Take or Pay Contracts and Market Segmentation *

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Abstract

This paper examines competition in the liberalized natural gas market. Each firm has zero marginal cost core capacity, due to long term contracts with take or pay obligations, and additional capacity at higher marginal costs. The market is decentralized and the firms decide which customers to serve, competing then in prices. In equilibrium each firm approaches a different segment of the market and sets the monopoly price, i.e. market segmentation. Antitrust ceilings do not prevent such an outcome while a wholesale pool market induces generalized competition and low margins in the retail segment.

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JEL Classification numbers: L11, L13, L95

1 Introduction

This paper wants to analyze if competition may emerge in the natural gas markets as shaped by the liberalization process implemented in Europe since the second part of the Nineties. In this period the European Commission has promoted through several Directives the liberalization of the main public utility markets, such as telecommunications, electricity and natural gas; the framework adopted is by and large common to these industries, and rests on the open access to the network infrastructures, the unbundling of monopolistic from competitive activities and the opening of demand.

The natural gas Directive 98/30 has specified the lines of reform that the Member Countries then followed in the national liberalization plans. Contrary to the case of electricity markets, no wholesale pool market is recommended

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for the natural gas. The general *principle of Third Party Access (TPA)* has been confirmed, with one relevant exception, namely when giving access to the network would create technical or financial problems to the incumbent because of its take-or-pay (TOP) obligations.[1]

We argue that the existence of take-or-pay obligations not only creates problems in the application of the TPA, but creates a natural strategic incentive for firms to avoid competition for final customers. Therefore, entry may entail no actual competition (and no benefit for the consumers) as the firms will choose to concentrate on different customers, thus segmenting demand.

We derive this result on the basis of three main assumptions which refer to key features of the industry. First, long term import contracts, the bulk of gas supply in most European countries, impose take-or-pay obligations to the buyer, that pays a high portion of the contracted gas no matter if it is sold or not. Consequently, each seller has negligible marginal costs up to its obligations, although it has additional capacity at higher marginal cost, coming from extentions of the long term contracts and/or from purchases on the spot market. Second, in a decentralized market setting each firm decides which customers to approach; this marketing decision requires to sink some resources (say, local commercial networks), and it is therefore medium term in nature. Third, once chosen their potential customers firms compete mainly in prices, with some horizontal differentiation in their service.

In this setting we study the (marketing and price) equilibria when a new comer enters in the market competing with the incumbent. In a decentralized market each firm decides which customers to serve. When two firms with TOP obligations target the same customers, the two firms have the same (zero) marginal costs, and equilibrium margins are low due to price competition. When instead only one of the two firms has TOP obligations, the high marginal cost competitor is unable to obtain positive profits in a price equilibrium. This feature of price competition with TOP obligations drives the commercial strategies of the firms: entering the same market is never convenient because it gives low profits and leaves residual obligations to the two firms (fostering competing entries in other submarkets). Leaving a fraction of the customers to the rival, instead, allows it to exhaust its TOP obligations and makes it a high cost (potential) rival with no incentive to compete on the residual demand. In a word, leaving the rival to act as a monopolist on a fraction of the market guarantees a firm to be a monopolist on the residual demand. It should be stressed that the high fixed TOP payments play no role in our result, that would still hold even with negligible or no fixed costs. The segmentation result, instead, is driven entirely by the existence of low cost capacity due to TOP obligations.

[1] A take-or-pay obligation entails an unconditional fixed payment, which enables the importer of gas to get up to a certain threshold quantity of gas. This payment is due whether or not the company actually decides to import, and further payments are due if the company wants to receive additional quantities. Take-or-pay obligations can add further conditions, as the possibility to shift across different years part of the obligations. But the very nature of this kind of contracts, i.e. substituting variable payments conditional on actual deliveries with a fixed unconditional payment up to a certain threshold level of delivery, is captured looking even at their simplest version.

Our results may have some interest in the policy debate on gas liberalization. The discussion so far has focussed on the development and access to international and national transport infrastructures and on the unbundling of activities of incumbent firms.[2] The recent Energy sector inquiry of the European Commission (2006) stresses that problems of access are still the main concern of policy makers. Although we share this concern, we argue that even if the access problems were solved there would still be a serious issue of (wholesale and retail) market design that so far has received little attention. We show that even gas release programmes aimed at reducing the incumbent's market shares can be unable to provide actual benefits to the customers.

A more competitive outcome might instead be obtained if a centralized pool market is created, where the importers (burdened by TOP obligations) sell and the dealers buy gas. In this case, the retailers when designing their marketing strategies, have the same flat marginal cost equal to the wholesale price for any amount of gas they want to supply, and therefore they will obtain, contrary to the benchmark case, small but positive margins in any market they enter. A wholesale market, therefore, ensures to enhance competition and to squeeze the margins over the wholesale price in the retail market.

The existing literature on take or pay contracts (see Creti and Villeneuve, 2004, for a broad survey) focusses almost entirely on the reasons which justify their existence. For instance, Crocker and Masten (1985) argue that a simple contract of this kind provides appropriate incentives to limit opportunistic behaviour, while Hubbard and Weiner (1986) emphasize the risk sharing properties of such a contract. However, the consequences of these contracts on competition remain out of the scope of these analyses.

A second stream of literature which is relevant to our analysis is the one on market competition with capacity constraints or decreasing returns. Although our motivation is primarely on liberalization of the gas industry, our segmentation result may be of independent interest in the analysis of price equilibria with capacity constraints. While price competition with constant marginal costs leads to the Bertrand outcome, since the seminal work by Kreps and Scheinkman (1983) we know that capacity constraints may modify the incentives to cutthroat price competition. When a firm faces constant marginal costs up to a certaint absolute capacity constraint, the subgame perfect equilibrium outcome is equivalent to the corresponding Cournot equilibrium if firms follow an efficient rationinig rule, while it is intermediate between Cournot and Bertrand if proportinal rationing is applied (Davidson and Deneckere (1986).Vives (1986) shows that if marginal costs are flat up to capacity and then they are increasing, their steepness determines how the equilibrium ranges from Bertrand to Cournot. The literature on supply function equilibria (Klemperer and Meyer (1989)) has generalized this intuition showing that if firms can choose and commit to any supply function, all the individually rational outcomes can be implemented in equilibrium. Our paper adopts the same technology as Maggi (1996), that intro-

[2] For an extensive discussion of the liberalization process in the energy markets along these lines see Polo and Scarpa (2003).

duces discontinuous marginal costs as those that emerge with TOP obligations. Maggi shows that the amplitude of the stepwise increase in the marginal cost determines equilibrium outcomes that range from Bertrand (no jump) to Cournot. Finally, a further reference for our work is the entry deterrence paper by Dixit (1980) where, in case of accomodated entry, the incumbent can impose to the entrant (follower) a residual role in the market.

The paper is organized as follows. In section 2 we describe the main assumptions of the model; section 3 analyzes the sequential entry case; section 4 considers the endogenous choice of TOP obligations by the entrant. Antitrust ceilings and centralized vs. decentralized markets are discussed in section 5 and 6. Concluding remarks follow, while an Appendix contains the proofs of the results.

2 The model

Our model is based on three main assumptions:

1. Due to take-or-pay import contracts the firms have a zero marginal cost core capacity equal to TOP obligations, and unbounded additional capacity with higher marginal costs.
2. The liberalized gas market is decentralized (single transactions may take place with different customers at different times and at different prices) and each firm has to commit on which customers it wants to serve, an irreversible decision in the short run.
3. Once chosen their marketing strategy, the firms compete in prices, possibly with a slight differentiation in the commercial service provided.

Costs

Two firms, the incumbent (I) and the entrant (E), are active in this market. The firms purchase the natural gas from the extractors and resell it to the final customers through the pipeline network. Although third party access is far from established in the natural gas industry in many European countries, in this paper we want to study the effects of entry in the retail market, absent any entry barriers to the transport infrastructures. Consequently, we assume that TPA is fully implemented, implying that no bottleneck or abusive conduct prevents the access of the entrant to the transportation network at non discriminatory terms. Hence, the network access costs are assumed to be the same for E and I and, w.l.o.g., equal to zero.

Each (retail) firm $i = I, E$ has a portfolio of long term contracts with the extractors, where the unit cost of gas w_i and a TOP obligation $\overline{q}_i$ per unit of time are specified, such that the purchaser has to pay to the extractor an amount $w_i\overline{q}_i$ no matter if the gas is taken or not, while it can receive additional gas beyond $\overline{q}_i$ at the unit cost w_i. Hence, the firms have no capacity constraints but a discontinuous marginal cost curve, that jumps from 0 to w_i once the obligations are exhausted[3]. For simplicity, we assume $w_E = w_I = w$.

The cost function of firm i is therefore[4]:

$$C_i(q_i, \overline{q}_i) = \begin{cases} w\overline{q}_i & \text{for } 0 \leq q_i \leq \overline{q}_i \\ w\overline{q}_i + w(q_i - \overline{q}_i) & \text{for } \ q_i \geq \overline{q}_i \end{cases} \tag{1}$$

Demand

Individual consumers $d = 1, .., D$ have completely inelastic unit demand; total demand is therefore D. They view the gas supplied in the market as perfectly homogeneous; for the sake of generality, we admit that consumers can attach to each firm other (commercial or locational) characteristics that make the services slightly differentiated. We adopt a Hotelling-type specification. The customers are uniformly distributed with respect to their preferred variety of the service according to a parameter $v \in [0, 1]$. The utility of a consumer with preferred variety v purchasing one unit of gas at price p_i from firm i offering a service with characteristic $x_i \in [0, 1]$ is $u^* - p_i - \psi(v - x_i)^2$, where ψ is a parameter describing the importance of the commercial services (product differentiation) for the client. Since gas is a commodity, we assume that product differentiation is very limited in scope, i.e. ψ is very low, with $\psi = 0$ as the limit case of perfectly homogenous sales. The parameter u^*, instead, indicates the maximum reservation price and captures the overall importance of gas for the clients. We assume that, since gas is an essential input in many activities, the provision of gas creates a large surplus for the client, i.e. u^* is much larger than the unit cost of gas w. More precisely, we assume that

$$u^* \geq \max \left\{ \frac{33}{16}\psi, w + \frac{9}{16}\psi \right\} \tag{2}$$

We show in the proof of Proposition 1 that the first term ensures that a monopolist prefers to cover the entire market at the highest possible price rather than further rise it and ration the market, while the second one guarantees that the equilibrium profit is non negative.

Each firm $i = I, E$ is characterized by a specific variety x_i of the service, due to its location and/or commercial practices. We assume that $x_I = 1/4$ and $x_E = 3/4$, i.e. the two firms have some (exogenous) difference in the service provided[5]. The firms do not observe the individual customer's tastes

[3] Usually long term contracts specify also a total annual capacity, which is 25-30% larger than the TOP obligations. If a firm wants to deliver more gas than the long term capacity, a firm can purchase on the spot market at some price $w' \geq w_i$. Hence, even in a more complete setting we have no absolute capacity constraint and a marginal cost schedule that jumps up (once the obligations are exhausted and once the capacity is fulfilled). TOP obligations are sufficient to obtain a discontinuous marginal cost curve, and including also capacity constraints and the spot market doesn't add anything to the results. Hence, we use the simpler setting with TOP obligations and no capacity constraint in the long term contracts..

[4] Maggi (1996) uses the same cost function in a different set-up.

[5] Since we already analyze an asymmetric model, with the incumbent endowed with larger obligations and with and advantage in approaching the customers, we do not endogenize the

(her preferred service variety v) but know only the (uniform) distribution of the customers according to their tastes. We can easily derive the expected demand of the two firms from a subset of $D^t \leq D$ consumers (market t). Let us define $\widehat{v}$ as the consumer indifferent between the offers of I and $E, \overline{v}_I$ as the consumer indifferent between the offer of the incumbent and buying nothing, and $\overline{v}_E$ as the consumer indifferent between buying from E or nothing. It is easy to check that:

$$\begin{aligned} \widehat{v} &= \frac{1}{2} + \frac{p_E - p_I}{\psi} \\ \overline{v}_I &= \left[\frac{u^* - p_I}{\psi}\right]^{\frac{1}{2}} + \frac{1}{4} \\ \overline{v}_E &= \left[\frac{u^* - p_E}{\psi}\right]^{\frac{1}{2}} + \frac{3}{4} \end{aligned}$$

Then, the demand for firm I in market t is

$$D_I^t = D^t \cdot \left[\max\{0, \min\{\widehat{v}, \overline{v}_I, 1\}\} - \max\left\{\frac{1}{2} - \overline{v}_I, 0\right\}\right] \tag{3}$$

and the demand for E corresponds to

$$D_E^t = D^t \cdot \left[\min\{1, \overline{v}_E\} - \min\left\{1, \max\left\{0, \widehat{v}, \frac{3}{2} - \overline{v}_E\right\}\right\}\right] \tag{4}$$

The two expressions give the demand for the active firm(s) if one or both firms entered market t (and offer relevant prices to the customers): for instance, when both firms are active and the market is covered we obtain the usual demand system of the Hotelling model, $D_I^t = D^t\widehat{v}$ and $D_E^t = D^t(1-\widehat{v})$; when only the incumbent entered in market t and the market is not completely covered, due to the very high price set, the demand is $D_I^t = D^t\overline{v}_I$, etc.

TOP obligations and capacities

The portfolios of long term contracts of the two firms reflect their different positions: before the liberalization, the incumbent was the only supplier of the market, while the entrant is trying to capture some market share. The obligations of the incumbent, given its previous position, are very large but do not exceed market demand, i.e $\overline{q}_I \leq D$. In the equilibrium analysis we'll concentrate on the case $\overline{q}_I < D$ in which the incumbent's obligations do not cover the entire demand; once understood the equilibrium in this case, the extension to the case $\overline{q}_I = D$ will be straightforward. Regarding the entrant's

choice of variety, where the incumbent might obtain additional advantages by locating its variety more centrally.

long term contracts, we initially assume that its obligations are equal to the residual demand, i.e

$$\overline{q}_E = D - \overline{q}_I \tag{5}$$

Once the benchmark model is analyzed, we'll endogenize the entrant's choice of obligations $\overline{q}_E$, showing that indeed the entrant selects obligations equal to the residual market $D - \overline{q}_I$.

To sum up, the long term contracts of the two firms enable them to supply the market at zero marginal cost, since total obligations are equal to total demand. Moreover, the market is very liquid, as each firm can obtain additional capacity (at the same unit cost w) from the extractors.

Competition and timing

The market is decentralized, so that firms have to decide which clients to deal with, and propose a price to their potential customers. A given customer may thus face no offer, one offer (by a firm that would then be a monopolist for that customer), or two offers from the two competing firms. Price competition arises in a particular submarket if both firms approach the same group of customers. We assume that the decision to serve a submarket is irreversible in the short run, as it requires to sink some resources (e.g. local distribution networks, local offices and dedicated personnel). Moreover, the incumbent is able to move first in approaching the customers, due to his existing relationships with the clients, followed by the entrant[6].

Customers are visited by the firms sequentially, and, for each customer, once the marketing choices are taken, the active firms simultaneously propose their prices. When we analyze price competition for the single customer, the crucial element is the amount of residual TOP obligations of the firms, that enable them to serve the customer at zero marginal cost. Then, from the point of view of equilibrium analysis, since the incumbent moves first, all the contracting stages where the incumbent has residual TOP obligations greater (or equal) than the submarket demand are similar: if I decides to enter, E anticipates that by entering in its turn, total TOP obligations will exceed submarket demand. Hence, analyzing all these contracting stages sequentially, with I and then E deciding to enter or not, is equivalent to grouping them together, assuming that there are only two relevant submarkets, the first one as large as the incumbent's obligations, $D^1 = \overline{q}_I$, and the second one covering the residual demand, $D^2 = D - D^1 = \overline{q}_E$. As this compact formulation lends itself to a shorter (but equivalent) equilibrium analysis, we'll adopt it: we assume that the two firms decide sequentially at first whether or not to enter market 1 and then market 2, as defined above. We thus define a variable $e_i^t = \{0, 1\}$, $i = I, E$, $t = 1, 2$, which

[6] In the working paper version of the paper, available on www.igier.uni-bocconi.it, we analyze also the simultaneous entry case. We show that equilibria with segmentation exist also in this case and Pareto dominate other equilibria in which each firm enters every market.

refers to the decision to enter ($e = 1$) or not ($e = 0$) in a particular market at a particular time.

From our discussion, the timing when $\overline{q}^I < D$ is as follows:

- at $t = 1$ the incumbent decides whether to enter ($e_I^1 = 1$) or not ($e_I^1 = 0$) in D^1; then, having observed whether or not I participates, the entrant chooses to enter ($e_E^1 = 1$) or not ($e_E^1 = 0$) in market D^1. Then the participating firm(s) (if any) set a price simultaneously.
- at $t = 2$ the incumbent decides whether to enter ($e_I^2 = 1$) or not ($e_I^2 = 0$) in D^2; then, having observed whether or not I participates, the entrant chooses to enter ($e_E^2 = 1$) or not ($e_E^2 = 0$) in market D^2. Then the participating firm(s) (if any) set a price simultaneously.

Before moving to the equilibrium analysis, it appears convenient to anticipate the main result, and then to show (backwards) how this can be proven. The equilibrium of the game can be described as follows:

Result. In the unique subgame perfect equilibrium, the incumbent enters in the first market, while the entrant enters in the second market. Both firms charge to their customer(s) the monopoly price.

In order to understand how this result can be obtained, let us start from the last stage of the game

3 The sequential entry game

In this section we analyze the subgame perfect equilibria in the sequential entry game, where competition in the second market takes place once the outcome in the first one is determined. Although the two markets are separate, a strategic link between them remains, because the residual TOP obligations in the second market depend on the outcome of the game in the first stage. As we solve the model backwards, we must first consider the price equilibria and entry decisions in the second market as a function of the number of firms applying for the second group of customers and of their residual TOP obligations.

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3.1 Pricing and entry in the second market

The entry and price subgames in the second stage depend on the entry and price decisions in the first market, which, in turn, determine the amount of residual obligations: we can therefore parametrize the second stage subgames to $(\overline{q}_I^2, \overline{q}_E^2)$, where $\overline{q}_i^2 \leq \overline{q}_i$ is the residual TOP obligation of firm i in the second market. The profit function of firm i in the second market, if it enters, is:

$$\Pi_i^2 = p_i D_i^2(p_i, p_j) - C_i(q_i, \overline{q}_i^2)$$

The equilibrium depends on how many firms enter and on their residual TOP obligations.

When only one firm enters the second market, it will behave as a monopolist, and the outcome is straightforward. If both firms enter in the second market, we have to look for the Nash equilibrium. First of all, notice that the profit functions are continuous and concave, but kinked at $\overline{q}_i^2$, due to thjump in the marginal costs from 0 to w once the TOP obligations are exhausted.

Hence, the necessary and sufficient conditions for a maximum at $(\widehat{p}_I^2, \widehat{p}_E^2)$ are:

$$\begin{aligned} \left.\frac{\partial \Pi_i^2(\widehat{p}_I^2, \widehat{p}_E^2)}{\partial p_i}\right|_{p^-} &\geq 0 \\ \left.\frac{\partial \Pi_i^2(\widehat{p}_I^2, \widehat{p}_E^2)}{\partial p_i}\right|_{p^+} &\leq 0 \end{aligned} \tag{6}$$

From this perspective, we have two possibilities.

- If $D_i^2(\widehat{p}_I^2, \widehat{p}_E^2) \neq \overline{q}_i^2$, i.e. if the quantity sold in equilibrium by firm i is different from its residual obligations, the profit function is smooth at the equilibrium prices and the two inequalities collapse to the single condition that the firm's first derivative is zero, with a marginal cost equal to w if $D_i^2(.) > \overline{q}_i^2$ (and 0 if $D_i^2(.) < \overline{q}_i^2$).
- If $D_i^2(\widehat{p}_I^2, \widehat{p}_E^2) = \overline{q}_i^2$, i.e. if at the equilibrium prices firm i uses exactly its obligations, both inequalities must be satisfied. Notice that since the first one is computed with a marginal cost equal to w while the second one with a marginal cost equal to 0, they will identify not a single point but a region of prices consistent with a maximum. In this case, the multiplicity of Nash equilibria is quite a natural result, and when this occurs we single out Pareto efficient price pairs as "the" equilibrium prices.

Since $\overline{q}_I + \overline{q}_E = D$, i.e. total TOP obligations equal total demand, the residual TOP obligations once the first market has been served cannot be lower than D^2, and thus we have to consider two possible cases. If in the first market the firm(s) have sold a quantity of gas equal to D^1, residual obligations in the second market are $\overline{q}_I^2 + \overline{q}_E^2 = D^2$; if instead sales in the first market have been lower than D^1, in the second market we have residual obligations in excess to market demand, i.e. $\overline{q}_i^2 + \overline{q}_j^2 > D^2$.

The price equilibria according to different entry patterns are described in the following proposition.

Proposition 1 *Equilibrium prices in the second stage of the game are as follows:*

a) If in stage 2 only firm i enters, it sets price $\widehat{p}_i^2 = u^* - \frac{9}{16}\psi$ *and serves the entire market* D^2.

b) If both firms enter the second market and if $\overline{q}_I^2 + \overline{q}_E^2 = D^2$, *the (Pareto efficient) equilibrium prices are*

$$\begin{aligned} \widehat{p}_i^2 &= w + \psi \frac{\overline{q}_i^2}{D^2} \\ \widehat{p}_j^2 &= w + \psi \frac{4\overline{q}_i^2 - D^2}{2D^2} \end{aligned} \tag{7}$$

where $\overline{q}_i^2 \leq D^2/2 \leq \overline{q}_j^2$, *i.e. i is the smaller and j the larger firm. Each firm sells all its residual TOP obligation.*

c) If both firms enter the second market and if $\overline{q}_i^2 + \overline{q}_j^2 > D^2$ *and* $\overline{q}_i^2 \leq D^2/2 < \overline{q}_j^2$ *the equilibrium prices are*

$$\begin{aligned} \widehat{p}_i^2 &= \psi \frac{3D^2/2 - 2\overline{q}_i^2}{D^2} \\ \widehat{p}_j^2 &= \psi \frac{D^2 - \overline{q}_i^2}{D^2} \end{aligned} \tag{8}$$

The smaller firm sells all its residual TOP obligation.

d) If both firms enter the second market and if $\overline{q}_i^2 + \overline{q}_j^2 > D^2$ *and* $\overline{q}_i^2, \overline{q}_j^2 > D^2/2$ *the equilibrium prices are*

$$\begin{aligned} \widehat{p}_i^2 &= \psi/2 \\ \widehat{p}_j^2 &= \psi/2 \end{aligned} \tag{9}$$

and each firm serves half of the market.

Proof. See Appendix. ■

Figure 1 depicts the best reply functions and the price equilibria when both firms are active in market 2: case b) correspondes to prices pairs along AB (when $\overline{q}_I^2 \geq \overline{q}_E^2$) and BC (when $\overline{q}_I^2 \leq \overline{q}_E^2$), case c) to points along AD (when $\overline{q}_I^2 \geq \overline{q}_E^2$) or DC (when $\overline{q}_I^2 \leq \overline{q}_E^2$) and case d) corresponds to point D[7]

[7] Figure 1 is drawn under the assumption $\psi = 2w/3$; in this case the locus $D_I(.) = 0$ passes through the intersection of $BR_E(0)$ and $BR_I(w)$, that belongs both to case b) and c). Equivalently, the locus $D_I(.) = D$ passes through the intersection of $BR_I(0)$ and $BR_E(w)$, that belongs both to case b) and c). Hence, the equilibrium prices in this case vary continuously when we move from the case b) ($\overline{q}_I^2 + \overline{q}_E^2 = D^2$) to case c) ($\overline{q}_I^2 + \overline{q}_E^2 > D^2$). When $\psi < 2w/3$, instead, the locus $D_I(.) = 0$ lies below the point of intersection of $BR_E(0)$ and $BR_I(w)$ and moving from case b) to case c) implies a discrete fall in prices.

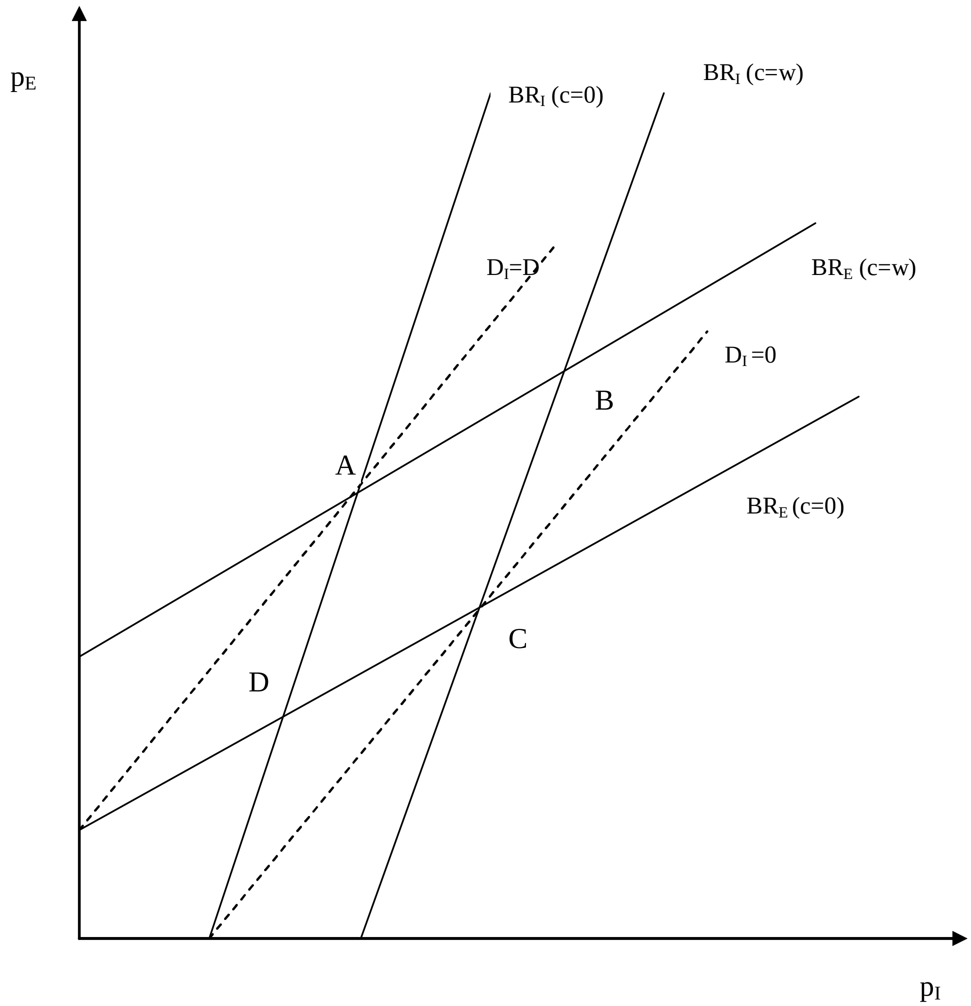

Figure 1: Best Replies (BR_i) and equilibrium prices: Proposition 1

Part (a) of Proposition 1 simply defines monopoly prices. Case (b) refers to a situation where capacity equals demand, and equilibrium prices cannot be larger than $w + \psi/2$.

If residual TOP capacity is larger than demand, we have two additional cases (labelled (c) and (d)). In both of them, competition leads to prices lower than in case (b), but above the zero marginal cost simply because of product differentiation (the demand parameter ψ). Prices would fall to zero, in line with the Bertrand result, with homogeneous goods ($\psi \to 0$).

Corollary 2 *In the second stage of the game, whenever both firms enter, a firm's sales in equilibrium do not exceed its residual TOP obligations; hence, firms which enter with no TOP obligations sell nothing.*

We can now move to the entry decisions of the two firms in the subgames of the second market. Consider that Proposition 1 under (a) describes the optimal price when only one firm (either I or E) enters in the second market for any previous entry choices in the first market. When both firms enter in stage 2, instead, cases (b), (c) or (d) apply, depending on the entry and price equilibrium in the first market, which determines the residual obligations of the two firms. In the entry decision we assume that if a firm by entering expects zero profits (zero sales in our setting), that firm will remain out (no frivolous entry)[8].

The following Proposition identifies the entry equilibrium in all possible cases.

Proposition 3 *In the second market, a firm enters if and only if its residual TOP obligations are positive.*

Proof. See Appendix. ■

The intuition behind the equilibrium entry pattern is straightforward. At the second stage, the price equilibria give positive sales and profits as long as a firm has positive residual obligations; if a firm with residual TOP obligations competes with one that already exhausted them (but still decides to enter), at the equilibrium prices the latter sells nothing. Hence, there is an incentive to enter only if a firm has still obligations to be covered. Notice that this entry pattern is entirely driven by the properties of price equilibria and the associated sales for given residual obligations.

[8] An analogous result would be obtained if we assumed that there are (however small) entry costs.

3.2 Equilibrium

Once obtained the entry and price equilibria in the second market in the four subgames, we can turn our attention to the analysis of the entry and price subgames in the first market, when the two firms have still all their obligations $\overline{q}_I$ and $\overline{q}_E$. Given the link between first stage choices and the equilibrium in the second market, firm i maximizes its overall profits

$$\Pi_i = e_i^1 \cdot \Pi_i^1(p_i^1, p_j^1; e_i^1, e_j^1) + \widehat{e}_i^2(p_i^1, p_j^1; e_i^1, e_j^1) \cdot \widehat{\Pi}_i^2(p_i^1, p_j^1; e_i^1, e_j^1)$$

where $\widehat{e}_i^2$ and $\widehat{\Pi}_i^2$ are respectively the second stage equilibrium entry choices and the second stage equilibrium profits.

We start our analysis of the first market by considering the price games. If only one firm enters in the first market, we have to check whether the optimal price entails covering the entire market (as shown for the second stage in Proposition 1) or prescribes to ration the first market (through a higher price) retaining some obligations in the second market. Since TOP obligations (with zero marginal cost) imply a more aggressive pricing behaviour, this choice might be justified if it leads to exclude the rival from the second market, a sort of leveraging effect.

The link between pricing in the first market and the equilibria in the second one makes the analysis of equilibria more complex especially when both firms enter initially: if one firm sells all its obligations, in fact, it will not enter anymore in the second market, leaving monopoly profits to the rival. Hence, pricing in the first market in such a way to force the rival selling all its obligations would secure monopoly profits in the second market. But since this incentive applies to both firms if they enter the first market, this strategy is mutually inconsistent, leading to non existence of price equilibria in pure strategies. The following proposition analyses the different cases.

Proposition 4 *The following price equilibria occur in the first market:*

a) If only firm i enters in the first market, it sets the price $\widehat{p}_i^1 = u^* - \frac{9}{16}\psi$ and supplies the entire market D^1.

b) If both firms enter in the first market:

1. *there is no price equilibrium in pure strategies,*
2. *an equilibrium in mixed strategies μ_I^*, μ_E^* exists.*
3. *in the mixed strategy equilibrium both firms obtain positive expected profits and the expected total profits of the entrant in the two markets are $E\Pi_E(\mu_I^*, \mu_E^*) < (u^* - \frac{9}{16}\psi)D^2$.*

Proof. See Appendix. ■

Some comments are in order.

Part (a) of Proposition 4 shows that the strategic link between the two markets is insufficient to distort the first market pricing decisions when only one firm enters. In this case the entrant faces two alternatives: extract the monopoly rents from all those consumers, or retain some residual obligations for the second market by overpricing above the monopoly price, leaving some customers unserved. In this latter case, however, the firm cannot extend its monopoly to the second market (where the rival will enter being still endowed with positive TOP obligations) and it will obtain competitive, rather than monopoly, returns on its residual obligations. Hence, this firm sets the monopoly price and covers the entire market D^1 without entering market.2.

As for the price game when both firms enter in the first market, when we evaluate total equilibrium profits as a function of p_i^1 (given p_j^1) we find the following. When firm i's offer is much cheaper than firm j's, the former sells all its obligations in the first market and does not enter the second one, as shown in Proposition 3. When the prices of the two firms are closer both use only part of their TOP obligations in market 1, and therefore both firms enter the second market. Finally, when firm i's offer is much more expensive than firm j's, this latter exhausts its obligations in market 1, and only firm i enters as a monopolist in market 2. Inducing the rival to sell all its obligations in the first market becomes the dominant strategy for both firms, since it secures monopoly rents in the second market; and this is why we do not have a price equilibrium in pure strategies in the first market.

The crucial feature of the mixed strategy equilibrium (that arises when also E enters in market 1, so that both firms enter market 2 as well) is that the total expected profits E can earn in both markets are below the monopoly profits that it can earn with certainty in market 2 by staying out of market 1.

We have completed our analysis of the price games in the first market, obtaining all the ingredients to address the entry decisions in the first stage. The following Proposition - in line with the claim expressed at the beginning of the section - establishes our main segmentation result.

Proposition 5 *When $\overline{q}^I < D$, in the unique subgame perfect equilibrium, the incumbent enters in the first market, while the entrant enters in the second market. Both firms charge to their customer(s) the monopoly price $u^* - \frac{9}{16}\psi$.*

Proof. See Appendix. ■

Once analyzed the case where the incumbent's obligations do not cover the entire demand, we can easily consider the complementary case in which $\overline{q}^I = D$. The following Corollary establishes the result.

Corollary 6 *When $\overline{q}^I = D$, in the unique subgame perfect equilibrium, the incumbent enters in the market and charges the monopoly price $u^* - \frac{9}{16}\psi$., while the (potential) entrant does not enter.*

When the incumbent is endowed with obligations equal to total demand while the potential entrant has none, the results established in Proposition 1, part (b) and Corollary 2 can be used to describe the equilibrium prices if the entrant enters in the market after the incumbent and the associated entry decisions. Since the entrant's equilibrium sales are zero, E will prefer to stay out of the market, that is completely monopolized by the incumbent.

3.3 Comments to the result

The result obtained shows that when entry is allowed, the incumbent serves a fraction of the market equal to its TOP obligations and leaves the rest (if any) to the entrant. Liberalization, in this setting, allows the entry of new firms but does not bring in competition, inducing segmentation and monopoly pricing.

When a firm has TOP clauses, in fact, its cost structure is characterized by zero marginal costs up to the obligations and higher marginal cost for larger quantities. If both firms enter in the first market, we have two consequences: the low marginal cost capacity is used in a competitive price game obtaining low returns; moreover, both firms remain with positive residual obligations, that induce them to enter in the second market as well, again with competitive low returns. On the other hand, leaving a fraction of the market to the rival comes out to be a mutually convenient strategy. The other firm, in fact, once exhausted its TOP obligations serving its customers in a monopoly position, becomes a high (marginal) cost competitor[9] with no incentives to enter the residual fraction of the market, since even entering it will not obtain any sales in the price equilibrium. By leaving the rival in a monopoly position on a part of the market a firm acquires a monopoly position on the residual customers.

The key ingredients of this result are decentralized trades and a core low cost capacity, due to TOP obligations, two central features of the natural gas industry. Decentralized trades implies that the firms can decide which customers they want to serve. The gas provision contracts signed with the producers create the incentives to selective entry in the retail market. First, long term contracts are a natural commitment device, since they cannot be renegotiated or modified at will. Secondly, although the market is apparently very liquid, since overall capacity is unbounded, what matters to determine the basic market interaction is the amount of low marginal cost capacity, i.e of TOP obligations.

Finally, it should be stressed that the large amount of fixed costs implied by TOP obligations plays no role in our entry and segmentation result. Hence, it is not the fixed outlays of the obligations that suggest to enter different submarkets, but the low (zero) marginal cost of the TOP obligations that drives the equilibrium[10].

[9] This is an example of the "fat cat" strategy considered in Fudenberg and Tirole (1984).

[10] Consequently, the segmentation outcome simply requires low cost core capacity and decentralized markets, and in this sense it is not specific to the gas industry.

4 Endogenizing the entrant's obligations

So far we have assumed that the entrant, facing an incumbent endowed with TOP obligations equal to $\overline{q}_I$, has a long term contract with obligations equal to $D-\overline{q}_I$, so that total obligations equal total demand. Here we want to show that if the entrant chooses $\overline{q}_E$ in order to maximize profits, it will actually choose exactly $\overline{q}_E = D-\overline{q}_I$. In this section therefore we add an initial stage where the entrant signs its long term contract deciding the amount of TOP obligations.

We already know that if the entrant chooses TOP obligations equal to the residual demand, $\overline{q}_E = D - \overline{q}_I$, in equilibrium its profits can be written as $(u^* - \frac{9}{16}\psi - w)(D - \overline{q}_I)$.

Let us first consider a game where the entrant chooses obligations lower than the residual demand, i.e. $\overline{q}_E < D - \overline{q}_I$. Having discussed in detail the pricing and entry decisions in the benchmark case, we just sketch the analysis, which remains quite similar. Maintaining the sequential contracting structure, this is equivalent to considering all the contracting stages $d = 1, .., D$ in a sequence or to group them in *three* submarkets of sizes equal to $\overline{q}_I$, $\overline{q}_E$ and $D-\overline{q}_I-\overline{q}_E$. We can then study the entry and pricing decisions according to the timing of the benchmark case: in each of the three submarkets, that are opened sequentially, I decides whether to enter, then E chooses as well and finally the active firms price simultaneously. The equilibrium analysis of the benchmark model points to the following conclusions[11]:

- in the first submarket of size $\overline{q}_I$, only the incumbent enters and sets the monopoly price;
- in the second submarket, of size $\overline{q}_E$, the roles are reversed and the entrant is monopolist in this segment;
- for the residual customers, $D - \overline{q}_I - \overline{q}_E$, both firms would have marginal cost equal to w having exhausted their obligations. If they both enter, the equilibrium is symmetric with $\widehat{p}_I = \widehat{p}_E = w + \frac{\psi}{2}$, and the two firms serve half of the residual demand gaining positive profits. Hence, both firms enter.

The total profits obtained by the entrant are now $(u^* - \frac{9}{16}\psi - w)\overline{q}_E + \frac{\psi}{4}(D - \overline{q}_I - \overline{q}_E) < (u^* - \frac{9}{16}\psi - w)(D - \overline{q}_I)$. Hence, the entrant[12] does not gain from having obligations lower than $D - \overline{q}_I$.

Second, consider the case $\overline{q}_E > D - \overline{q}_I$, where total obligations are larger than total demand. The arguments are quite similar to the benchmark case. We can analyze the equilibrium distinguishing the two submarkets $\overline{q}_I = D^1$ and $D - \overline{q}_I = D^2$ as before. From the previous analysis, going through the same

[11] To save space we leave a formal proof, which is basically the same as the benchmark model, to the reader.

[12] Alternatively, in the spirit of our entry model, we can notice that if $D > \overline{q}_I + \overline{q}_E$ there is room for a third firm with obligations $D - \overline{q}_I - \overline{q}_E$ to enter and monopolize the residual demand. The first entrant then would obtain profits $(u^* - \frac{9}{16}\psi - w)\overline{q}_E < (u^* - \frac{9}{16}\psi - w)(D - \overline{q}_I)$ if installing $\overline{q}_E < D - \overline{q}_I$.

steps, it is easy to see that the equilibrium entry and price decisions are the same as in Proposition 5, with I entering the first market, and E the second one, with sales $D^2 < \overline{q}_E$.

Although E has TOP obligations exceeding residual demand $D - \overline{q}_I$, it prefers not to enter as long as the incumbent has exhausted its own obligations. In fact, if E decides to enter the first market, it would share D^1 with the incumbent and, as a consequence, I would not exhaust its obligations $\overline{q}_I$ in the first market. Hence, the incumbent would enter the second market as well, destroying the monopoly profits that E would gain otherwise. Hence, the entrant would prefer to maintain its residual obligations idle (and therefore does not choose excessive obligations).

Therefore, the entrant will choose to sign obligations equal to the residual demand $D - \overline{q}_I$, as assumed in the benchmark model. We summarize this discussion in the following Proposition.

Proposition 7 *If the entrant chooses its obligations $\overline{q}_E$ at time 0, given the incumbent's obligations $\overline{q}_I$, and then the game follows as in the benchmark model, the entrant chooses obligations equal to the residual demand, i.e. $\overline{q}_E = D - \overline{q}_I$.*

The allocation of demand between the incumbent and the entrant in our model depends on the amount of TOP obligations held by I when liberalization starts. The market share of the incumbent after entry therefore can be very large if $\overline{q}^I \cong D$, with a very limited scope for newcomers. In the limit, if I has TOP obligations equal to market demand, there is no room for entry in the market as claimed above.

To avoid such an outcome, the liberalization plans in some European countries, as Italy, Spain and UK, have introduced constraints on the incumbent market share, as antitrust ceilings or release of import contracts. In the following section we consider whether this instrument can help to promote competition in the retail market.

5 Antitrust ceilings and the persistence of segmentation

In this section we enrich the benchmark model, introducing a further restriction in line with the gas release decisions of a few countries following liberalization: we assume that the incumbent cannot supply more than a certain amount of gas, $\widehat{q}_I < \overline{q}_I$.

In this regime, I can sell (or it is forced to sell, in some cases) its TOP obligations exceeding $\widehat{q}_I$ to other operators, i.e. it can resell its long run contracts exceeding the ceiling. Consequently, given $\overline{q}_E$, the TOP obligations of the entrant in the benchmark model, its overall obligations when antitrust ceilings are introduced become $\widehat{q}_E = \overline{q}_E + (\overline{q}^I - \widehat{q}_I)$. The main difference relative to the previous case is that TOP obligations introduce a jump up in marginal costs but do not prevent the incumbent from producing more than $\overline{q}^I$, while market share ceilings imply an absolute capacity constraint $\widehat{q}_I$ for the incumbent.

We can analyze the sequential entry game assuming that the two markets are $D_1 = \widehat{q}_I$ and $D_2 = D - D_1$ and that they are opened sequentially, assuming the same timing of entries and pricing decisions of the benchmark model. Considering second stage price equilibria, if only one firm enters and has residual obligations at least as large as market demand D_2, the analysis remains completely unchanged. However, the introduction of (absolute) capacity constraints instead of (milder) TOP obligations changes the nature of equilibrium price when both firms enter in the second market. In this case, when the residual antitrust ceilings of the incumbent and the residual obligations of the entrant add up to market demand, i.e. $\widehat{q}_I^2 + \widehat{q}_E^2 = D_2$, no price equilibrium in pure strategies exists. However, a mixed strategy equilibrium with positive profits exists, as the following Lemma establishes.

Lemma 8 *When both firms enter in the second market and* $\widehat{q}_I^2 + \widehat{q}_E^2 = D^2$, $\widehat{q}_I^2 > 0$ *and* $\widehat{q}_E^2 > 0$*, there is no pure strategy equilibrium. An equilibrium in mixed strategies* μ_I^*, μ_E^* *exists. The expected profits of the entrant in the mixed strategy equilibrium are positive but lower than the monopoly profits in market 2, i.e.* $E\Pi_E^2(\mu_I^*, \mu_E^*) \in (0, (u^* - \frac{9}{16}\psi - w)D_2)$.

Proof. See Appendix. ■

The entry decisions in the second market largely correspond to those of the benchmark model: E enters if and only if it has still residual obligations, while I enters if and only if it has not yet reached its ceiling. For any price pair (p_I^1, p_E^1) the incumbent will be able to cover its demand, since $D_I^1(p_I^1, p_E^1) \leq \widehat{q}$. Then, as in the benchmark model, each firm has the incentive to price sufficiently high in order to induce the rival to exhaust its take-or-pay obligations. (and ceiling) and stay out of the second market, where the former firm will gain monopoly power. These strategies are mutually incompatible, which leads to mixed strategies equilibria. Consequently, it is easy to check that the same price equilibria and entry decision already analyzed in the benchmark model still apply, even taking into account the different second market price equilibrium analyzed in Lemma 8. The following Proposition summarizes the results.

Proposition 9 *In the subgame perfect equilibrium of the game with antitrust ceilings, the incumbent enters in the first market* D^1 *while the entrant enters in the second market* D^2*. Both firms charge to their customer(s) the monopoly price* $u^* - \frac{9}{16}\psi$.

The only effect of antitrust ceilings is therefore to create scope for entry and to shift market shares and profits from the incumbent to newcomers. Notice that forcing the incumbent to sell import contracts or setting a corresponding ceiling to its final sales would yield the same result. Customers do not benefit from gas release programs of this type, as the segmentation result and monopoly pricing still hold.

6 The introduction of a wholesale market

Antitrust ceilings are not able to prevent the segmentation of the market, because even in this regime the sellers are selecting their customers while holding long run contracts with TOP clauses. In this section we want to explore the consequences of creating a wholesale gas market, where the wholesalers sell and the retailers buy their gas at a common price.

In this section we argue that the key element in our results is that firms competing for final customers are endowed with TOP contracts. Consequently, their entry decisions are driven by the amount of residual obligations they retain, since a firm with no obligations cannot expect positive profits when competing with a rival still burdened by TOP obligations. Breaking the link between the decentralised retail market, where entry decisions in the customers' submarkets are taken, and the upstream segment, where TOP are imposed by producers, may offer a solution. To this end, firms I and E dealing with gas producers under TOP obligations should be forced to sell to a centralized market. The wholesale demand for gas comes from retailers who buy their gas at a linear wholesale price and are the only ones allowed to deal with final customers.

The pool market. On the supply side of the wholesale market, we have two large operators (our firms I and E). They obtain gas from the producers on the basis of long term contracts with TOP clauses as described in the benchmark model, up to output levels $\overline{q}_I$ and $\overline{q}_E$ with $\overline{q}_I + \overline{q}_E = D$. On the demand side we have the retail firms, which can only buy gas from this market and resell it to final consumers. The equilibrium wholesale price p^w - unique for all participants - clears the market.

The retail market. The retailers are free from TOP obligations, and each of them has the same constant marginal cost, equal to the wholesale gas price. Final demand can be decomposed into D (groups of) customers, and the retailers have to decide which customers to serve. Each group of customers considers the retailers' supplies as differentiated according to service or location elements. In order to keep the structure of the model as similar as possible to the benchmark case, we maintain the assumption that the retail market is also a duopoly[13], with firm a offering variety $x_a = \frac{1}{4}$ and firm b offering variety $x_b = \frac{3}{4}$.

Given that retailers buy at the same wholesale price, unlike the wholesalers they have no low cost capacity $\overline{q}$. Thus, when analysing the retailers' decisions there is no need to group the consumers in two subsets D^1 and D^2 (equal to

[13] The extension to the N retailers case using the circular road version of the Hotelling model (Salop (1979)) is however straightforward.

$\overline{q}_I$ and $\overline{q}_E$ respectively) as we did in the benchmark model, since in the present setting the entry decisions in the different submarkets are all identical. The expected demand for firm $j = a, b$ from customer d , D_j^d, correspond to the expressions (3) and (4), where we normalise the mass of customer in submarket d so that $D^d = 1$.

To sum up, the final demand is the same as in the benchmark model, and the same is true of the wholesale supply of gas and the costs of TOP contracts. However, once a wholesale market is introduced, we obtain a separation between the wholesale market, where the commodity is exchanged through a centralized pool, and the retail market, where retailers free of TOP obligations face a decentralised final demand.

For reasons that will be clear in a moment, we prefer to discuss the entry and price strategies assuming that the firms decide sequentially to approach each (group of) customer separately. Total demand for retailer $j = a, b$ is therefore $D_j(p_a, p_b) = \sum_{d=1}^{D} D_j^d(p_a^d, p_b^d)$ where p_a and p_b are the vectors of prices set by the two firms in the D submarkets. The timing of the game is now:

- at $t = 1$ the retail firms $j = a, b$ decide sequentially whether to deal with the customers $d = 1, .., D$ (with total demand D); the entry choices become public information once taken. Once every firm has decided which customers to approach, they set simultaneously the prices and collect the orders.
- at $t = 2$ the wholesale suppliers of gas I and E compete in prices in the (wholesale) market, given the demand from the retail traders $D_a + D_b$.

Let us consider the equilibrium of the game, starting from the second stage, where the two wholesale suppliers I and E compete in prices, each endowed with TOP obligations $\overline{q}_I$ and $\overline{q}_E$, $\overline{q}_I + \overline{q}_E = D$. Since the wholesale market is a commodity market, Bertrand competition describes the basic interaction between the two firms: they simultaneously post their prices, the demand is allocated and each firm supplies its notional demand. In case of equal prices, the allocation of demand is indeterminate and we'll assume that the two firms decide how to share total demand among them. The following Proposition establishes the wholesale price equilibrium.

Proposition 10 *Let total wholesale demand be $D^w = D_a(p_a, p_b) + D_b(p_a, p_b)$. If $D^w = D$ the equilibrium wholesale prices are $p_I = p_E = p^w = w$. If $D^w < D$ the equilibrium wholesale prices are $p_I = p_E = p^w \in [0, w)$ and they are increasing in total sales D^w.*

Proof. See Appendix. ■

The wholesale equilibrium prices described in the Proposition above are equal to the unit cost of gas w if $D^w = D$ $(= \overline{q}_I + \overline{q}_E)$, i.e if the retailers serve all the consumers, while $p^w < w$ if the retail market is rationed, i.e. $D^w < D$. Hence, although the wholesale gas suppliers have a stepwise marginal cost curve, the equilibrium wholesale price is an increasing function of total wholesale supply of gas. We can now conclude our analysis considering the equilibrium in the retail market.

Proposition 11 *In the retail market, each firm $j = a, b$ approaches all groups of customers $d = 1, ..D$, and sets a price $\widehat{p}_j^d = p^w + \frac{\psi}{2}$. The subgame perfect equilibrium of the game is therefore characterized by $\widehat{p}_I = \widehat{p}_E = w$ and $\widehat{p}_a^d = \widehat{p}_b^d = w + \frac{\psi}{2}$.*

Proof. See Appendix. ■

A wholesale market, determining a flat marginal cost curve at p^w , eliminates the strategic links among the entering decisions in the different submarkets: the marginal cost is always the same, and it does not depend on the entry and price strategies in the other submarkets. Then, the entry decisions are determined by the (positive) contribution to total profits of the additional segment that is served.[14]

A wholesale market succeeds to avoid the segmentation of the retail market and to obtain generalized competition and lower retail margins (prices). The wholesale firms, on the other hand, are able to cover their TOP obligations with no losses. In this setting, the competitive bias deriving from long term supply contracts and take or pay clauses is avoided, because when the retailers purchase the gas in a liquid wholesale market they have symmetric costs independently of individual output levels. The basic mechanism of the benchmark model, such that by leaving a submarket to the rival a firm would secure to be monopolist on the residual demand, does not work anymore: by entering the additional submarkets a firm would have the same costs as the rivals and would gain margins over the wholesale price. Hence, generalized entry and competition replace selective entry and monopoly pricing.

It should be stressed that competition in the upstream segment, where the wholesale suppliers sell to the market, may not necessarily lead to a wholesale price equal to the unit cost of gas w, according to the Bertrand equilibrium.

[14] Although in our setting proving that there is no incentive to restrict entry (or rationing demand through pricing) is easy, because the equilibrium mark-up is additive over the relevant marginal cost, a more general argument can be used if the margin itself depends on the marginal cost. Suppose that the retail market is such that the mark-up is decreasing in the marginal cost p^w. In this case it may be convenient for the firms to enter all the submarkets but 1, so that total demand is $D-1$ and the marginal cost p^w is below w: in this case the firms are trading off the profits in the last submarkets with the higher profits in the inframarginal markets, and might find it convenient to restrict entry. However, if entry is allowed, as in the spirit of a competitive retail market, a new comer, that has no inframarginal profits to consider, would enter and serve the last submarket, making the marginal cost increasing to w.

The literature on supply function equilibria[15] has shown that the Bertrand equilibrium corresponds to the firms using a supply curve equal to their true marginal costs; but if firms are able to commit to a supply curve that includes a mark-up over marginal costs, the equilibrium wholesale prices may be much higher that the competitive ones. In our case, while the downstream margins $\frac{\psi}{2}$ are low, due to competition and the limited scope for product differentiation, the wholesale price might be much higher than w if the gross providers use more complex strategies, increasing accordingly the price for the final customers. A wholesale market, therefore, ensures to squeeze retail margins, while competition in the wholesale market may be weak. Even in this case, however, we cannot obtain an outcome that is worse for customers than that of the benchmark model: if the wholesalers collude they will find it profitable to set a wholesale price $\overline{p}^w$ such that all the final customers purchase given the equilibrium retail prices, i.e. $\overline{p}^w + \frac{\psi}{2} = u^* - \frac{9}{16}\psi$. In this case, we have no improvement with respect to the case of decentralized markets. Any wholesale price below $\overline{p}^w$, however, will increase final customers surplus by decreasing retail prices. In this sense, introducing a wholesale market makes customers (weakly) better off.

7 Conclusions

We have considered in this paper entry and competition in the liberalized natural gas market. The model rests on three key assumptions, that correspond to essential features of the gas industry: due to TOP obligations the firms are endowed with low marginal cost core capacity, with higher marginal costs for additional supply. The market is decentralized and the marketing decision on which customers to serve is medium term and sunk once taken. Once chosen the submarkets to serve, firms compete in prices, with slight differentiation in the commercial service.

Our main finding is that entry can lead to segmentation and monopoly pricing rather than competition. The key mechanism works as follows: in a decentralized market each firm has to choose which customers to approach; since both firms have TOP obligations, if both compete for the same customer(s) the equilibrium price gives very low margins. However, if a firm exhausts its obligations acting as a monopolist in a segment of the market, it looses any incentive to further enter in the residual part of the market, because it would be unable to obtain positive sales and profits competing with a (low cost) rival still burdened with TOP obligations. Hence, leaving a fraction of the market to the competitor ensures to remain monopolist on the residual demand, maximizing the rents over the low cost capacity. The equilibrium entry pattern requires to select different submarkets and pricing as a monopolist. The outcome is therefore one of entry without competition.

[15] See Klemperer and Meier (1989) and, on the electricity market, Green and Newbery (1992).

This result persists even when antitrust ceilings or forced divestiture of import contracts are imposed, with the only effect of shifting market shares and profits from the incumbent to the entrant. Introducing a wholesale market, instead, can have positive effects on competition. If the gross importers, burdened with TOP obligations, sell "to the market" and the retailers, that select the final customers to serve, buy "from the market", those latter have the same flat marginal cost equal to the wholesale price for any amount of gas, and obtain positive profits in any submarket they enter. Generalized entry and low retail margins therefore follow. The level of the wholesale price (and competition in the pool market) becomes crucial in this perspective. With intense competition the final price of gas becomes very low, although we might imagine more complex strategies, e.g. competition in supply functions, that can implement high (wholesale) prices. In any case, customers are not worse off in a wholesale market setting compared with a decentralized one.

These results suggest that the liberalization plans, focussed so far on the task of creating opportunities of entry and a level playing field for new comers, should not take as granted that entry will bring in competition in the market. The issue of promoting competition seems the next step that the liberalization policies need to address.

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8 Appendix

Proof. of Proposition 1.

Case (a). If only firm i enters market 2, the demand is described above by (3) or (4). The highest price at which every consumer buys one unit of the good is $p^m = u^* - \frac{9}{16}\psi$. As long as $u^* \geq \frac{33}{16}\psi$, any price above p^m implies a fall in the monopolist's profit. Moreover, we require that $p^m \geq w$. The two conditions are met under assumption (2).Therefore, the equilibrium price if only one firm enters in the market is $\widehat{p}_i^2 = u^* - \frac{9}{16}\psi = p^m$.

Case (b). In this case total TOP obligations equal demand. For each pair of TOP obligations, we can construct a continuum of equilibrium prices and that that are Pareto ranked, where each firm exactly sells its residual TOP obligations. We then pick up the highest prices (associated to the highest profits). We finally check that no price equilibrium exists, in which one firm produces more and the other one less than its TOP obligations.

If $\overline{q}_i^2 + \overline{q}_j^2 = D^2$, if in equilibrium each firm uses its obligations it must be that:

$$\begin{aligned}
\left.\frac{\partial \pi_i^2}{\partial p_i}\right|_{p^-} &\equiv \tfrac{1}{2} + \tfrac{p_j + w}{\psi} - \tfrac{2p_i}{\psi} \geq 0 \\
\left.\frac{\partial \pi_i^2}{\partial p_i}\right|_{p^+} &\equiv \tfrac{1}{2} + \tfrac{p_j}{\psi} - \tfrac{2p_i}{\psi} \leq 0 \\
\left.\frac{\partial \pi_j^2}{\partial p_j}\right|_{p^-} &\equiv \tfrac{1}{2} + \tfrac{p_i + w}{\psi} - \tfrac{2p_j}{\psi} \geq 0 \\
\left.\frac{\partial \pi_j^2}{\partial p_j}\right|_{p^+} &\equiv \tfrac{1}{2} + \tfrac{p_i}{\psi} - \tfrac{2p_j}{\psi} \leq 0 \\
& \quad\; \tfrac{1}{2} + \tfrac{p_j - p_i}{\psi} = \tfrac{\overline{q}_i^2}{D^2}
\end{aligned} \tag{10}$$

The first four conditions correspond to the left- and right-hand derivatives of the two firms' profits while the last one specifies that firm i covers its obligations (since $\overline{q}_i^2 + \overline{q}_j^2 = D^2$ an analogous condition on firm j would be redundant). These conditions are met by price pairs that lie in the area ABCD and along the relevant 45^0 line of the fifth equation (see Figure 1). In the Pareto dominant equilibrium the last and the first condition (taken as equality) are binding. Solving the system, we obtain the prices of case (b) in the Proposition. The segment AB in Figure 1 corresponds to the case where the incumbent has the higher amount of TOP obligations left ($i = I$), while the segment BC represents the case $i = E$.

Let us now consider the case in which the firms do not sell anymore exactly their TOP obligations, and calculate the equilibrium prices when one firm (say, firm i) produces more and the other (say, firm j) less than their respective obligations. We'll see that no such equilibrium exists.

The equilibrium requires the first derivatives to be zero; in the case considered, the relevant derivatives are the first one - $BR_i(w)$ in Fig. 1 - (since i produces more than $\overline{q}_i^2$ its marginal cost is w) and the fourth one - $BR_j(0)$ in Fig.1 - (since j is not using all its obligations, it has zero marginal costs). Solving for the price pair we get: $p_i = \frac{2}{3}w + \frac{\psi}{2}$ and $p_j = \frac{1}{3}w + \frac{\psi}{2}$. However, this price pair would be such that i produces nothing and j supplies the whole market, which is a contradiction, as if this were true, j would have marginal cost equal to w and not to 0 and i would have marginal cost equal to 0 and not to w. Point C in Figure 1 corresponds to this case when $i = I$, and clearly implies that j is covering the entire market while point A refers to the case $i = E$.

Let us now move to case (c), where $\overline{q}_i^2 \leq D^2/2$ and $\overline{q}_j^2 > D^2 - \overline{q}_i^2$. We can construct an equilibrium $\left(\widehat{p}_i^2, \widehat{p}_j^2\right)$ with the following properties: $D_i^2\left(\widehat{p}_i^2, \widehat{p}_j^2\right) = \overline{q}_i^2$ and $D_j^2\left(\widehat{p}_i^2, \widehat{p}_j^2\right) = D^2 - \overline{q}_i^2 < \overline{q}_j^2$. We will then show that this equilibrium is unique.

Referring to the set of conditions above, the necessary and sufficient equilibrium conditions are given by the first two derivatives as inequalitites, the fourth as an equality and the fifth, corresponding, when $j = I$ and $i = E$, to $BR_I(0)$, $BR_E(0)$, $BR_E(w)$ and the relevant 45^0 line in figure 1. The fourth and fifth conditions are binding and it is easy to check that the prices obtained also satisfy the first two inequalities. Solving we obtain the prices in the Proposition (part (c)). These equilibrium price pairs lie along AD when $j = I$ and DC when

$j = E$.

Finally, no price equilibrium exists in which firm i produces less than its obligations: if both firms produce less then their obligation, the equilibrium prices are at the intersection of $BR_I(0)$ and $BR_E(0)$, i.e. at point D in figure 1 that corresponds to $D_j^2(\cdot) = D_i^2(\cdot) = D^2/2 \geq \overline{q}_i^2$, which contradicts the assumption of the statement.

Let us now move to case (d), where $\overline{q}_i^2 > D^2/2$ and $\overline{q}_j^2 > D^2/2$ the residual obligations are so large that, in a symmetric equilibrium, the marginal cost is zero for both firms. In this case the relevant conditions are the second and the fourth as equalities and the equilibrium prices are at the intersection of $BR_I(0)$ and $BR_E(0)$, i.e. at point D in figure 1. Solving for the equilibrium prices we obtain $\widehat{p}_I^2 = \widehat{p}_E^2 = \frac{\psi}{2}$. Each firm sells half of D^2 and the marginal cost is 0 as implicit in the equilibrium conditions. ■

Proof. of Proposition 3

Consider first the subgame following the decision of the two firms to enter in the first market ($e_I^1 = e_E^1 = 1$): since we have not yet solved for the price equilibrium in market 1 we have to analyze the second stage for any combination of residual capacities such that $\overline{q}_I^2 \geq 0, \overline{q}_E^2 \geq 0, \overline{q}_I^2 + \overline{q}_E^2 = D^2$. The corresponding price equilibrium has been shown in Proposition 1 and the associated profits are $\Pi_i^2 = (w + \psi\overline{q}_i^2/D^2)\overline{q}_i^2$ and $\Pi_j^2 = (w + \psi(3D^2 - 4\overline{q}_j^2)/2D^2)\overline{q}_j^2$, where i and j are such that $\overline{q}_i^2 \in [0, D^2/2]$ and $\overline{q}_j^2 \in [D^2/2, D^2]$: notice that the profits are positive if the residual obligations of the firm are positive. Since not entering gives zero stage profits, a firm will enter if it has some residual obligation and stays out otherwise.

Consider now the two subgames following the entry of a single firm in the first market ($e_I^1 = 1, e_E^1 = 0$ and $e_I^1 = 0, e_E^1 = 1$): although covering all the first market exhausts the obligations of either firm ($D^1 = \overline{q}_I > \overline{q}_E$) we cannot exclude that the entrant in the first market has priced so high to serve only a fraction of D^1, retaining some residual capacity in the second market. Hence, $\overline{q}_I^2 \geq 0, \overline{q}_E^2 \geq 0, \overline{q}_I^2 + \overline{q}_E^2 \geq D^2$. Let's analyze the different cases. If the incumbent entered the first market using all its obligations (setting $p_I^1 = p^m$) then $\overline{q}_I^2 = 0, \overline{q}_E^2 = D^2$. Proposition 1 describes the price equilibrium if both enter: since the entrant makes positive profits it will enter in any case, while the incumbent, entering the second market, realizes no profits since $D_I^2 = 0$ being $\overline{q}_I^2 = 0$; thus, I will stay out. Hence, $\widehat{e}_I^2 = 0$ and $\widehat{e}_E^2 = 1$. If I entered the first market but rationed the demand retaining some obligations, $\overline{q}_I^2 > 0, \overline{q}_E^2 = D^2$. Since $\overline{q}_I^2 + \overline{q}_E^2 > D^2$ cases c) or d) in Proposition 1 apply. The equilibrium profits if both firms enter are therefore $\Pi_I^2 = \psi \min \left\{ \frac{D^2}{4}, \frac{\left(3D^2/2 - 2\overline{q}_I^2\right)}{D^2}\overline{q}_I^2 \right\}$ and $\Pi_E^2 = \psi \max \left\{ \frac{D^2}{4}, \frac{(D^2 - \overline{q}_I^2)^2}{D^2} \right\}$. Since both are positive for $\overline{q}_I^2 > 0$, both firms will enter if the incumbent has retained some capacity from the first stage. Hence, we conclude that a firm will enter in the second market if it has some residual obligation to cover. The same arguments apply to the complementary case in which only E entered in the first market ($e_I^1 = 0, e_E^1 = 1$), showing that if the entrant used all its obligations in the first market it stays out of the second market, that will be monopolized by the incumbent, while if $\overline{q}_E^2 > 0$ both firms enter in stage 2.

Finally, if no firm enters in the first market each firm has residual obligations sufficient to cover D^2: if both enter Proposition 1 applies and both firms obtain positive profits. Hence, they will enter. ■

Proof. of Proposition 4

Point (a). We consider the incentives to overpricing of the incumbent, that has a larger TOP obligations. From Proposition 1 we know that firm I's profits in market 1 are maximized by setting $\widehat{p}_I^1 = u^* - \frac{9}{16}\psi$. If firm I sets a price $p_I^1 > u^* - \frac{9}{16}\psi$, $D_I^1(p_I^1) < D^1$, leaving some residual obligation $\overline{q}_I^2 > 0$. Proposition 3 has shown that if the firm active in the first market retains some residual obligations $\overline{q}_i^2 > 0$, both firms will enter in the second market (no foreclosure realized). If firm I has entered in the first market, its overall profits if it does not cover D^1 are $\Pi_I = p_I^1 D_I^1(p_I^1) + \min\left\{\psi\frac{D^2}{2}, (3\psi - 4\psi\overline{q}_I^2/D^2)\overline{q}_I^2\right\}$ where $D_I^1(p_I^1)$ is the demand when only one firm (I) is active in market 1 and $\overline{q}_I^2 = D^1 - D_I^1(p_I^1)$. Then the derivative of the profit function evaluated at $p_I^1 \longrightarrow^+ u^* - \frac{9}{16}\psi$ is

$$\frac{\partial \Pi_I}{\partial p_I^1} = 1 - \frac{2}{3\psi}(u^* - \frac{9}{16}\psi) - \frac{9D^1 - 12D^2}{12D^2\psi} < 0$$

that is, the second market profit gains do not compensate the reduced profits in the first market. The same holds true *a fortiori* if only firm E enters in the first market.

Point (b). Let us define the following subsets of the strategy space $P = \left\{(p_I^1, p_E^1) \in [0, u^*]^2\right\}$:

$$P^A = \left\{(p_I^1, p_E^1)\,\middle|\, p_I^1 \in [0, u^*], p_E^1 \in [0, \min\left\{p_I^1 + \psi\widetilde{D}, u^*\right\}]\right\} \tag{11}$$
$$P^B = \left\{(p_I^1, p_E^1)\,\middle|\, p_I^1 \in [0, u^* - \psi\widetilde{D}], p_E^1 \in (p_I^1 + \psi\widetilde{D}, \min\left\{p_I^1 + \frac{\psi}{2}, u^*\right\})\right\}$$
$$P^C = \left\{(p_I^1, p_E^1)\,\middle|\, p_I^1 \in [0, u^* - \frac{\psi}{2}], p_E^1 \in [p_I^1 + \frac{\psi}{2}, u^*]\right\}$$

where $\widetilde{D} = \frac{D^1 - 2D^2}{2D^1}$. When $(p_I^1, p_E^1) \in P^A$ firm E exhausts its obligations in the the first market ($D_E^1(p_I^1, p_E^1) \geq D^2 = \overline{q}_E$) and does not enter in the second. Conversely, when $(p_I^1, p_E^1) \in P^C$ firm E doesn't sell anything in the first market and I exhausts its capacity; therefore in the second market only E will enter. Finally, for $(p_I^1, p_E^1) \in P^B$ no firm exhausts its obligations in the first market and therefore both will enter also in the second. Hence, the three sets define different entry patterns in the second stage. Notice, for future reference, that P^A and P^C are closed sets while P^B is open. From the previous discussion, the incumbent's profits jump up at the boundary of P^A while the entrant's profits have a similar pattern at the boundary of P^C since in the two cases one of the firms remains monopolist in the second market. Finally, the industry profits $\Pi = \Pi_I + \Pi_E$ are discontinuous at the boundaries of P^A and P^C, since the joint profits when the second market is a duopoly (region P^B) are strictly lower than those obtained when it becomes a monopoly. Once introduced this notation we can move to proving part (b) distinguishing the three points.

Point 1. We prove that no price equilibrium in pure strategies exists if $e^1_I = e^1_E = 1$. The incumbent's profit function in the first market is $\Pi^1_I = D^1_I(p^1_I, p^1_E)p^1_I$. If $(p^1_I, p^1_E) \in P^C$, it corresponds to the overall profits Π_I since the incumbent does not enter in the second market; at the boundary of P^B with P^C (where the two firms enter in the second market) the residual capacity of the incumbent $\overline{q}^2_I$, and the second market profits, tend to zero. Hence, Π_I is continuous moving from P^C to P^B. At the boundary of P^B and P^A the entrant exhausts all its obligations in market 1, and I becomes monopolist in market 2, adding $(u^* - \frac{9}{16}\psi)D^2$ to the first market profits. Hence, since I produces in the first market in all the three regions Π_I has a global maximum at the boundary of P^A where the market 2 monopoly profits are added, and the incumbent best reply is $p^1_I = p^1_E - \psi\widetilde{D}$. Turning to the entrant's profits, a similar pattern occurs, with a discrete jump in the profit function entering region P^C, where $\Pi_E = (u^* - \frac{9}{16}\psi)D^2$. The entrant's profits has a global maximum at the boundary of P^C and its best reply is $p^1_E = p^1_I + \frac{\psi}{2}$. Hence, there is no price pair that satisfies the two best reply functions simultaneously. Each firm wants the rival to sell all its obligations in the first market, in order to monopolize the second market. This proves point 1.

Point 2. Now we turn to proving the existence of a mixed strategy equilibrium in prices, relying on Dasgupta and Maskin (1986) Theorem 5. First notice that firm i's strategy space $P_i \subseteq R^1$ and the discontinuity set for the incumbent is (using Dasgupta and Maskin notation)

$$P^{**}(I) = \left\{ (p^1_I, p^1_E) \middle| p^1_I \in [0, u^* - \psi\widetilde{D}], p^1_E = p^1_I + \psi\widetilde{D} \right\},$$

i.e. the boundary of P^C. Analogously, the discontinuity set for the entrant is

$$P^{**}(E) = \left\{ (p^1_I, p^1_E) \middle| p^1_I \in [0, u^* - \frac{\psi}{2}], p^1_E = p^1_I + \frac{\psi}{2} \right\},$$

i.e. the boundary of P^A. Hence, the discontinuities occur when the two prices are linked by a one-to-one relation, as required (see equation (2) in Dasgupta and Maskin (1986)), while $\Pi_i(p^1_i, p^1_j)$ is continuous elsewhere. Second, $\Pi = \Pi_I + \Pi_E$ is upper semi-continuous (see Definition 2 in Dasgupta and Maskin (1986)): since Π_I, Π_E and Π are continuous within the three subsets P^A, P^B and P^C, for any sequence $\{p^n\} \subseteq P^j$ and $p \in P^j$, $j = A, B, C$, such that $p^n \longrightarrow p$, $\lim_{n \longrightarrow \infty} \Pi(p^n) = \Pi(p)$. In other words, at any sequence that is completely internal to one of the three subsets P^j the joint profits are continuous. If instead we consider a sequence $\{p^n\}$ converging to the discontinuity sets from the open set P^B, i.e.$\{p^n\} \subseteq P^B$ and $p \in P^{**}(i)$, $i = I, E$, such that $p^n \longrightarrow p$, then $\lim_{n \longrightarrow \infty} \Pi(p^n) < \Pi(p)$, i.e. the joint profits jump up. Third, $\Pi_i(p^1_i, p^1_j)$

is weakly lower semi-continuous in p_i^1 according to Definition 6 in Dasgupta and Maskin (1986). At $(\overline{p}_I^1, \overline{p}_E^1) = \overline{p}^1 \in P^{**}(I)$, if we take (see Dasgupta and Maskin (1986) $\lambda = 0$, $\lim_{p_I^1 \longrightarrow^+ \overline{p}_I^1} \Pi_I(p_I^1, \overline{p}_E^1) = \Pi_I(\overline{p}_I^1, \overline{p}_E^1)$. Analogously, at $(\overline{p}_I^1, \overline{p}_E^1) = \overline{p}^1 \in P^{**}(E)$, if we take $\lambda = 1$, $\lim_{p_E^1 \longrightarrow^- \overline{p}_E^1} \Pi_E(\overline{p}_I^1, p_E^1) > \Pi_E(\overline{p}_I^1, \overline{p}_E^1)$. Then all the conditions required in Theorem 5 are satisfied and a mixed strategy equilibrium (μ_I^*, μ_E^*) exists.

Point 3. Finally, we prove that $E\Pi_i(\mu_I^*, \mu_E^*) > 0$ and $E\Pi_E(\mu_I^*, \mu_E^*) < (u^* - \frac{9}{16}\psi)D^2$. The first inequality simply follows from the fact that $\Pi_i(p_i^1, p_j^1) > 0$ for any $p \in P$. To establish the second inequality, notice that $\max_{p \in P} \Pi_E(p_I^1, p_E^1) = (u^* - \frac{9}{16}\psi)D^2$, occurring when $p \in P^C$. Let the support of the mixed strategy μ_i^* be M_i^*. Suppose that the mixed strategies μ_I^*, μ_E^* are such that in the mixed strategy equilibrium $p \in P^C$ occurs with probability 1: since μ_I^* and μ_E^* are independent, it means that $M_I^* \subseteq [0, (u^* - \frac{\psi}{2})/2]$ and $M_E^* \subseteq [(u^* + \frac{\psi}{2})/2, u^*]$. But then the incumbent can profitably deviate from μ_I^* while E plays μ_E^* by setting a price $\overline{p}_I^1 \notin M_I^*$ sufficiently high to be in P^A with positive probability, a contradiction. Hence, in a mixed strategy equilibrium it cannot be that P^C (and, for the same argument, P^A) occur with probability 1. Then, $E\Pi_E(\mu_I^*, \mu_E^*) < (u^* - \frac{9}{16}\psi)D^2$. ■

Proof. of Proposition 5

Consider, for different entry choices in the first market, the profits of the two firms evaluated at the equilibrium price in the first stage and at the entry and price equilibrium in the second stage:

- $e_I^1 = 1, e_E^1 = 1$: we have seen that in the mixed strategy equilibrium the two firms obtain expected gross profits $E\Pi_I(\mu_I^*, \mu_E^*) > 0$ and $0 < E\Pi_E(\mu_I^*, \mu_E^*) < (u^* - \frac{9}{16}\psi)D^2$.
- $e_I^1 = 1, e_E^1 = 0$: the first market equilibrium price implies that the incumbent uses all its obligations and stays out of the second market. The profits are therefore $\Pi_I = (u^* - \frac{9}{16}\psi - w)D^1$ and $\Pi_E = (u^* - \frac{9}{16}\psi - w)D^2$.
- $e_I^1 = 0, e_E^1 = 1$: in this case it is the entrant that covers all the first market demand at the monopoly price staying out at the second stage. We have therefore $\Pi_I = (u^* - \frac{9}{16}\psi)D^2 - wD^1$ and $\Pi_E = (u^* - \frac{9}{16}\psi - w)D^1$.
- $e_I^1 = 0, e_E^1 = 0$: if no firm enters in the first market, both will enter in the second with profits $\Pi_I = \psi\frac{D^2}{2} - wD^1$ and $\Pi_E = \psi\frac{D^2}{2} - wD^2$.
- Since the incumbent moves first, and makes positive profits entering the first market for any reaction of the entrant, I enters. Since $E\Pi_E(\mu_I^*, \mu_E^*) < (u^* - \frac{9}{16}\psi)D^2$ the entrant is better off staying out of the first market and becoming a monopolist in the second market. Uniqueness simply follows by construction.

■

Proof. of Lemma 8

From the analysis of the benchmark case, we know that an equilibrium, if any, must entail the two firms selling their residual obligations or ceilings. Consider a price pair (p_I^2, p_E^2) with $p_E^2 < u^* - \frac{\psi}{16}$, such that $D_I^2(p_I^2, p_E^2) = \widehat{q}_2^I$ and $D_E^2(p_I^2, p_E^2) = \overline{q}_E^2$. As long as $\frac{\partial \Pi_I^2(c_I=0)}{\partial p_I^2} \leq 0$, this price pair is a maximum for the incumbent: I does not gain from raising the price (producing less that the ceiling at a marginal cost 0), as the derivative states, and it does not gain from reducing price, since it cannot sell more than $\widehat{q}_I^2$. On the other hand, E can profitably raise p_E^2, because the antitrust ceilings prevent the incumbent from serving any more customers, that will be served by the entrant as long as the price is not too high ($p_E^2 < u^* - \frac{\psi}{16}$). But once the price is very high and the two firms set prices such that $D_2^I(p_I^2, p_E^2) = \widehat{q}_I^2$, it is easy to see that $\frac{\partial \Pi_E^2(c_E=w)}{\partial p_E^2} < 0$, i.e. the entrant is better off by reducing its price and serving (at a marginal cost w) a fraction of the market larger than its residual obligations, i.e.$D_E^2(p_I^2, p_E^2) > \overline{q}_E^2$. Hence, no price equilibrium in pure strategies exists.

From the discussion above it is clear that the entrant's profit function (not surprisingly) is not quasi-concave in its price when the incumbent has antitrust ceilings (capacity constraints). However, it is continuous and the strategy space $p_i \in [0, u^*]$ is compact and convex. Hence, we can apply Glicksberg (1952) Theorem establishing that a mixed strategy equilibrium (μ_I^*, μ_E^*) exists.

Finally, $E\Pi_E^2(\mu_I^*, \mu_E^*) = 0$ would occur only if in the mixed strategy equilibrium $p_E^2 = 0$ with probability 1, since any other price pair, given that $\widehat{q}_I^2 < D^2$, would leave at least $D^2 - \widehat{q}_I^2$ sales and positive profits to the entrant. But then E might deviate from the mixed strategy setting a higher price with certainty and gaining positive profits. Secondly, $E\Pi_i^2(\mu_I^*, \mu_E^*) = (u^* - \frac{9}{16}\psi - w)D^2$ would be the case only if the support of the incumbent mixed strategy would include only prices so high that I does not sell anything when the entrant is pricing at $p_E^2 = u^* - \frac{9}{16}\psi$. But this cannot occur in a mixed strategy equilibrium since the incumbent would be better off by setting with probability one a lower price, selling its residual ceilings and making profits. ■

Proof. of Proposition 10

First notice that wholesale demand is $D^w \leq D$. The firms are not capacity constrained, as they can purchase from the extractors at unit cost w any quantity exceeding their obligations. Hence, setting a price above the rival leaves with no sales and no profits, and it is never an optimal reply as long as the rival is pricing above w. considering the price pairs not higher than w, if firm i sets the same price as the rival, i.e. $p_i = p_j$, its profits are $\Pi_i = p_j D_i$, where D_i are firm i sales: if $D^w = \overline{q}_I + \overline{q}_E$, then $D_i = \overline{q}_i$ while if $D^w < \overline{q}_I + \overline{q}_E$, then $D_i \leq \overline{q}_i$, with strict inequality for at least one firm. If firm i undercuts firm j, setting $p_i = p_j - \varepsilon$, taking the limit for $\varepsilon \to 0$ the profits are $\Pi_i = p_j D^w - w(D^w - \overline{q}_i)$, i.e. firm i supplies the entire demand and purchases additional gas $D^w - \overline{q}_i$ at unit price w. Then, comparing the two profits (and remiding that for $p_j > w$ it is always optimal to undercut) we can identify the condition that makes undercutting profitable:

$$p_j > w\frac{D^w - \overline{q}_i}{D^w - D_i} \equiv \underline{p}_j$$

Hence, firm i will undercut firm j if $p_j > \underline{p}_j$ and firm j will undercut firm i if $p_i > \underline{p}_i$. Since overpricing is never profitable, the equilibrium prices will be $p_i = p_j = \min\left\{\underline{p}_i, \underline{p}_j\right\}$. Notice that $\underline{p}_i$ and $\underline{p}_j$ depend on the allocation of demand between the two firms, D_i and D_j. If $D^w = \overline{q}_I + \overline{q}_E$, then $D_i = \overline{q}_i$ and $\min\left\{\underline{p}_i, \underline{p}_j\right\} = w$. If instead $D^w < \overline{q}_I + \overline{q}_E$, $\min\left\{\underline{p}_i, \underline{p}_j\right\} < w$. Since $\min\left\{\underline{p}_i, \underline{p}_j\right\}$ depends on the rule the firms follow in allocating total demand when they set the same price, i.e. on the way D_i and D_j are determined, we have no explicit solution without choosing a precise rule. However, assuming that any reasonable rule should require $\frac{\partial D_i}{\partial D^w} \geq 0$, i.e. that if total demand falls individual demand cannot increase when firms set the same price, we obtain

$$\frac{\partial \underline{p}_i}{\partial D^w} = w\frac{\overline{q}_i - D_i + \frac{\partial D_i}{\partial D^w}(D^w - \overline{q}_i)}{(D^w - D_i)^2} > 0$$

Hence, even without choosing an explicit allocation rule we are able to show that the equilibrium wholesale price p^w is increasing in total sales D^w. ∎

Proof. of Proposition 11

Let us first consider the retail market equilibrium prices. The marginal costs of the two firms is $p^w = w$ if total demand for gas D^w is equal to D and $p^w < w$ if total demand for gas is lower than D. If both firms enter in submarket $\widetilde{d}$, firm i's profits are

$$\Pi_j^{\widetilde{d}} = \left[\frac{1}{2} + \frac{p_i^{\widetilde{d}} - p_j^{\widetilde{d}}}{\psi}\right]\left(p_j^{\widetilde{d}} - p^w\right)$$

If we consider submarket $\widetilde{d}$ in isolation, the unique simmetric equilibrium in prices is $\widehat{p}_i^d = \widehat{p}_j^d = p^w + \frac{\psi}{2}$ and the profits in this submarket are $\widehat{\Pi}_j^{\widetilde{d}} = \frac{\psi}{2}$, independently of the level of the marginal cost p^w. We conclude that if we look at submarket $\widetilde{d}$ profits only, there is no incentive to ration the demand setting a price such that $D_a^{\widetilde{d}} + D_b^{\widetilde{d}} < 1$. But there is no incentive to ration the submarket demand even if we consider the overall effect on the wholesale price (marginal costs) p^w applied to the overall purchase of gas. If by rationing submarket d total demand becomes lower than D, the wholesale price falls to $p^w < w$, the final prices reduce accordingly to $p^w + \frac{\psi}{2}$, with no effects on the firm profits. Hence, the price equilibrium entails setting a margin $\frac{\psi}{2}$ over the relevant marginal costs p^w. Turning to the entry decisions, no matter how large is total demand for gas (and therefore the wholesale price and the marginal cost p^w), the entry in each submarket increases overall profits by a positive amount ($\frac{\psi}{2}$ if also the other firm enters and $u^* - \frac{9}{16}\psi - p^w$ if the rival stays out).

Since entering in each submarket is the dominant strategy for each firm, both firms will enter in all submarkets and will set a price such that all the submarket demand is covered. Total demand equals D and the wholesale price (marginal cost) is w. $\blacksquare$