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July 11, 2007

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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 the separation of wholesale and retail activities and the creation of a wholesale market induces generalized competition and low margins in the retail segment.

*Keywords* Entry, Segmentation, Decentralized market

*JEL classification:* L11, L13, L95

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June 2007

## 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 the separation of wholesale and retail activities and the creation of a wholesale market induces generalized competition and low margins in the retail segment.

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## 1 Introduction

In this paper we 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.

A take-or-pay obligation entails an unconditional fixed payment, which enables the purchaser to get up to a certain threshold quantity of gas. This payment is due whether or not the company actually decides to get (and resell) it, and further payments are due if the company wants to receive additional quantities. The very nature of this kind of contracts, therefore, is to substitute variable payments conditional on actual deliveries with a fixed unconditional payment up to a certain threshold level of delivery.<sup>1</sup>

We argue that the existence of take-or-pay obligations not only creates problems in the application of the TPA, but introduces 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 European gas industry and by the main lines of reform of the European Directives. First, wholesalers purchase gas under long term import contracts, the bulk of gas supply in most European countries, that impose take-or-pay obligations to the buyer. Consequently, each wholesaler has negligible marginal costs up to its obligations, although it has additional capacity at higher marginal cost, coming for instance from extensions of the long term contracts. Second, there is no separation of wholesale and retail activities nor a wholesale market, and the retail market is decentralized: the wholesalers can directly operate in the retail market, selecting which customers to approach. Third, once chosen their potential customers firms compete in prices, with some horizontal differentiation in their service. Horizontal differentiation is an easy way to justify the idea that retail markets can be opened to competition and they are not natural monopolies, even if firms compete in prices and supply a homogenous product as the natural gas. A limited product differentiation, indeed, allows some small but positive margins to cover possible entry costs and sustain a fragmented market.

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 en-

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<sup>1</sup>Take-or-pay obligations can add further conditions, as the possibility to shift across different years part of the commitments. However, the essential feature of these clauses is captured by the simple version we consider in the model.

tries 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.

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.<sup>2</sup> 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 claim, 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 wholesale and retail activities are separated and a centralized wholesale market is created, where the wholesalers (burdened by TOP obligations) sell and the retailers 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. Generalized entry becomes the dominant strategy, bringing in intense price competition and low margins 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 primarily 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 cut-throat price competition. When a firm faces constant marginal costs up to a

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<sup>2</sup>For an extensive discussion of the liberalization process in the energy markets along these lines see Polo and Scarpa (2003).

certain absolute capacity constraint, the subgame perfect equilibrium outcome is equivalent to the corresponding Cournot equilibrium if firms follow an efficient rationing rule, while it is intermediate between Cournot and Bertrand if proportional 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)<sup>3</sup>, that introduces 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.

Our paper shares many features of the analysis of Bertrand-Edgeworth competition with dynamic pricing<sup>4</sup>: Dubey (1992) shows that absolute capacity constraints and dynamic pricing over a sequence of consumers avoids price cycles (or mixed strategy equilibria) and leads to almost monopoly prices. We show in our paper that similar results can be obtained with no absolute capacity constraint and with simultaneous pricing, provided that entry and pricing in the submarkets are taken sequentially.

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

Two firms, the incumbent ( $I$ ) and the entrant ( $E$ ), are active in the retail market for natural gas provision. The firms purchase the natural gas from the extractors and resell it to the final customers transporting it 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 features of entry and competition in the retail market, absent any entry barriers to the transport infrastructures that might distort the competitive process. Consequently, we assume that Third Party Access is fully implemented, implying that no bottleneck or abusive conduct prevents the access of the entrant to the transportation network at non discriminatory terms.

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<sup>3</sup>The same technology can be found in Dixit (1980): in this paper the incumbent has already sunk a given capacity and therefore has marginal costs deriving from variable inputs up to this capacity and a higher marginal cost, that includes the cost of installing additional capacity, for higher output.

<sup>4</sup>See also Ghemawat and McGahan (1998) on order backlogs for similar arguments.



Our model of the retail market is based on three main features.

1. The wholesale activity (buying gas from extractors) and the retail activity (selling gas to the final customers) are not separated and are managed by the same firms (retailers). The main source of supply for the retailers are long term contracts with the extractors with take-or-pay obligations on a certain amount of gas; hence, the retailers have zero marginal cost up to the output that fulfills these obligations. They can obtain additional gas from other sources, as spot contracts or extensions of the main contract, at a (higher) marginal cost that reflects the marginal purchase price.
2. The liberalized retail gas market is decentralized (single transactions may take place with different customers at different times and at different prices) and each firm has to decide which customers/submarkets it wants to approach, an irreversible decision in the short run. Submarkets can be identified by location (geographical submarkets) or by the type of customers (residential, business, specific industries, etc.) that require dedicated (sunk) sales resources.
3. Once chosen which customers to approach (their marketing strategy) the firms compete in prices, possibly with a slight differentiation in the commercial service provided.

We now move on describing in details the costs, demand and timing of the game.

### Costs

The retailers's costs refer to the purchase, transport and sales of gas. Since we assume that transport services are offered at non discriminatory terms, the network access costs are the same for  $E$  and  $I$  and, w.l.o.g., equal to zero. Variable sales costs are assumed to be zero as well. Purchase costs depend on the nature of the upstream contractual arrangements. The bulk of retailer's costs refer therefore to the purchase of gas from the extractors. Each retailer  $i = I, E$  has a portfolio of long term contracts with the extractors, where the unit cost of gas  $w^i$  and a TOP obligation  $\bar{q}^i$  per unit of time are specified, such that the retailer has to pay to the extractor an amount  $w^i \bar{q}^i$  no matter if the gas is taken or not. Retailers can obtain additional supply from secondary sources, as extensions of the main contract or spot contracts with other providers. In our setting what distinguishes the primary from the secondary source is the nature of the marginal purchase price: it is zero up to the TOP obligations  $\bar{q}^i$  while it is positive and (w.l.o.g.) equal to  $w^i$  for additional supply<sup>5</sup>. Notice that in our model the firms have no capacity constraints but a discontinuous marginal cost

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<sup>5</sup>Long term contracts usually include additional clauses, as a total annual capacity that can be 25-30% larger than TOP obligations, and rules to anticipate or postpone the fulfillment of TOP obligations across years. All these elements do not modify the key element in our analysis, a discontinuous marginal purchase price once TOP obligations are exhausted. Hence, we model the costs according to this essential feature.

curve, that jumps from 0 to  $w^i$  once the TOP obligations are exhausted. For simplicity, we assume  $w^E = w^I = w$ .

The cost function of firm  $i$  is therefore:

$$C^i(q^i, \bar{q}^i) = \begin{cases} w\bar{q}^i & \text{for } 0 \leq q^i \leq \bar{q}^i \\ w(q^i - \bar{q}^i) + w\bar{q}^i & \text{for } q^i \geq \bar{q}^i \end{cases} \quad (1)$$

### Demand

Individual consumers  $d = 1, \dots, D$  have completely inelastic unit demand; total demand is therefore  $D$ . They view the gas supplied in the market as perfectly homogeneous; however, consumers 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  $\psi \geq 0$  is a parameter describing the importance of the commercial services (product differentiation) for the client. Our model, therefore, includes perfect substitutability ( $\psi = 0$ ) as a special case.

There are three key parameters in the model,  $u^*$ ,  $w$  and  $\psi$ , whose values influence the equilibrium outcomes. Qualitatively, we claim that gas is an important input in many activities ( $u^*$  is high), it is costly ( $w$  is large as well) and it is a commodity, with limited opportunities to differentiate the offers ( $\psi$  is very low). We translate these qualitative claims into the following assumptions:

$$u^* \geq w + \frac{33}{16}\psi \quad (2)$$

$$w > \frac{\psi}{2} \geq 0 \quad (3)$$

Assumption (2) is sufficient to ensure that a monopolist prefers to cover the entire market at the highest possible price rather than further rise it and ration the market and that its equilibrium profits are non negative.<sup>6</sup> Assumption (3) ensures that internal solutions give non negative prices in any subgame where the two firms compete. See Proposition 1's proof for details.

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<sup>7</sup>. The firms do not observe the individual customer's tastes (her preferred service variety  $v$ ) but know only the (uniform) distribution of

<sup>6</sup>This assumption ensures also that when the incumbent has an absolute capacity constraint (antitrust ceilings in section 5), it is not convenient for the two firms to jointly exploit the second market by setting monopoly prices and sharing the consumers - see Lemma 3's proof.

<sup>7</sup>Since we already analyze an asymmetric model, with the incumbent endowed with larger obligations and with an advantage in approaching the customers, we do not endogenize the choice of variety, where the incumbent might obtain additional advantages by locating its variety more centrally.

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  $\hat{v}$  as the consumer indifferent between the offers of  $I$  and  $E$ ,  $\bar{v}^I$  as the consumer indifferent between the offer of the incumbent and buying nothing, and  $\bar{v}^E$  as the consumer indifferent between buying from  $E$  or nothing. It is easy to check that:

$$\begin{aligned}\hat{v} &= \frac{1}{2} + \frac{p^E - p^I}{\psi} \\ \bar{v}^I &= \left[ \frac{u^* - p^I}{\psi} \right]^{\frac{1}{2}} + \frac{1}{4} \\ \bar{v}^E &= \left[ \frac{u^* - p^E}{\psi} \right]^{\frac{1}{2}} + \frac{3}{4}\end{aligned}$$

Then, the demand for firm  $I$  in market  $t$  is

$$D_t^I = D_t \cdot \left[ \max \{0, \min \{\hat{v}, \bar{v}^I, 1\}\} - \max \left\{ \frac{1}{2} - \bar{v}^I, 0 \right\} \right] \quad (4)$$

and the demand for  $E$  corresponds to

$$D_t^E = D_t \cdot \left[ \min \{1, \bar{v}^E\} - \min \left\{ 1, \max \left\{ 0, \hat{v}, \frac{3}{2} - \bar{v}^E \right\} \right\} \right] \quad (5)$$

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,

$$D_t^I = D_t \left[ \frac{1}{2} + \frac{p_t^E - p_t^I}{\psi} \right]$$

and

$$D_t^E = D_t \left[ \frac{1}{2} + \frac{p_t^I - p_t^E}{\psi} \right];$$

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  $D_t^I = D^t \bar{v}^I$ , 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.  $\bar{q}^I \leq D$ . In the equilibrium analysis we'll

concentrate on the case  $\bar{q}^I < D$  in which the incumbent's obligations do not cover the entire demand;<sup>8</sup> once understood the equilibrium in this case, the extension to the case  $\bar{q}^I = D$  will be straightforward. Regarding the entrant's long term contracts, we initially assume that its obligations are equal to the residual demand, i.e

$$\bar{q}^E = D - \bar{q}^I \tag{6}$$

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

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. Once received the offer(s) - if any - the customer decides whether to sign a contract or not. Once a contract is signed, the selected provider supplies all the gas demanded by the customer, since the technology does not imply absolute capacity constraints but simply a discontinuous marginal cost. 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 always able to move first in approaching the customers, due to his pre-existing relationships with the clients, followed by the entrant.

Customers are visited by the firms sequentially,<sup>9</sup> 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

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<sup>8</sup>Long term contracts usually admit additional capacity beyond TOP obligations. Hence, to maintain some flexibility, it is realistic to assume that the incumbent in the pre-liberalization scenario did not accept obligations equal to market demand.

<sup>9</sup>In the working paper version of the paper, available on [www.igier.uni-bocconi.it](http://www.igier.uni-bocconi.it), we analyze also a (simultaneous entry) two stage game, in which  $I$  and  $E$  decides simultaneously which submarkets to enter, and then, observed the entry decisions, they simultaneously set a price in each submarket.. We show that equilibria with segmentation exist also in this case and Pareto dominate other equilibria in which each firm enters every market. We present here the sequential entry case since it allows to easily solve the coordination problems in the pattern of submarket entries that otherwise would characterize the equilibria. On dynamic price competition with capacity constraints see Dubey (1992) and Ghemawat P and McGahan A. (1998).

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,  $D_1 = \bar{q}^I$ , and the second one covering the residual demand,  $D_2 = D - D_1 = \bar{q}^E$ . 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  $e_t^i = \{0, 1\}$ ,  $i = I, E$ ,  $t = 1, 2$ , which refers to firm  $i$ 's decision to enter ( $e = 1$ ) or not ( $e = 0$ ) in a particular submarket  $t$ .

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

- at  $t = 1$  the incumbent decides whether to enter ( $e_1^I = 1$ ) or not ( $e_1^I = 0$ ) in  $D_1$ ; then, having observed whether or not  $I$  participates, the entrant chooses to enter ( $e_1^E = 1$ ) or not ( $e_1^E = 0$ ) in market  $D_1$ . Then the participating firm(s) (if any) set a price simultaneously.
- having observed the outcome of stage  $t = 1$ , at  $t = 2$  the incumbent decides whether to enter ( $e_2^I = 1$ ) or not ( $e_2^I = 0$ ) in  $D_2$ ; then, having observed whether or not  $I$  participates, the entrant chooses to enter ( $e_2^E = 1$ ) or not ( $e_2^E = 0$ ) 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.

### 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  $(\bar{q}_2^I, \bar{q}_2^E)$ , where  $\bar{q}_2^i \leq \bar{q}^i$  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:

$$\Pi_2^i = p_2^i D_2^i(p_2^i, p_2^j) - C^i(D_2^i(\cdot), \bar{q}_2^i)$$

where we set  $q^i = D_2^i(p_2^i, p_2^j)$  since each firm always supplies the gas demanded by its customers.

We start by identifying precisely the combinations of residual obligations  $(\bar{q}_2^I, \bar{q}_2^E)$  that can occur in the second market for any possible entry and pricing decision of the two firms in the first market. This allows us to restrict our analysis of the equilibrium in the second market to the relevant cases.

**Lemma 1:** *In the second market the residual obligations of the two firms fall in one of the three following cases:*

- 1)  $\bar{q}_2^I + \bar{q}_2^E = D_2$  with  $\bar{q}_2^i \in [0, D_2]$ ,  $i = I, E$
- 2)  $\bar{q}_2^I + \bar{q}_2^E > D_2$  with  $0 \leq \bar{q}_2^i \leq D_2/2 < \bar{q}_2^j$ ,  $i, j = I, E, i \neq j$
- 3)  $\bar{q}_2^I + \bar{q}_2^E > D_2$  with  $\bar{q}_2^i > D_2/2$ ,  $i = I, E$

**Proof.** See Appendix. ■

We proceed now by identifying the best reply function when both firms enter in the second market and compete in prices. First of all, notice that the profit functions are continuous and concave, but kinked at  $\bar{q}_2^i$ , due to the jump in the marginal costs from 0 to  $w$  once the TOP obligations are exhausted. We start by deriving firm  $i$ 's best reply to  $p^j$ . Let  $\hat{p}_2^i(p_2^j, c)$  be the price that maximizes profits for given  $p_2^j$  when the marginal cost is  $c = \{0, w\}$ :

$$\frac{\partial \Pi_2^i(p_2^i, p_2^j, c)}{\partial p^i} = \frac{1}{2} + \frac{p_2^j + c}{\psi} - \frac{2p_2^i}{\psi} = 0$$

Let us further define  $\bar{p}_2^i(p_2^j, \bar{q}_2^i)$  as the solution to:

$$D_2^i = D_2 \left[ \frac{1}{2} + \frac{p_2^j - p_2^i}{\psi} \right] = \bar{q}_2^i$$

i.e. the price  $p_2^i$  that, for given  $p_2^j$ , makes firm  $i$ 's demand equal to its residual obligations. Solving explicitly we obtain:

$$\begin{aligned}\widehat{p}_2^i(p_2^j, c) &= \frac{p_2^j + c}{2} + \frac{\psi}{4} \\ \overline{p}_2^i(p_2^j, \overline{q}_2^i) &= p_2^j - \frac{\psi}{2D_2}(2\overline{q}_2^i - D_2)\end{aligned}$$

The following Lemma characterizes the best reply for firm  $i$ .

**Lemma 2 :** *Let  $BR_2^i(p_2^j)$  be the best reply to  $p_2^j$ . Then*

$$BR_2^i(p_2^j) = \begin{cases} \widehat{p}_2^i(p_2^j, 0) & \text{for } p_2^j \in \left[0, \max\left\{0, \frac{\psi}{2D_2}(4\overline{q}_2^i - D_2)\right\}\right] \\ \overline{p}_2^i(p_2^j, \overline{q}_2^i) & \text{for } p_2^j \in \left[\max\left\{0, \frac{\psi}{2D_2}(4\overline{q}_2^i - D_2)\right\}, w + \frac{\psi}{2D_2}(4\overline{q}_2^i - D_2)\right] \\ \widehat{p}_2^i(p_2^j, w) & \text{for } p_2^j \in \left[w + \frac{\psi}{2D_2}(4\overline{q}_2^i - D_2), u^*\right] \end{cases}$$

**Proof.** See Appendix. ■

Figure 1 below shows the best reply  $BR_2^i(p_2^j)$  that is piecewise linear and continuous, with the lower segment  $AB$  (if any) corresponding to  $\widehat{p}_2^i(p_2^j, 0)$ , the intermediate segment  $BC$  given by  $\overline{p}_2^i(p_2^j, \overline{q}_2^i)$  and the upper segment  $CD$  equal to  $\widehat{p}_2^i(p_2^j, w)$ . Notice that when the residual obligation  $\overline{q}_2^i$  increases,  $\overline{p}_2^i(p_2^j, \overline{q}_2^i)$  decreases, shifting up the intermediate segment  $BC$  of the best reply characterized by a 45° slope.

Figure 1 about here

Having identified the relevant subgames, corresponding to combinations of the residual obligations described in Lemma 1, and the best reply function when both firms enter in the second market (Lemma 2), we can now proceed analyzing the price equilibria that occur in the different subgames according to the entry decisions of the two firms in the second market.

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

1) *If both firms enter the second market and if  $\overline{q}_2^I + \overline{q}_2^E = D_2$  with  $\overline{q}_2^i \in [0, D_2]$ ,  $i = I, E$  (case 1), the (Pareto efficient) equilibrium prices are*

$$\begin{aligned}p_2^{i*} &= w + \psi \frac{\overline{q}_2^i}{D_2} \\ p_2^{j*} &= w + \psi \frac{4\overline{q}_2^i - D_2}{2D_2}\end{aligned}\tag{7}$$

where  $\bar{q}_2^i \leq D_2/2 \leq \bar{q}_2^j$ , i.e.  $i$  is the smaller and  $j$  the larger firm. Each firm sells all its residual TOP obligation.

2) If both firms enter the second market and if  $\bar{q}_2^I + \bar{q}_2^E > D_2$  with  $0 \leq \bar{q}_2^i \leq D_2/2 < \bar{q}_2^j$ ,  $i, j = I, E, i \neq j$  (case 2), the equilibrium prices are

$$\begin{aligned} p_2^{i*} &= \psi \frac{3D_2 - 4\bar{q}_2^i}{2D_2} \\ p_2^{j*} &= \psi \frac{D_2 - \bar{q}_2^i}{D_2} \end{aligned} \quad (8)$$

Only the smaller firm  $i$  sells all its residual TOP obligation.

3) If both firms enter the second market and if  $\bar{q}_2^I + \bar{q}_2^E > D_2$  with  $\bar{q}_2^i > D_2/2$ ,  $i = I, E$  (case 3), the equilibrium prices are

$$\begin{aligned} p_2^{i*} &= \frac{\psi}{2} \\ p_2^{j*} &= \frac{\psi}{2} \end{aligned} \quad (9)$$

and each firm serves half of the market.

4) If only firm  $i$  enters, it sets price  $p_2^{i*} = u^* - \frac{9}{16}\psi$  and serves the entire market  $D_2$  for any residual obligation it has.

**Proof.** See Appendix. ■

Case (1) 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 (2) and (3). In both of them, competition leads to prices lower than in case (1), but above the zero marginal cost due to product differentiation (the demand parameter  $\psi$ ). Prices would fall to  $w$  in case (1) and to 0 in case (2) and (3), in line with the Bertrand result, when we converge to the homogeneous products case ( $\psi \rightarrow 0$ ). Our equilibrium prices imply an allocation of demand between  $i$  and  $j$  in all cases (including the limiting case of homogeneous products) such that in case (1) both firms sell their residual obligations, in case (2) only the small firm sells its residual obligations and in case (3) the two firms equally share the market. Case (4) of Proposition 1 identifies monopoly prices for any level of the residual obligations.

Figure 2 shows the three cases 1), 2) and 3) in which both firms are active in market 2 and the different points of intersection of the two best reply functions.

Figure 2 about here

We can now move to the entry decisions of the two firms in the subgames of the second market, having characterized the equilibrium prices in any subgame. 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)<sup>10</sup>.

<sup>10</sup> An analogous result would be obtained if we assumed that there are (however small) entry costs.



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

**Proposition 2:** *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 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.

### 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  $\bar{q}^I$  and  $\bar{q}^E$ . The firms choose their entry and pricing strategies in the first market taking into account the impact through the residual obligations on the equilibrium in the subgames of the second market.

We start our analysis of the first market by considering the price games. In general, pricing in the first market determines the amount of residual obligations retained by the firms, and therefore the equilibrium profits that can be obtained in the second market. This link makes the analysis of pricing decisions more complex than in the second stage.

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 it prescribes to ration the first market (through a price higher than  $p_m$ ) retaining some residual obligations for the second market that will induce further entry in the second market.

When both firms enter, if a firm sets its price in the first market in such a way to make the rival selling all its obligations, it gains 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 3:** *The following price equilibria occur in the first market:*

- a) *If only firm  $i$  enters in the first market, it sets the price  $p_m = u^* - \frac{9}{16}\psi$  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  $\mu_1^{I*}, \mu_1^{E*}$  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  $E\Pi^E(\mu_1^{I*}, \mu_1^{E*}) < (u^* - \frac{9}{16}\psi)D_2$ .*

**Proof.** See Appendix. ■

Some comments are in order.

Part (a) of Proposition 3 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 active firm faces two alternatives: extract the monopoly rents from the consumers in the first market, or retain some residual obligations for the second market by overpricing above the monopoly price, leaving some market 1 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, shifting some obligations to the second (competitive) market is not convenient, and the 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  $p_1^i$  (given  $p_1^j$ ) 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 2. 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 both firms enter 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 4:** *When  $\bar{q}_I < D$ , 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  $p_m = u^* - \frac{9}{16}\psi$ .

**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  $\bar{q}_I = D$ . The following Corollary establishes the result.

**Corollary 1:** *When  $\bar{q}_I = D$ , in the unique subgame perfect equilibrium, the incumbent enters in the market and charges the monopoly price  $p_m = u^* - \frac{9}{16}\psi$ , 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, case 1 can be used to describe the equilibrium prices if the entrant enters in the market after the incumbent. 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 the customers in a monopoly position, becomes a high (marginal) cost competitor 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.<sup>11</sup>

<sup>11</sup>Similar results can be found in Dubey (1992) on dynamic pricing with (absolute) capacity constraints. Dubey's paper modifies the standard Edgeworth-Bertrand setting assuming that consumers enter in the market sequentially and purchase during the period; the firms, endowed with a fixed capacity, compete in prices in each period to attract the current consumer. In this setting, pricing in different periods is the key ingredient that allows firms to avoid cut-throat competition or Edgeworth-cycling, exhausting their capacity sequentially and serving

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 have to decide which customers they want to serve by committing to a certain marketing strategy, that in our model corresponds to the initial decision to enter or not a given submarket. 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 our segmentation result is not just an example of the well known result that with high fixed costs (the fixed payments entailed by TOP obligations) a market with intense price competition becomes a monopoly in a free entry equilibrium. Suppose, in fact, that the firms have large fixed costs and *constant* marginal cost, with positive but limited margins over marginal costs in a price equilibrium. In a free entry equilibrium where the incumbent and the entrant decide sequentially to enter or not, we would observe the incumbent monopolizing the entire market: it would enter in each submarket and induce the entrant to stay out to avoid losses over the fixed costs. This traditional story would not deliver the alternating monopoly result that we obtain, such that an incumbent with a first mover advantage in entering any submarket will leave a fraction of the market to the entrant, once exhausted its obligations. What drives our result, indeed, is the low cost capacity of the competitors, that eliminates the incentive to enter once exhausted and that creates reciprocity in the entry/no entry strategy.

## 4 Endogenizing the entrant's obligations

So far we have assumed that the entrant, facing an incumbent endowed with TOP obligations equal to  $\bar{q}^I$ , has a long term contract with obligations equal to  $D - \bar{q}^I$ , so that total obligations equal total demand. Here we want to show that if the entrant chooses  $\bar{q}^E$  in order to maximize profits, it will actually choose exactly  $\bar{q}^E = D - \bar{q}^I$ . 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,  $\bar{q}^E = D - \bar{q}^I$ , in equilibrium its profits can be written as

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the consumers at monopoly prices.

We obtain similar results without absolute capacity constraints and without dynamic pricing. In our setting, in fact, the key ingredient is the different timing in entry and pricing decisions. In the wp version of the paper we prove that segmentation occurs even when both firms decide simultaneously to enter in the different submarkets and then, having observed the entry choices, set simultaneously a price in each of the submarket where they entered. Sequential entry in our case simply allows to eliminate the coordination problem that simultaneous entry otherwise would imply in the choice of submarkets.

$$(u^* - \frac{9}{16}\psi - w)(D - \bar{q}^I).$$

Let us first consider a game where the entrant chooses obligations lower than the residual demand, i.e.  $\bar{q}^E < D - \bar{q}^I$ . 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  $d = 1, \dots, D$  in a sequence or to group them in *three* submarkets of sizes equal to  $\bar{q}^I$ ,  $\bar{q}^E$  and  $D - \bar{q}^I - \bar{q}^E$ . 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<sup>12</sup>:

- in the first submarket of size  $\bar{q}^I$ , only the incumbent enters and sets the monopoly price;
- in the second submarket, of size  $\bar{q}^E$ , the roles are reversed and the entrant is monopolist in this segment;
- for the residual customers,  $D - \bar{q}^I - \bar{q}^E$ , both firms would have marginal cost equal to  $w$  having exhausted their obligations. If they both enter, the equilibrium is symmetric with a price equal to  $w + \frac{\psi}{2}$ , and the two firms serve half of the residual demand gaining positive profits  $\frac{\psi}{4}(D - \bar{q}^I - \bar{q}^E)$ . Hence, both firms enter.

The total profits obtained by the entrant are now  $(u^* - \frac{9}{16}\psi - w)\bar{q}^E + \frac{\psi}{4}(D - \bar{q}^I - \bar{q}^E) < (u^* - \frac{9}{16}\psi - w)(D - \bar{q}^I)$ . Hence, the entrant<sup>13</sup> does not gain from having obligations lower than  $D - \bar{q}^I$ .

Second, consider the case  $\bar{q}^E > D - \bar{q}^I$ , 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  $\bar{q}^I = D_1$  and  $D - \bar{q}^I = D_2$  as before. From the previous analysis, going through the same steps, it is easy to see that the equilibrium entry and price decisions are the same as in Proposition 4, with  $I$  entering the first market, and  $E$  the second one, with sales  $D_2 < \bar{q}^E$ .

Although  $E$  has TOP obligations exceeding residual demand  $D - \bar{q}^I$ , 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  $\bar{q}^I$  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

<sup>12</sup>To save space we leave a formal proof, which is basically the same as the benchmark model, to the reader.

<sup>13</sup>Alternatively, in the spirit of our entry model, we can notice that if  $D > \bar{q}^I + \bar{q}^E$  there is room for a third firm with obligations  $D - \bar{q}^I - \bar{q}^E$  to enter and monopolize the residual demand. The first entrant then would obtain profits  $(u^* - \frac{9}{16}\psi - w)\bar{q}^E < (u^* - \frac{9}{16}\psi - w)(D - \bar{q}^I)$  if installing  $\bar{q}^E < D - \bar{q}^I$ .

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  $D - \bar{q}^I$ , as assumed in the benchmark model. We summarize this discussion in the following Proposition.

**Proposition 5:** *If the entrant chooses its obligations  $\bar{q}^E$  at time 0, given the incumbent's obligations  $\bar{q}^I$ , and then the game follows as in the benchmark model, the entrant chooses obligations equal to the residual demand, i.e.  $\bar{q}^E = D - \bar{q}^I$ .*

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  $\bar{q}^I \cong D$ , 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,  $\hat{q}^I < \bar{q}^I$ .

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

We can analyze the sequential entry game assuming that the two markets are  $D_1 = \hat{q}^I$  and  $D_2 = D - D_1 = \hat{q}^E$  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 the

optimal price is  $p_m = u^* - \frac{9}{16}\psi$  and the firm covers  $D_2$  unless it is the incumbent and has residual obligations  $\hat{q}_2^I < D_2$ . 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 no price equilibrium in pure strategies exists. However, a mixed strategy equilibrium with positive profits exists, as the following Lemma establishes.

**Lemma 3:** *When both firms enter in the second market and  $\hat{q}_2^I + \hat{q}_2^E \geq D_2$ ,  $\hat{q}_2^I > 0$  and  $\hat{q}_2^E > 0$ , there is no pure strategy equilibrium. An equilibrium in mixed strategies  $\mu_2^{I*}, \mu_2^{E*}$  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.  $E\Pi_2^E(\mu_2^{I*}, \mu_2^{E*}) \in (0, (u^* - \frac{9}{16}\psi - w)D_2)$ .*

**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. Moving to the first market pricing strategies, for any price pair  $(p_1^I, p_1^E)$  the incumbent will be able to cover its demand, since  $D_1^I(p_1^I, p_1^E) \leq \hat{q}_1^I$ . 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 3. The following Proposition summarizes the results.

**Proposition 6:** *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: even in this setting, the incentive to spend in different markets the low marginal cost

capacity due to TOP obligations drives the marketing phase of the game, where the firms decide which customers to approach. In this section we want to explore the consequences of separating the wholesale and retail activities, creating a wholesale gas market, where the wholesalers bearing TOP obligations sell and the retailers buy their gas at a (linear) wholesale price.

We argue that breaking the link between the decentralised retail market, where entry decisions in the customers' submarkets are taken, and the upstream wholesale segment, where TOP are imposed by producers, may offer a solution. To this end, two reforms of the market are needed. First of all, operators in the upstream market (wholesalers), that contract and purchase gas from the extractors, cannot participate also in the downstream market (retailers), where firms provide gas to the final consumers. Secondly, a compulsory wholesale market is created where wholesalers sell and retailers buy gas at a common wholesale price. We try to model this alternative environment keeping the structure of the model as close as possible to the benchmark case.

**The wholesale 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  $\bar{q}^I$  and  $\bar{q}^E$  with  $\bar{q}^I + \bar{q}^E = D$ . On the demand side we have the retail firms, which buy gas from the wholesale market and resell it to final consumers. Since gas is a commodity, wholesale transactions entail perfectly homogenous product by the two wholesalers. The equilibrium wholesale price  $p_w$  clears the market.

**The retail market.** The retailers buy at the wholesale price and therefore are free from TOP obligations, and each of them has the same constant marginal cost, equal to the wholesale gas price  $p_w$ , for any amount of gas demanded. As in the benchmark model, final demand can be decomposed into  $D$  (groups of) customers of size equal to 1, 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<sup>14</sup>, with firm  $a$  offering variety  $x^a = \frac{1}{4}$  and firm  $b$  offering variety  $x^b = \frac{3}{4}$  in each submarket.

To sum up, the final demand is the same as in the benchmark model, and the same is true for the wholesale supply of gas and the costs of TOP contracts. However, once a wholesale market is introduced, we obtain a separation between the wholesalers  $I$  and  $E$  bearing TOP obligations and the retailers  $a$  and  $b$ , that select the submarkets to serve with a constant marginal cost  $p_w$ .

Since the retailers in this setting have always the same marginal cost  $p_w$ , when analysing their entry and price decisions there is no need to group the consumers in two subsets  $D_1$  and  $D_2$  (equal to  $\bar{q}^I$  and  $\bar{q}^E$  respectively) as we did in the benchmark model, since in the present setting the entry decisions in the different submarkets  $d = 1, \dots, D$  are all identical. When analyzing the

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<sup>14</sup>The extension to the  $N$  retailers case using the circular road version of the Hotelling model (Salop (1979)) is however straightforward.



retail market we maintain the key assumption of the benchmark model, that is the firms decide entry and price at different stages.

In the benchmark model we also assumed sequential entry in each submarket, with the incumbent moving first: as we claimed in the discussion, this assumption is not crucial for the results, since an equilibrium with segmentation arises even when entry is simultaneous. However, in the asymmetric equilibrium characterized by segmentation the firms had to solve a coordination problem in selecting the "right" submarkets to serve as monopolists. This problem was easily addressed by assuming sequential entry and first mover advantage by the incumbent. Even in the present setting the entry pattern is the same with sequential and simultaneous entry; moreover, we'll show that generalized entry occurs in equilibrium, implying that we have no coordination problem to solve. Therefore we can assume simultaneous entry in each submarket in the first stage, followed by the simultaneous price stage.

Entering and setting prices allows the two retailers to collect the orders. The expected demand for firm  $j = a, b$  from customer  $d$ ,  $D_d^j$ , can be derived according to the same logic of the benchmark model (expressions (4) and (5)). In particular, if both firms  $a$  and  $b$  enter in submarket  $d$  (of size 1) the demand for firm  $j = a, b$  is:

$$D_d^j = \frac{1}{2} + \frac{p_d^i - p_d^j}{\psi}$$

Total demand for retailer  $j = a, b$  is therefore  $D^j(p^a, p^b) = \sum_{d=1}^D D_d^j(p_d^a, p_d^b)$  where  $p^a$  and  $p^b$  are the vectors of prices set by the two firms in the  $D$  submarkets. Finally,  $D(p^a, p^b) = D^a(p^a, p^b) + D^b(p^a, p^b)$  is total demand from the retailers in the wholesale market. The two wholesalers  $I$  and  $E$  compete in prices given total demand.

The timing of the game is therefore:

- at  $t = 1$  the retailers  $j = a, b$  decide simultaneously whether to enter submarkets  $d = 1, \dots, D$  (with total demand  $D$ ); the entry choices become public information once taken;
- at  $t = 2$  the retailers set simultaneously the price vectors  $p^a$  and  $p^b$  and collect the orders in the submarket where they entered;
- at  $t = 3$  the wholesalers  $I$  and  $E$  compete in prices in the (wholesale) market, given the demand from the retailers  $D(p^a, p^b)$ . The retailers purchase at the equilibrium wholesale price  $p_w$  and serve the final customers at the contracted prices  $p^a$  and  $p^b$ .

Let us consider the equilibrium of the game, starting from the third stage, where the two wholesalers  $I$  and  $E$  compete in prices, each endowed with TOP obligations  $\bar{q}^I$  and  $\bar{q}^E$ ,  $\bar{q}^I + \bar{q}^E = D$ . 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 7:** *Let total wholesale demand be  $D(p^a, p^b) = D^a(p^a, p^b) + D^b(p^a, p^b)$ . When  $D(p^a, p^b) = D$  the equilibrium wholesale prices are  $p^I = p^E = p_w = w$ . When  $D(p^a, p^b) < D$  the equilibrium wholesale prices are  $p^I = p^E = p_w \in [0, w)$  and if  $\frac{\partial D^i}{\partial D(p^a, p^b)} \geq 0$  they are increasing in  $D(p^a, p^b)$ .*

**Proof.** See Appendix. ■

The wholesale equilibrium prices described in the Proposition above are equal to the unit cost of gas  $w$  if  $D(p^a, p^b) = D$  ( $= \bar{q}_I + \bar{q}_E$ ), i.e if the retailers serve all the consumers, while  $p_w < w$  if the retail market is rationed, i.e.  $D(p^a, p^b) < D$ . Moreover, under the reasonable assumption that when firms set the same price the individual demand is noncreasing in total demand, the wholesale price is increasing in total sales. Hence, although the wholesalers 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 8:** *In the retail market, each firm  $j = a, b$  approaches all groups of customers  $d = 1, \dots, D$ , and sets a price  $\hat{p}_d^j = p_w + \frac{\psi}{2}$ . The subgame perfect equilibrium of the game is therefore characterized by  $\hat{p}_I = \hat{p}_E = w$  and  $\hat{p}_a^d = \hat{p}_b^d = w + \frac{\psi}{2}$ .*

**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.<sup>15</sup>

A wholesale market succeeds to avoid the segmentation of the retail market and to obtain generalized competition and lower retail margins (prices). The

<sup>15</sup>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 retailers 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 retailers are trading off the profits in the last submarket 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  $w$ .

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 flat and symmetric marginal 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. Notice that sequential entry would determine the same result, since there is no strategic link among submarkets and it is a dominant strategy to enter in each submarket.

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. The literature on supply function equilibria<sup>16</sup> 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 than 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 wholesalers use more complex strategies, increasing accordingly the price for the final customers. The separation of wholesalers and retailers and the creation of a wholesale market, therefore, ensure to squeeze retail margins, but has no effect on the kind of competition in the wholesale market. Even in this case, however, the outcome in the present setting cannot be worse for customers than that of the benchmark model: if the wholesalers collude they will find it profitable to set a wholesale price  $\bar{p}^w$  such that all the final customers purchase given the equilibrium retail prices, i.e.  $\bar{p}^w + \frac{\psi}{2} = u^* - \frac{9}{16}\psi$ . In this case, we have no improvement with respect to the case of decentralized markets. Any wholesale price below  $\bar{p}^w$ , 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: wholesale and retail activities are not separated and are run by the same firms (retailers, that, due to TOP obligations, are endowed with low marginal cost core capacity, with higher marginal costs

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<sup>16</sup>See Klemperer and Meier (1989) and, on the electricity market, Green and Newbery (1992).

for additional supply. The retail market is decentralized and the marketing decision regarding 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 that justifies the expectation of a fragmented market structure in the downstream market.

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 loses 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.

This result persists even when antitrust ceilings or forced divestiture of import contracts are imposed to the incumbent, as in some national liberalization plans in Europe is prescribed: the only effect of these measures is that of shifting market shares and profits to the entrant, without inducing competition in the same submarkets. A more complex reform, instead, can have positive effects on competition. It requires to separate wholesalers, that purchase gas from the producers according to long term contract with TOP clauses, from retailers, that select the submarket to serve and set final prices, creating a wholesale market where the former supply and the latter demand gas. In this case the retailers, when designing their marketing strategy, have a flat marginal cost equal to the wholesale price and their dominant strategy is to enter each and every submarket. Then, generalized price competition occurs and the retail margins are squeezed compared to the benchmark case. The level of the wholesale price (and competition in the wholesale market) becomes crucial in this perspective. With intense competition the final price of gas becomes very low, although we might imagine more complex strategies of the wholesalers, 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 the benchmark case.

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 Lemma 1.

Let's consider first all the possible cases in which the firm(s) set a price that induce all the consumers in the first market to purchase. Since  $\bar{q}^I + \bar{q}^E = D_1 + D_2$  if only  $I$  enters it exhausts its obligations while  $E$  still retains all its obligations:  $\bar{q}_2^I = 0$  and  $\bar{q}_2^E = D_2$  (case 1). If only  $E$  enters the opposite occurs:  $\bar{q}_2^I = D_1 > D_2$  and  $\bar{q}_2^E = 0$  (case 2). If both enter in the first market and  $E$  sets a price such that it does not sell more than its obligations,  $\bar{q}_2^I + \bar{q}_2^E = D_2$  with  $\bar{q}_2^i \in [0, D_2]$ ,  $i = I, E$  (case 1). If both enter and  $E$  sets a price such that it sells more than its obligations,  $I$  remains with residual obligations larger than the second market, i.e.  $\bar{q}_2^I > D_2$  and  $\bar{q}_2^E = 0$  (case 2).

We turn now to all the cases in which the price(s) set by the entrant(s) induce only a fraction of consumers in the first market to purchase. If only  $I$  enters it retains some of its initial obligations while  $E$  still retains all its obligations:  $\bar{q}_2^I + \bar{q}_2^E > D_2$  with  $\bar{q}_2^I > 0$  and  $\bar{q}_2^E = D_2$  (case 2 or 3). If only  $E$  enters it can either exhaust its obligations or retain some of them, according to the price set, while  $I$  retains all its obligations:  $\bar{q}_2^I = D_1 > D_2$  and  $\bar{q}_2^E \geq 0$  (case 2 or 3). If both enter in the first market and  $E$  sets a price such that it does not sell more than its obligations,  $\bar{q}_2^I + \bar{q}_2^E > D_2$  with  $\bar{q}_2^I > D_2$  and  $\bar{q}_2^E \geq 0$  (case 2 or 3). If both enter and  $E$  sets a price such that it sells more than its obligations,  $I$  remains with residual obligations larger than the second market, i.e.  $\bar{q}_2^I > D_2$  and  $\bar{q}_2^E = 0$  (case 2).

Finally, if no firm enters in the first market, both retain their initial obligations:  $\bar{q}_2^I = D_1$  and  $\bar{q}_2^E = D_2$  (case 3). ■

**Proof.** of Lemma 2.

Notice at first that for given  $p_2^j$  any  $p_2^i \leq \bar{p}_2^i(p_2^j, \bar{q}_2^i)$  implies  $D_2^i(p_2^i, p_2^j) \geq \bar{q}_2^i$  and  $c = w$  and any  $p_2^i > \bar{p}_2^i(p_2^j, \bar{q}_2^i)$  implies  $D_2^i(p_2^i, p_2^j) < \bar{q}_2^i$  and  $c = 0$ . Now, suppose that for a given  $p_2^j$  we have  $D_2^i(\hat{p}_2^i(p_2^j, 0), p_2^j) < \bar{q}_2^i$ . Then, it must be that the optimal reply for firm  $i$  is  $BR_2^i(p_2^j) = \hat{p}_2^i(p_2^j, 0)$ . We have in fact  $\bar{p}_2^i(p_2^j, \bar{q}_2^i) < \hat{p}_2^i(p_2^j, 0)$ , the profits are maximized at  $\hat{p}_2^i(p_2^j, 0)$  for any  $p_2^i > \bar{p}_2^i(p_2^j, \bar{q}_2^i)$ , they are increasing (from above) at  $\bar{p}_2^i(p_2^j, \bar{q}_2^i)$  and become steeper for lower  $p_2^i$  as the marginal costs switches from 0 to  $w$ . Hence,  $\hat{p}_2^i(p_2^j, 0)$  is the global maximum. Solving explicitly the condition  $D_2^i(\hat{p}_2^i(p_2^j, 0), p_2^j) = \bar{q}_2^i$  in terms of  $p_2^j$  gives us the boundary of this region. If  $\frac{\psi}{2D_2}(4\bar{q}_2^i - D_2) > 0$  this region is non-empty.

Suppose now that for a given  $p_2^j$  we have  $D_2^i(\hat{p}_2^i(p_2^j, w), p_2^j) \geq \bar{q}_2^i$ , that implies  $\bar{p}_2^i(p_2^j, \bar{q}_2^i) \geq \hat{p}_2^i(p_2^j, w)$ , the profits are maximized at  $\hat{p}_2^i(p_2^j, w)$  for any  $p_2^i \leq \bar{p}_2^i(p_2^j, \bar{q}_2^i)$ , they are decreasing and continuous at  $\bar{p}_2^i(p_2^j, \bar{q}_2^i)$  and decreasing for higher  $p_2^i$  when we enter into the region where the marginal costs switches from  $w$  to 0, since  $\hat{p}_2^i(p_2^j, 0) < \hat{p}_2^i(p_2^j, w)$ . Hence,  $\hat{p}_2^i(p_2^j, w)$  is the global maximum. Solving explicitly the condition  $D_2^i(\hat{p}_2^i(p_2^j, w), p_2^j) = \bar{q}_2^i$  in terms of  $p_2^j$  gives us the boundary of this region.

For intermediate values of  $p_2^j$  we have  $D_2^i(\hat{p}_2^i(p_2^j, 0), p_2^j) > \bar{q}_2^i \geq D_2^i(\hat{p}_2^i(p_2^j, w), p_2^j)$ , that implies  $\hat{p}_2^i(p_2^j, 0) < \bar{p}_2^i(p_2^j, \bar{q}_2^i) \leq \hat{p}_2^i(p_2^j, w)$ . Hence, at  $\bar{p}_2^i(p_2^j, \bar{q}_2^i)$  the profits are kinked,  $\Pi_2^i(p_2^i, p_2^j, w)$  is nondecreasing from below and  $\Pi_2^i(p_2^i, p_2^j, 0)$  is nonincreasing from above, implying that  $\bar{p}_2^i(p_2^j, \bar{q}_2^i)$  is a maximum. If  $\frac{\psi}{2D_2}(4\bar{q}_2^i - D_2) > 0$ , when  $p_2^j = \frac{\psi}{2D_2}(4\bar{q}_2^i - D_2)$  we have  $\hat{p}_2^i(p_2^j, 0) = \bar{p}_2^i(p_2^j, \bar{q}_2^i)$ , i.e. the best reply  $BR_2^i(p_2^j)$  is continuous moving from the first to the second region. For  $p_2^j = w + \frac{\psi}{2D_2}(4\bar{q}_2^i - D_2)$  we have  $\hat{p}_2^i(p_2^j, w) = \bar{p}_2^i(p_2^j, \bar{q}_2^i)$  and the best reply  $BR_2^i(p_2^j)$  is continuous moving from the second to the third region. ■

**Proof.** of Proposition 1 .

If both firms enter in the second market, we have price competition with residuals obligations that fall in one of the three cases analyzed in Lemma 1. The best reply functions in these subgames differ for the position of the intermediate segments

$$\begin{aligned}\bar{p}_2^i(p_2^j, \bar{q}_2^i) &= p_2^j - \frac{\psi}{2D_2}(2\bar{q}_2^i - D_2) \\ \bar{p}_2^j(p_2^i, \bar{q}_2^j) &= p_2^i - \frac{\psi}{2D_2}(2\bar{q}_2^j - D_2).\end{aligned}$$

In order to identify their relative position we can substitute the second in the first:

$$\bar{p}_2^i(\bar{p}_2^j(p_2^i, \bar{q}_2^j), \bar{q}_2^i) = p_2^i - \frac{\psi}{D_2}(\bar{q}_2^i + \bar{q}_2^j - D_2).$$

This expression can be interpreted in the following way: pick a price  $p_2^i$  and identify the price of firm  $j$  that makes firm  $j$ 's demand equal to its residual obligations:  $\bar{p}_2^j(p_2^i, \bar{q}_2^j)$ . Evaluate at  $\bar{p}_2^j(p_2^i, \bar{q}_2^j)$  the price of firm  $i$  that gives a demand for firm  $i$  equal to its residual obligation, i.e.  $\bar{p}_2^i(\bar{p}_2^j(p_2^i, \bar{q}_2^j), \bar{q}_2^i)$ . If this

price for firm  $i$  is smaller than the original price  $p_2^i$ , then  $\bar{p}_2^i(p_2^j, \bar{q}_2^i)$  lies to the left of  $\bar{p}_2^j(p_2^i, \bar{q}_2^j)$ , etc.

If  $\bar{q}_2^i + \bar{q}_2^j = D_2$  the two segments overlap, i.e.  $\bar{p}_2^i(\bar{p}_2^j(p_2^i, \bar{q}_2^j), \bar{q}_2^i) = p_2^i$  while if  $\bar{q}_2^i + \bar{q}_2^j > D_2$  we have  $\bar{p}_2^i(\bar{p}_2^j(p_2^i, \bar{q}_2^j), \bar{q}_2^i) < p_2^i$ , implying that  $\bar{p}_2^i(p_2^j, \bar{q}_2^i)$  lies to the left (above)  $\bar{p}_2^j(p_2^i, \bar{q}_2^j)$  in the  $(p_2^i, p_2^j)$  space. Let us now consider the three cases in the statement of the Proposition.

In case 1),  $\bar{q}_2^i + \bar{q}_2^j = D_2$ , the two best reply functions overlap along the intermediate segments giving a continuum of Nash equilibria. Among them, we select the Pareto dominant price pair. If  $\bar{q}_2^i \leq D_2/2$  the two best reply functions overlap below or at the locus  $p_2^i = p_2^j$  and the higher price pair is identified - see figure 2 - by the intersection of  $\bar{p}_2^i(p_2^j, \bar{q}_2^i)$  and  $\hat{p}_2^i(p_2^j, w)$ , i.e.  $p_2^{i*} = \hat{p}_2^i(p_2^{j*}, w)$  and  $p_2^{j*} = \bar{p}_2^j(p_2^{i*}, \bar{q}_2^j)$ . The solution is given in the statement of the Proposition. Notice that the two firms sell exactly their residual obligations and that  $p_2^{i*} > p_2^{j*} > 0$  due to assumption (3).

In case 2) we have  $\bar{q}_2^i + \bar{q}_2^j > D_2$  and  $\bar{q}_2^i \leq D_2/2 < \bar{q}_2^j$ . Hence,  $\bar{p}_2^i(p_2^j, \bar{q}_2^i) < \bar{p}_2^j(\bar{p}_2^i(p_2^i, \bar{q}_2^i), \bar{q}_2^j) < p_2^i$ , that is, the intermediate segments of both best reply functions are below the locus  $p_2^i = p_2^j$ , with  $\bar{p}_2^i(p_2^j, \bar{q}_2^i)$  above  $\bar{p}_2^j(p_2^i, \bar{q}_2^j)$ . Then, the two best reply functions intersect - see figure 2 - at  $p_2^{i*} = \bar{p}_2^i(p_2^{j*}, \bar{q}_2^i)$  and  $p_2^{j*} = \hat{p}_2^j(p_2^{i*}, 0)$ : the explicit solutions are in the statement. Notice that at the equilibrium prices only firm  $i$  sells all its capacity ( $p_2^{j*} > \bar{p}_2^j(p_2^{i*}, \bar{q}_2^j)$ )

In case 3)  $\bar{q}_2^i + \bar{q}_2^j > D_2$  and  $\bar{q}_2^i, \bar{q}_2^j > D_2/2$  we have  $\bar{p}_2^i(\bar{p}_2^j(p_2^i, \bar{q}_2^i), \bar{q}_2^j) < \bar{p}_2^j(p_2^i, \bar{q}_2^j) < p_2^i$ , that is, the intermediate segment  $\bar{p}_2^i(p_2^j, \bar{q}_2^i)$  lies above the locus  $p_2^i = p_2^j$  while  $\bar{p}_2^j(p_2^i, \bar{q}_2^j)$  lies below it. Then, the two best reply functions intersect - see figure 2 - at  $p_2^{i*} = \hat{p}_2^i(p_2^{j*}, 0)$  and  $p_2^{j*} = \hat{p}_2^j(p_2^{i*}, 0)$  and in the symmetric equilibrium each firm covers half of the market.

In case 4) if only firm  $i$  enters market 2, the demand is described above by (4) or (5). 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). The profits are maximized at  $p_m$  for any level of the marginal cost, and therefore, the equilibrium price if only one firm enters in the market is  $p_2^{i*} = u^* - \frac{9}{16}\psi = p_m$  for any possible level of the residual obligations of the entrant. ■

**Proof.** of Proposition 2.

In Lemma 1 we have identified the relevant subgames in the second market, indexed to the residual obligations  $\bar{q}_2^I$  and  $\bar{q}_2^E$  of the two firms (cases 1-3), while in Proposition 1 we have characterized the corresponding price equilibria in case one or both firms enter. If both firms enter, no firm in the relevant subgames sells more than its residual obligations and obtains positive profits if it has positive residual obligations. If a firm already exhausted its obligations and enters, it obtains no sales and profits in the corresponding price equilibrium. Hence, according to the no frivolous entry assumption, it does not enter. If, instead, a firm has positive residual obligations, entering is a dominant strategy: if the



other firm does not enter the entrant realizes the monopoly profits; if it enters as well, the former firm obtains positive sales and profits. ■

**Proof.** of Proposition 3.

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 at  $p_m = u^* - \frac{9}{16}\psi$ . If firm  $I$  sets a price  $p_1^I > p_m$ ,  $D_1^I(p_1^I) < D_1$ , leaving some residual obligation  $\bar{q}_2^I = D_1 - D_1^I(p_1^I) > 0$ . Proposition 2 has shown that in this case both firms will enter also in the second market.  $I$ 's overall profits are  $\Pi^I = p_1^I D_1^I(p_1^I) + \min\{\psi \frac{D_2}{2}, (3\psi - 4\psi \bar{q}_2^I / D_2) \bar{q}_2^I\}$ . Then the derivative of the profit function evaluated at  $p_1^I \rightarrow^+ u^* - \frac{9}{16}\psi$  is

$$\frac{\partial \Pi^I}{\partial p_1^I} = 1 - \frac{2}{3\psi}(u^* - \frac{9}{16}\psi) - \frac{9D_1 - 12D_2}{12\psi D_2} < 0$$

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  $P = \{(p_1^I, p_1^E) \in [0, u^*]^2\}$ :

$$\begin{aligned} P^A &= \left\{ (p_1^I, p_1^E) \mid p_1^I \in [0, u^*], p_1^E \in [0, \min\{p_1^I + \psi \tilde{D}, u^*\}] \right\} & (10) \\ P^B &= \left\{ (p_1^I, p_1^E) \mid p_1^I \in [0, u^* - \psi \tilde{D}], p_1^E \in (p_1^I + \psi \tilde{D}, \min\{p_1^I + \frac{\psi}{2}, u^*\}) \right\} \\ P^C &= \left\{ (p_1^I, p_1^E) \mid p_1^I \in [0, u^* - \frac{\psi}{2}], p_1^E \in [p_1^I + \frac{\psi}{2}, u^*] \right\} \end{aligned}$$

where  $\tilde{D} = (D_1 - 2D_2)/2D_1$ . When  $(p_1^I, p_1^E) \in P^A$  firm  $E$  exhausts its obligations in the the first market ( $D_1^E(p_1^I, p_1^E) \geq D_2 = \bar{q}^E$ ) and does not enter in the second. Conversely, when  $(p_1^I, p_1^E) \in P^C$  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  $(p_1^I, p_1^E) \in P^B$  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 prove part (b) distinguishing the three points.

**Point 1.** We prove that no price equilibrium in pure strategies exists if both firms enter in the first market. 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  $\Pi^I$  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  $\bar{q}_2^I$ , and the second market profits, tend to zero. Hence,  $\Pi^I$  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  $\Pi_I$  has a global maximum at the boundary of  $P^A$  where the market 2 monopoly profits are added, and the incumbent best reply is  $p_1^I = p_1^E - \psi\tilde{D}$ . 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  $P^i \subseteq R^+$  and the discontinuity set for the incumbent is (using Dasgupta and Maskin notation)

$$P^{**}(I) = \left\{ (p_1^I, p_1^E) \mid p_1^I \in [0, u^* - \psi\tilde{D}], p_1^E = p_1^I + \psi\tilde{D} \right\},$$

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

$$P^{**}(E) = \left\{ (p_1^I, p_1^E) \mid p_1^I \in [0, u^* - \frac{\psi}{2}], p_1^E = p_1^I + \frac{\psi}{2} \right\},$$

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  $\Pi^i(p_1^I, p_1^E)$  is continuous elsewhere. Second,  $\Pi = \Pi^I + \Pi^E$  is upper semi-continuous (see Definition 2 in Dasgupta and Maskin (1986)): since  $\Pi^I$ ,  $\Pi^E$  and  $\Pi$  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  $p^n \rightarrow p$ ,  $\lim_{n \rightarrow \infty} \Pi(p^n) = \Pi(p)$ . 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  $p^n \rightarrow p$ , then  $\lim_{n \rightarrow \infty} \Pi(p^n) < \Pi(p)$ , i.e. the joint profits jump up. Third,  $\Pi^i(p_1^I, p_1^E)$  is weakly lower semi-continuous in  $p_1^i$  according to Definition 6 in Dasgupta and Maskin (1986). At  $(\bar{p}_1^I, \bar{p}_1^E) \in P^{**}(I)$ , if we take (see Dasgupta and Maskin (1986)  $\lambda = 0$ ,  $\lim_{p_1^I \rightarrow +\bar{p}_1^I} \Pi^I(p_1^I, \bar{p}_1^E) = \Pi^I(\bar{p}_1^I, \bar{p}_1^E)$ ). Analogously, at  $(\bar{p}_1^I, \bar{p}_1^E) \in P^{**}(E)$ , if we take  $\lambda = 1$ ,  $\lim_{p_1^E \rightarrow -\bar{p}_1^E} \Pi^E(\bar{p}_1^I, p_1^E) > \Pi^E(\bar{p}_1^I, \bar{p}_1^E)$ . Then all the conditions required in Theorem 5 are satisfied and a mixed strategy equilibrium  $(\mu_1^{I*}, \mu_1^{E*})$  exists.

**Point 3.** Finally, we prove that  $E\Pi^I(\mu_1^{I*}, \mu_1^{E*}) > 0$  and  $E\Pi^E(\mu_1^{I*}, \mu_1^{E*}) < (u^* - \frac{9}{16}\psi)D_2$ . The first inequality simply follows from the fact that  $\Pi^i(p_1^I, p_1^E) >$

0 for any  $p \in P$ . To establish the second inequality, notice that  $\max_{p \in P} \Pi^E(p_1^I, p_1^E) = (u^* - \frac{9}{16}\psi)D_2$ , occurring when  $p \in P^C$ . Let the support of the mixed strategy  $\mu_1^{i*}$  be  $M^{i*}$ . Suppose that the mixed strategies  $\mu_1^{I*}, \mu_1^{E*}$  are such that in the mixed strategy equilibrium  $p \in P^C$  occurs with probability 1: since  $\mu_1^{I*}$  and  $\mu_1^{E*}$  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  $\mu_1^{I*}$  while  $E$  plays  $\mu_1^{E*}$  by setting a price  $\bar{p}_1^I \notin M^{I*}$  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,  $E\Pi^E(\mu_1^{I*}, \mu_1^{E*}) < (u^* - \frac{9}{16}\psi)D_2$ . ■

**Proof.** of Proposition 4.

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:

- $e_1^I = 1, e_1^E = 1$ : we have seen that in the mixed strategy equilibrium the two firms obtain expected gross profits  $E\Pi^I > 0$  and  $0 < E\Pi^E < (u^* - \frac{9}{16}\psi)D_2$ .
- $e_1^I = 1, e_1^E = 0$ : 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  $\Pi^E = (u^* - \frac{9}{16}\psi - w)D_2$ .
- $e_1^I = 0, e_1^E = 1$ : 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  $\Pi^E = (u^* - \frac{9}{16}\psi - w)D_1$ .
- $e_1^I = 0, e_1^E = 0$ : if no firm enters in the first market, both will enter in the second with profits  $\Pi^I = \psi\frac{D_2}{4} - wD_1$  and  $\Pi^E = \psi\frac{D_2}{4} - wD_2$ .
- Since the incumbent moves first, and makes positive profits entering the first market for any reaction of the entrant,  $I$  enters. Since  $E\Pi^E < (u^* - \frac{9}{16}\psi)D_2$  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 3.

We start by considering the best reply functions in the price game of the second market when  $\hat{q}_2^I + \hat{q}_2^E = D_2$ , keeping in mind that, contrary to the benchmark case, the incumbent cannot sell more than its ceiling  $\hat{q}_2^I$ . Its profit function in the second market is  $\Pi_2^I = p_2^I \min(D_2^I(p_2^I, p_2^E), \hat{q}_2^I)$ . Let us introduce the following notation:

$$\tilde{p}_2^I(\hat{q}_2^I) = u^* - \psi \max \left\{ \frac{1}{16}, \left( \frac{1}{4} - \hat{q}_2^I \right)^2 \right\}$$

that is the maximum price that induces all the  $\hat{q}_2^I$  consumers to buy from  $I$  rather than nothing. The best reply for the incumbent is therefore

$$BR_2^I(p_2^E) = \begin{cases} \tilde{p}_2^I(p_2^E, 0) & \text{for } p_2^E \in \left[0, \max\left\{0, \frac{\psi}{2D_2}(4\hat{q}_2^I - D_2)\right\}\right] \\ \min\{\bar{p}_2^I(p_2^E, \hat{q}_2^I), \tilde{p}_2^I(\hat{q}_2^I)\} & \text{for } p_2^E \in \left[\max\left\{0, \frac{\psi}{2D_2}(4\hat{q}_2^I - D_2)\right\}, u^*\right] \end{cases}$$

where  $\bar{p}_2^I(p_2^E, \hat{q}_2^I)$  is such that  $D_2^I(\bar{p}_2^I(p_2^E, \hat{q}_2^I), p_2^E) = \hat{q}_2^I$ . Hence, when  $p_2^E$  is very low the incumbent maximizes its profits selling less than its ceiling while for higher prices of the entrant  $I$  sets the price that induces all the  $\hat{q}_2^I$  consumers to buy from it: notice that for very high prices of the entrant the best alternative to  $I$  for those consumers is to buy nothing rather than purchasing from  $E$ .

The entrant's profits are  $\Pi_2^E = (p_2^E - c^E)(D_2 - \min(D_2^I(p_2^E, p_2^E), \hat{q}_2^I))$  with  $c^E = \{0, w\}$ . Since the incumbent cannot sell more than  $\hat{q}_2^I$ , the entrant has an incentive to set the highest price that induces all the  $D_2 - \hat{q}_2^I$  consumers to buy from it rather than nothing:

$$\tilde{p}_2^E(\hat{q}_2^I) = u^* - \psi \max\left\{\frac{1}{16}, \left(\frac{3}{4} - \hat{q}_2^I\right)^2\right\}$$

This price is the best reply for prices of the incumbent that are not extremely high. To check whether  $\tilde{p}_2^E(\hat{q}_2^I)$  is always the entrant best reply, let us consider

$$\frac{\partial \Pi_2^E(\tilde{p}_2^I(\hat{q}_2^I), \tilde{p}_2^E(\hat{q}_2^I), w)}{\partial p_2^E} = w - u^* + \psi \left( \frac{1}{2} - \max\left\{\frac{1}{16}, \left(\frac{1}{4} - \hat{q}_2^I\right)^2\right\} + 2 \max\left\{\frac{1}{16}, \left(\frac{3}{4} - \hat{q}_2^I\right)^2\right\} \right)$$

It is easy to check that for any value of  $\hat{q}_2^I \in (0, D_2]$  this derivative is negative given Assumption (2). Hence, while for relatively low values of  $p_2^I$  the entrant has an incentive to set the highest price  $\tilde{p}_2^E(\hat{q}_2^I)$  that allows it to serve the residual market  $D_2 - \hat{q}_2^I$ , when  $p_2^I$  approaches its maximum level  $\tilde{p}_2^I(\hat{q}_2^I)$  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.  $D_2^E(p_2^I, p_2^E) > D_2 - \hat{q}_2^I$ . Hence, no price equilibrium in pure strategies exists when  $\hat{q}_2^I + \hat{q}_2^E = D_2$ . The case  $\hat{q}_2^I + \hat{q}_2^E > D_2$  is basically the same, the only difference being the marginal cost of the entrant equal to 0 when computing the derivative  $\partial \Pi_2^E / \partial p_2^E$  at  $\tilde{p}_2^I(\hat{q}_2^I), \tilde{p}_2^E(\hat{q}_2^I)$ . It is evident that even in this case the derivative is negative.

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  $p_2^I \in [0, u^*]$  is compact and convex. Hence, we can apply Glicksberg (1952) Theorem establishing that a mixed strategy equilibrium  $(\mu_2^{I*}, \mu_2^{E*})$  exists.

Finally,  $E\Pi_2^E(\mu_2^{I*}, \mu_2^{E*}) = 0$  would occur only if in the mixed strategy equilibrium  $p_2^E = 0$  with probability 1, since any other price pair below  $\tilde{p}_2^E(\hat{q}_2^I)$  would leave at least  $D_2 - \hat{q}_2^I$  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,  $E\Pi_2^I(\mu_2^{I*}, \mu_2^{E*}) = (u^* - \frac{9}{16}\psi - w)D_2$  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  $p_2^E = u^* - \frac{9}{16}\psi$ . 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 7.

First notice that wholesale demand is  $D(p^a, p^b) \leq D$ . The wholesalers are not capacity constrained, as they can purchase from the extractors at unit cost  $w$  any quantity exceeding their obligations  $\bar{q}^i$ . 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.  $p^i = p^j$ ,  $i, j = I, E, i \neq j$ , its profits are  $\Pi^i = p^j D^i$ , where  $D^i$  are firm  $i$  sales: if  $D(p^a, p^b) = \bar{q}^I + \bar{q}^E$ , then  $D^i = \bar{q}^i$  while if  $D(p^a, p^b) < \bar{q}^I + \bar{q}^E$ , then  $D^i \leq \bar{q}^i$ , with strict inequality for at least one firm. If firm  $i$  undercuts firm  $j$ , setting  $p^i = p^j - \varepsilon$ , taking the limit for  $\varepsilon \rightarrow 0$  the profits are  $\Pi^i = p^j D(p^a, p^b) - w(D(p^a, p^b) - \bar{q}^i)$ , i.e. firm  $i$  supplies the entire demand and purchases additional gas  $D(p^a, p^b) - \bar{q}^i$  at unit price  $w$ . Then, comparing the two profits (and reminding that for  $p^j > w$  it is always optimal to undercut) we can identify the condition that makes undercutting profitable:

$$p^j > w \frac{D(p^a, p^b) - \bar{q}^i}{D(p^a, p^b) - D^i} \equiv \underline{p}^j$$

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  $p^i = p^j = \min\{\underline{p}^i, \underline{p}^j\}$ . 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  $D(p^a, p^b) = \bar{q}^I + \bar{q}^E$ , then  $D^i = \bar{q}^i$  and  $\min\{\underline{p}^i, \underline{p}^j\} = w$ . If instead  $D(p^a, p^b) < \bar{q}^I + \bar{q}^E$ ,  $\min\{\underline{p}^i, \underline{p}^j\} < w$ . Since  $\min\{\underline{p}^i, \underline{p}^j\}$  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  $\frac{\partial D^i}{\partial D(p^a, p^b)} \geq 0$ , i.e. that if total demand falls individual demand cannot increase when firms set the same price, we obtain

$$\frac{\partial \underline{p}^i}{\partial D(p^a, p^b)} = w \frac{\bar{q}^i - D^i + \frac{\partial D^i}{\partial D(p^a, p^b)}(\min\{\underline{p}^i, \underline{p}^j\} - \bar{q}^i)}{(\min\{\underline{p}^i, \underline{p}^j\} - D^i)^2} > 0$$

Hence, even without choosing an explicit allocation rule we are able to show that under reasonable conditions the equilibrium wholesale price  $p_w$  is increasing in total demand and sales  $D(p^a, p^b)$ . ■

**Proof.** of Proposition 8.

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  $D(p^a, p^b)$  is equal to  $D$  and  $p_w < w$  if total demand for gas is lower than  $D$ . If both firms enter in submarket  $d$ , firm  $i$ 's profits,  $i, j = a, b, i \neq j$ , are

$$\Pi_d^i = \left[ \frac{1}{2} + \frac{p_d^j - p_d^i}{\psi} \right] (p^d - p_w)$$

If we consider submarket  $d$  in isolation, the unique symmetric equilibrium in prices is  $p_d^{*i} = p_d^{*j} = p_w + \frac{\psi}{2}$ , with the two firms covering half of demand  $D_d = 1$ . The profits in this submarket are  $\Pi_d^i = \frac{\psi}{4}$ , independently of the level of the marginal cost  $p_w$ . Since the marginal cost of the two firms is flat for any level of output and the profits add-up a margin  $\frac{\psi}{2}$  over (any) marginal cost  $p_w$ , there is no strategic link among submarket and with total demand in the wholesale market, and this pricing strategy is the symmetric equilibrium in all submarkets where the two firms enter. 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 ( $\frac{\psi}{4}$  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  $w$ . ■

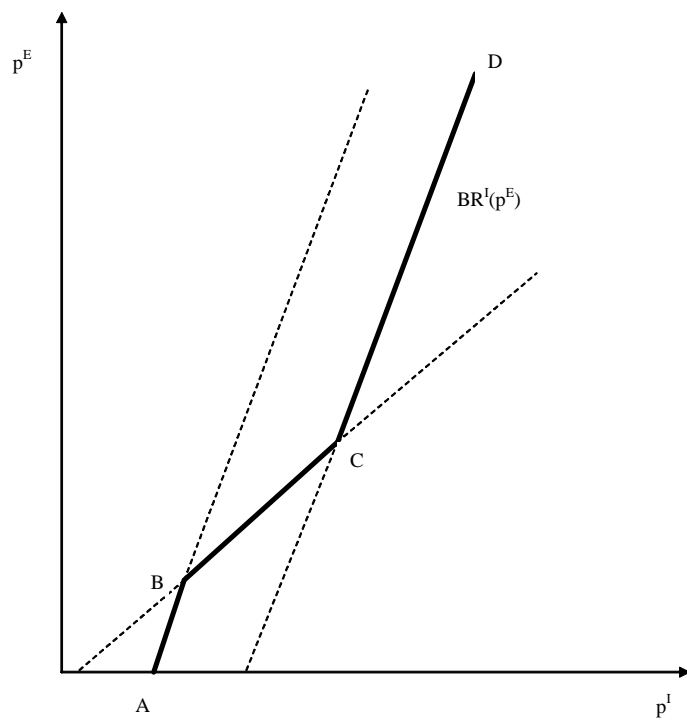


Figure 1: Best Reply:  $BR^I(p^E)$

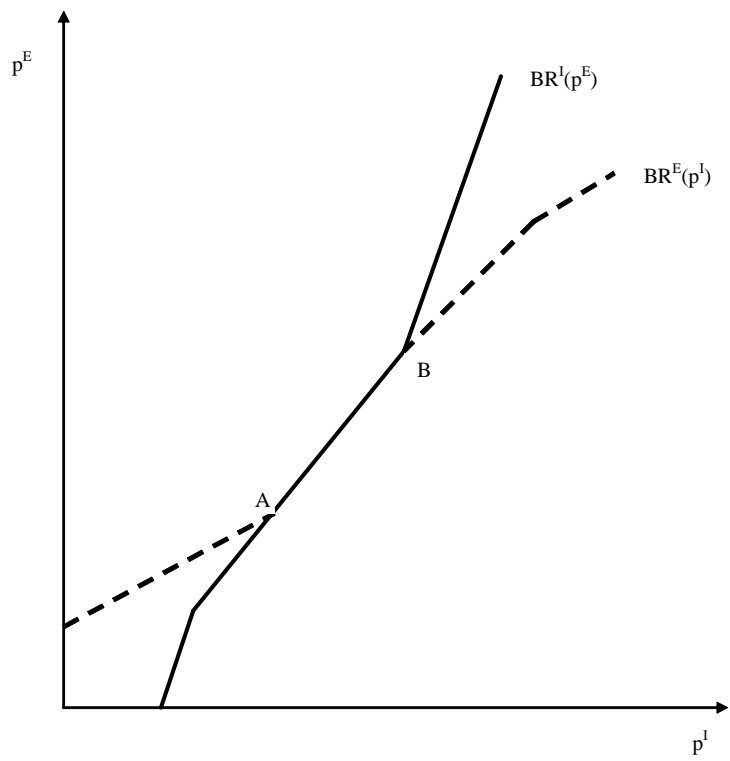


Figure 2: Equilibrium Prices: A-B (case 1)



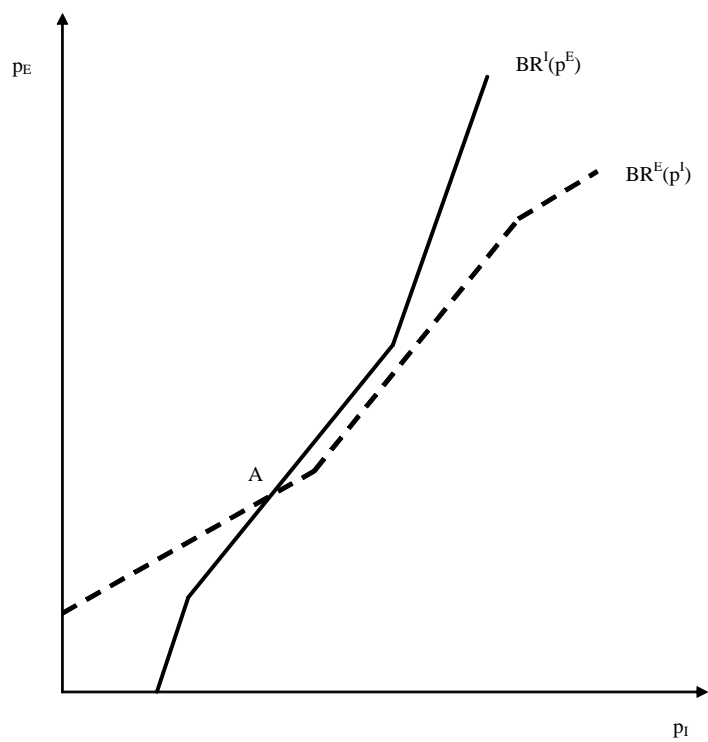


Figure 2: Equilibrium Price: A (case 2)

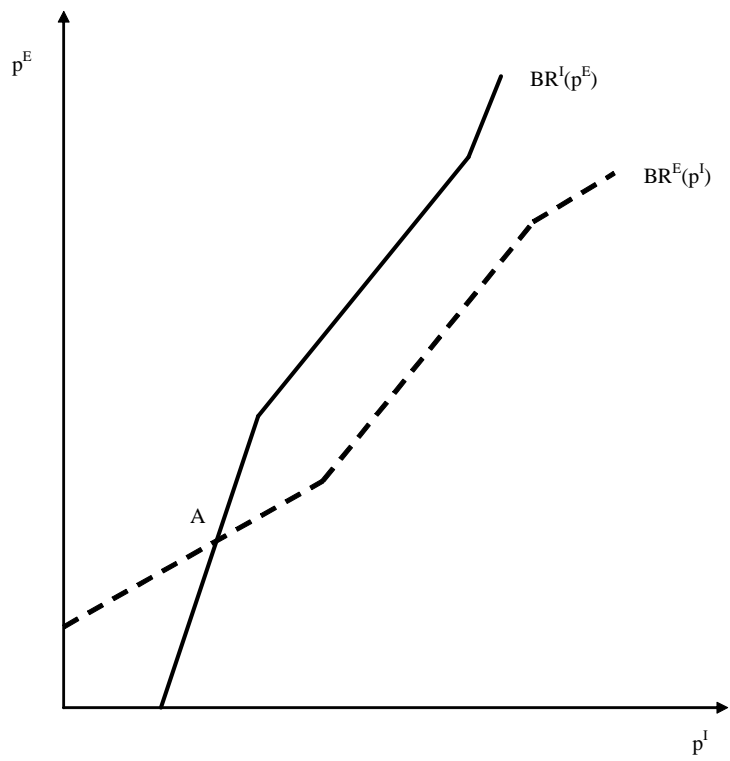


Figure 2: Equilibrium Price: A (case 3)