.4506
π	3.7700	2.0350	11.0300
π_S	0	9.0750	0
W	141.0659	142.9309	144.7559

Table 2: Given the parameters' values of Table 1, we compare the regulated case with $\gamma = 0.2$, the auction case and the second best ($\gamma = 1$) case.

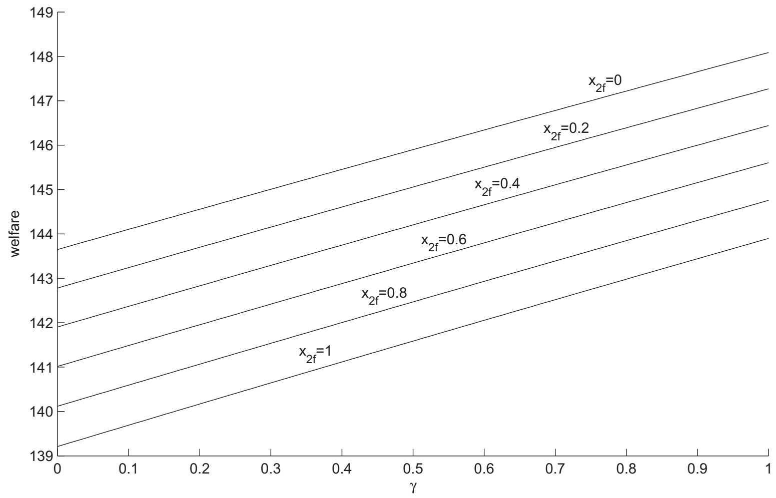

Figure 1: Welfare function for x_{2f} ranging from 0 to 1, steps 0.2. The larger x_{2f}, the lower the corresponding line.

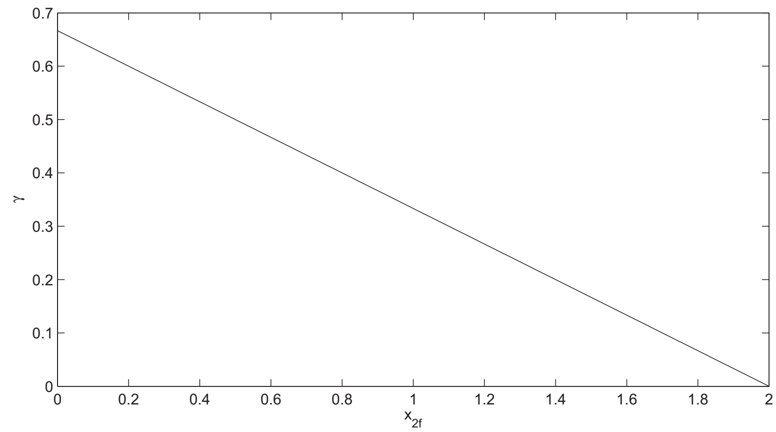

Figure 2: Share γ^A of storage given to the follower after an auction on its market. We compute γ^A for x_{2f} ranging from 0 to 2. We remark that the second best γ equals 1 on this range of x_{2f} values; it lowers below 1 for unrealistically large x_{2f} values (note that $x_{2f} = 2$, i.e. $x_{2f} = 2S$, is yet extremely large).

5. From the previous points, we remark that the maximum solial welfare is obtained with the combination $\gamma = 1$, $x_{2f} = 0$.

6. From the social welfare point of view the regulated case with $\gamma = 0.2$ is worse than the auction which in turn is worse than the regulated case with with $\gamma = 1$. The effect is clear: equilibrium gas quantity rises and price drops.

7. The auction (or any rule assigning more storage to the follower) produces larger welfare than the regulated case (with $\gamma = 0.2$).

8. The pro-competitive effect of the auction, with respect to the regulated case with $\gamma = 0.2$, yields a much larger γ, an increase in the total output and then in social welfare, but the competition on the storage market dramaticaly rises the storage price, shifting profits from the leader and follower to the storage company.

6 Conclusions

Despite the fact that storage is not a natural monopoly, competition for storage services remains unsatisfactory in most Countries across Continental Europe. Some Countries have adopted regulated access to storage based on cost-reflective storage tariffs coupled with centralized rationing rule to allocate scarce storage capacity. Most rationing rules are not based on efficiency criteria. Such inefficient rules lead to discrimination among gas suppliers to the extent that the idyosincratic value of storage is hardly considered by them. However in this contribution we have shown that even centralized rationing rules focused on the values of storage and aiming to maximise productive efficiency may be difficult to implement due to asymmetric information about the cost of storage substitutes. Such a claim was also made by Yarow (2003) when discussing capacity auctions in the UK energy sector, concerning the difficult implementation of Ramsey pricing due to asymmetric information about the price elasticity of storage demand by individual gas suppliers. Yarow (2003) also claimed that replacing centralized storage regulation with storage auctions may be worthwhile to the extent that auctions should reveal the willingness to pay for storage. Adopting a market mechanism for storage allocation may facilitate the transition to competition in storage with positive effects also for competition in gas markets.

However, we have also considered that the results of auctioning storage capacity may be distorted by strategic behavior, as far as the downstream market for gas is dominated by an incumbent firm while new entrants are grouped as a competitive fringe of gas suppliers. Imperfect competition in the downstream market necessarily introduces distorsions in storage allocations upstream. Assuming that storage and alternative flexibility inputs are perfect subsitutes and that the dominant firm is more efficient as a gas supplier, cost miniminzation criteria would lead to completly satisfy the demand for storage coming from the (less effcient) competitive fringe. Furthermore, if we assume that storage is allocated by a benvolent and informed social planner aiming to maximize social welfare, we find that storage capacity should be completely allocated to the competitive fringe, letting the leader supply gas by just resorting to the storage substitute. However, in equilibrium the storage auction never gives them the total amount of storage capacity, implying that some capacity hoarding by the dominant firm is at stake. In the meantime even the leader will not be assigned the complete amount of storage. Such a strategy may in fact be too costly even for the leader, which sets the equilibrium price of the storage auctions in order to maximise his profits in the downstream market. Despite the fact that auctions may be distorted by the strategic behaviour of the dominant firm, and their result deviates from the optimal allocation resulting from social welfare maximisation, we find that they work nicely in assigning storage capacity to the competitive fringe in proportion to the availability of the storage substitute. To the extent that the availability of a subsitute affects the eleasticity of storage demand, auctions reperesent a most efficient mechanism with respect to pro-quota allocation and other similar mechanisms currently adopted in Europe. In fact, the higher the relative effciency of the dominant gas supplier and the lower the availability of storage substitutes to the competitive fringe the higher the likelyhood that storage allocations resulting from storage auctions will improve social welfare. Such a result seems to confirm that storage auctions may be especialy valuable during the traisition to real competition both in the market for storage and in the commodity market. It is also worthwhile to notice that storage allocations implemented by a benevolent social planner – though difficult in practice – highlight the crucial role that is played by storage allocation with respect to the enforcement of competition in the social market to the benefits of final consumers. Therefore, removing current vertical restraints affecting storage in the European gas market could have a dramatic effect on the reduction of dominant positions, with susbstantial benefits for competition and efficiency.

All over our analysis we have supposed that storage capacity is provided by an independent firm, not involed in gas supply. If storage is on the contrary provided by a separate branch of the dominant gas supplier, then the equilibrium price within the storage auction is simply a transfer price from the point of view of the vertically integrated group. Therefore actual bids may be different from bids resulting from the equilibrium solutions resulting from our models and without any further regulatory intervention the extension of capacity hoarding may be much more greater than what we find. However in practice this problem has been solved in the UK by adding a quantity cap to the suppliers bids, such that no supplier can obtain more than a fixed share of the auctioned storage capacity (Hawdon and Stevens, 2001). In the meantime, our analysis suppose that the total amount of storage capacity obtained through any mechanism is completly used as an input to supply gas to final consumers. Some empirical evidence shows however that gas suppliers may even withold storage capacity without using it as an input. We think that such an assumption could be also incorporated in the framework of our model to see how the results change accordingly. A further natural extension concern the change of auction rules. for example the opportunity of introducing reserve prices and/or pay as bid as an alternative to marginal pricing.

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