International Journal of Industrial Organization 31 (2013) 64–82

Contents lists available at SciVerse ScienceDirect

International Journal of Industrial Organization

journal homepage: www.elsevier.com/locate/ijio

Liberalizing the gas industry: Take-or-pay contracts, retail competition and wholesale trade☆

Michele Polo [a,*], Carlo Scarpa [b]

[a] Bocconi University, IGIER and IEFE, Italy
[b] University of Brescia, Italy

ARTICLE INFO

Article history:
Received 15 September 2007
Received in revised form 13 August 2012
Accepted 7 October 2012
Available online 13 November 2012

JEL classification:
L11
L13
L95

Keywords:
Entry
Segmentation
Capacity constraints
Wholesale markets

ABSTRACT

This paper examines retail competition in a liberalized gas market. Vertically integrated firms run both wholesale activities (buying gas from the producers under take-or-pay obligations) and retail activities (selling gas to final customers). The market is decentralized and the firms decide which customers to serve, competing then in prices. We show that TOP clauses limit the incentives to face-to-face competition and determine segmentation and monopoly pricing even when entry of new competitors occurs. The development of wholesale trade, instead, may induce generalized entry and retail competition. This equilibrium outcome is obtained if a compulsory wholesale market is introduced, even when firms are vertically integrated, or under vertical separation of wholesale and retail activities when firms can use only linear bilateral contracts.

1. Introduction

In this paper, we analyze the obstacles to retail competition in a natural gas market, bearing in mind the liberalization process implemented in Europe. Since the second part of the Nineties 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 Directives 1998/30, 2003/55 and the third energy package in 2009 have specified the lines of reform that the Member Countries have then followed in their national liberalization plans. Although the wording is almost identical to the one in the electricity Directive 2003/54,[1] the solutions adopted in the gas and in the electricity markets concerning the organization of wholesale trades are quite different. In electricity markets, some form of organized wholesale trade has been introduced from the beginning throughout Europe, while the prevailing solution for the natural gas industry involves until recently a direct participation of producers and importers in the retail market, or bilateral trades between wholesalers and retailers with no particular attention to the organization of wholesale trades. Comparing the different measures, we can observe in the Second Directive a shift towards more effective forms of separation of the infrastructure from the upstream and downstream activities and in the third package a role for gas hubs and the development of wholesale markets.

☆ We want to thank two anonymous referees and especially the Editor for their suggestions, and Paolo Battigalli, Emilio Calvano Claude Crampes, Chiara Fumagalli, Joe Harrington, Alberto Iozzi, Massimo Motta, Fausto Panunzi, Nicolas Schutz, and Jonathan Stern, and seminar participants at Bocconi, CREST-LEI Paris, Idei-Toulouse, the Cresse Conference 2007 — Corfu, ESMT Berlin, the Italian Energy Regulator, EAFIT, Medellin and ZEW energy Conference 2012 for their comments. Usual disclaimers apply.

* Corresponding author at: Department of Economics, Bocconi University, Via Sarfatti 25, 20136 Milan, Italy. Tel.: +39 0258363307; fax: +39 0258365314.
E-mail address: michele.polo@uni-bocconi.it (M. Polo).

[1] "In order to ensure effective market access for all market players including new entrants, non discriminatory and cost-reflective balancing mechanisms are necessary. As soon as the gas market is sufficiently liquid, this should be achieved through the setting up of transparent market-based mechanisms for the supply and purchase of gas (electricity) needed in the framework of balancing requirements", EC 2003/54 (17) and EC 2003/55 (15).

0167-7187/$ – see front matter
http://dx.doi.org/10.1016/j.ijindorg.2012.10.003

The long term contracts adopted in the industry are typically characterized by take-or-pay (TOP) clauses.[2] A TOP 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 withdraw (and resell) it, and further payments at a marginal price are due if the company wants to receive additional supplies. 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 delivery threshold. With TOP clauses the structure of costs is affected, the marginal cost of gas being negligible up to the obligations and positive for larger amounts.

TOP clauses pre-exist the liberalization of European markets and are justified by risk-sharing and financial commitments when large investments in the extraction of gas and in the building of dedicated infrastructures are required. However, we argue that once the liberalization process starts, the existence of TOP obligations not only creates problems in implementing third party access to transport infrastructures, but may introduce a natural strategic incentive for firms to avoid face-to-face competition for final customers. This concern was perceived in the early stages of the discussion on gas liberalization. In a document of the House of Lords, for instance, we read that "*there was little or no gas-on-gas competition since the few importers there were had divided the market between them through a series of long term contracts characterized by costly take-or-pay clauses and supply prices based on the price of competing fuels*".[3]

Our paper shows that when wholesale trade is not developed and retailers directly bear TOP obligations, they have the incentive to target different groups of customers with neither competition nor benefits for the consumers. However, if wholesale trade develops, an impact on retail competition may arise. More precisely, we show that the creation of a compulsory wholesale market can promote retail competition even when wholesale and retail activities are not separated. Alternatively, retail competition is enhanced if wholesale and retail activities are unbundled and wholesale contracts are restricted to linear prices with unbounded deliveries. Gas release programs, instead, a measure adopted in some of the national liberalization plans, at best can promote competition only in a small segment of the retail market.

The discussion on the liberalization of the gas industry so far has focused on the development and access to international and national transport infrastructures and on the unbundling of infrastructures from the other activities of incumbent firms.[4] The 2006 Energy sector inquiry of the European Commission stresses that problems of access are still the main concern of policy makers, although in recent years some improvements have been realized. Our results suggest that there is still an element missing in the liberalization plans, and offer a set of solutions to make the development of competition in the retail market more effective.

The segmentation result can be illustrated in a very intuitive way. In a decentralized retail market organization as the one presently prevailing in Europe, retail activities require firms to select which segments of demand to approach and serve (marketing strategy), then competing in prices, while wholesale activities entail buying gas from producers or importers under long term contracts with TOP clauses, the only source of gas when domestic wholesale trade is not developed. When these activities are run within the same firm, short run price competition leads to the following outcomes: if two firms with TOP obligations target the same customers, they have the same (zero) marginal costs, and in equilibrium they obtain positive sales (and low margins due to price competition). If instead only one of the two firms has TOP obligations, the high marginal cost competitor is unable to obtain positive sales and profits in a price equilibrium. This feature of price competition with TOP obligations drives the marketing strategies of the firms. Entering the same market is never convenient because it gives low profits and leaves residual obligations to the two firms (fostering competing entries in other submarkets). Leaving a (sufficiently large) fraction of the customers to the rival, instead, induces this latter to exhaust its TOP obligations, making 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. In equilibrium, indeed, each firm enters a different submarket and serves the customers at the monopoly price.

The empirical evidence on the European liberalizations supports the idea that the gas market is particularly problematic, more so than electricity. The EU Commission in 2005 noted that "*Whilst the rates of larger electricity customers switching continue to rise, gas consumers … remain reluctant to exercise their right to choose. … Often competing offers are unavailable*" (European Commission, 2005). The situation is not improving much; as clearly pointed out more recently in Ergeg (2008), "Gas retail competition is almost non-existent in most member states". Switching rates (one of the few indicators of competition for final customers) are typically low. In 2007, only 3 to 4 EU countries have reported a switching rate above 1% per year. In Southern Australia, another country characterized by liberalized retail markets and take-or-pay wholesale contracts, analogous results emerge from several market surveys. For instance, in 2006 only 16% of small business gas customers received a competing offer, while the same figure rises to 54% in the electricity market (Escosa, 2006).

Going back to the EU situation, it is interesting to stress that switching rates are poorly correlated to concentration (Ergeg, 2008). For instance, in 2007 two of the relatively more fragmented markets,[5] namely Germany and Italy, displayed switching rates of about 1%, a case of entry without competition. Higher switching rates were instead observed in markets which were even more concentrated, but which were characterized either by a major role of LNG (Spain) or by the existence of an organized wholesale hub (e.g., Belgium).[6]

We acknowledge that the existing evidence of a poor development of competition in the gas market may be explained in different ways, including the persisting constraints in accessing the transportation network. However, we notice that it is consistent with our model's predictions and many elements are quite reminiscent of our segmentation story.

Once established the possibility of segmentation and monopolization of the retail markets, we move to consider additional policy measures that may contrast this outcome. We first show that gas release programs, that are adopted in several member countries to force the incumbent to sell part of its long term contracts to the competitors, at most can restore retail competition in niche markets. Developing domestic wholesale trade, instead, may affect more positively retail competition.

More specifically, we consider two alternative settings. In the first one a compulsory wholesale market is introduced, in which wholesalers have to sell their gas and from which the retailers can purchase

[2] Another difference between the electricity and gas liberalization process concerns the implementation of the general *principle of Third Party Access* (*TPA*). In gas markets a relevant exception is admitted, allowing to restrict the release of transport capacity when giving access to the network would create technical or financial problems to the incumbent because of its take-or-pay (TOP) obligations.

[3] House of Lords, Select Committee on European Communities, Seventh Report, "EU Gas Directive", 7th Report, Session 1997–1998, HL Paper 35, p8, para 15.

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

[5] The report by Ergeg (2008) provides data on the cumulated market share of the three largest suppliers in each country. According to these data, in 2007 this figure was 26.3% in Germany and 66.5% in Italy.

[6] In recent years, wholesale markets have been introduced in some European markets in order to ease the balancing of transport activities by providing purchase or sales opportunities when inflows and outflows do not match. There is actually a wide variety of arrangements, from physical hubs, to electronic exchange platforms to actual gas exchanges (particularly developed in Belgium, The Netherlands, the UK and more recently Germany and partially France).

the gas to serve final users. We show that in this setting, generalized entry and retail competition occur, even when wholesale and retail activities are vertically integrated within companies. Alternatively, we analyze a less complex market organization in which regulation only restricts the form of bilateral contracts. We show that when wholesalers have to post a linear and non discriminatory wholesale price and commit to provide gas upon request to any retailer that signs the contract, under vertical separation generalized entry and retail competition are realized. However, if vertical integration is maintained, the companies are able to make the intra-firms wholesale trade collapsing restoring the segmentation and monopolization outcome. Hence, regulation of bilateral contracts is a less complex institutional solution compared to the introduction of a compulsory wholesale market, but requires a stricter intervention on the unbundling of wholesale and retail activities of the firms.

1.1. Relationship to the literature

The existing literature on TOP contracts (see Cretì and Villeneuve, 2004, for a broad survey) focuses 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 behavior, 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.

The relationship between spot markets and long term contracts has been studied in a number of papers (Allaz and Villa (1993), Mahenc and Salanié (2004), Bushnell (2008) among others), suggesting that forward contracts affect short run competition in spot markets. The original paper by Allaz and Villa showed that forward contracts increase short run competition in a Cournot setting, a result that is reversed in Mahenc and Salanié under price competition. Although our setting is partly different, we add to this debate a result that stresses potential anticompetitive effects of long term contracts, when they take the form of TOP clauses.

Another stream of literature which is relevant to our analysis is the one on price competition with capacity constraints or decreasing returns. Since the seminal work by Kreps and Scheinkman (1983) we know that capacity constraints may modify the incentives to cut-throat price competition, leading to an outcome equivalent to Cournot.[7] 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)[8] that introduces discontinuous marginal costs as those that emerge with TOP obligations. Maggi shows that the amplitude of the upward jump in the marginal cost determines the equilibrium outcomes that range from Bertrand (no jump) to Cournot.

Finally, our paper shares many features with the analysis of dynamic price competition in Bertrand–Edgeworth settings[9]: Dudey (1992) shows that absolute capacity constraints and price competition over a sequence of consumers avoids, even with homogeneous products, price cycles (or mixed strategy equilibria) and leads to almost monopoly prices. We show in our paper that similar results can be obtained with discontinuous marginal costs rather than absolute capacity constraints, with differentiated as well as with homogeneous products, and even with simultaneous price posting to all customers, 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 3 considers the different policy reforms able to restore retail competition. Appendix I contains the proofs, and Appendix II endogenizes the competitor's choice of TOP obligations.

2. The model

We maintain in our modeling strategy the general premise that justifies the liberalization of the natural gas industry: the retail markets are potentially competitive, meaning that the basic technologies and demand conditions may be consistent with two or more equally efficient firms competing for the final customers. The focus of our analysis is on the effects of long term contracts and TOP clauses on the competitive process in the retail markets and the policy measures that can promote retail competition.

The provision of gas to final users is organized in different productive stages. The *wholesale activity* involves buying gas from the producers under long term contracts with the producers including TOP obligations. Hence a wholesaler has zero marginal costs up to the output that fulfills these obligations, and can obtain additional gas from extensions of the main contract at a (higher) marginal cost that reflects the marginal purchase price. The *retail activity* entails selling gas to final customers and requires to buy gas and to specify the commercial terms (price and ancillary clauses). The retail market is decentralized, in the sense that retailers have to select which submarkets they want to serve and to approach the potential customers accordingly. Submarkets can be identified by location (geographical submarkets) and/or by the type of customers (residential, business, specific industries, etc.). This marketing activity involves (limited) fixed costs. Although the gas provided is a commodity at the wholesale level, the retail service includes some element of horizontal product differentiation and consumers' heterogeneity.

In our benchmark model we focus on a market organization that reflects the early stages of the liberalization process, in which no wholesale trade is developed in the domestic markets and where gas companies are vertically integrated, running both the wholesale and retail activities. Then, the only source of gas upstream is through contracts with the producers. In the second part of the paper we show how retail competition is affected when different forms of wholesale trade develop. In this paper we want to study the features of competition in the retail market absent any entry barriers to the transport infrastructures that might limit entry. Consequently, we assume that Third Party Access is fully implemented, a result that in many countries is presently not very far from being realized, implying that no bottleneck or abusive conduct prevents competitors from accessing to the transportation network at non-discriminatory terms.[10]

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

2.1. Submarkets, preferences and demand

Consumers belong to a set of D identical submarkets, each of mass 1. Submarkets may be identified by geographical location (“areas”) and/or according to certain characteristics of the customers (e.g. domestic v. industrial ones, power plants, and heavy users). No matter how we interpret the different submarkets, an individual customer belongs to just one of them and cannot move to another one.

[7] Davidson and Deneckere (1986) have shown that if we substitute the efficient rationing rule adopted in Kreps and Scheinkman with a proportional rationing rule, the market outcome is intermediate between Bertrand and Cournot.

[8] 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.

[9] See also Ghemawat and McGaham (1998) on order backlogs for similar arguments.

[10] For a discussion of the impact of bottlenecks on downstream competition, with a reference to the US reform of the gas industry, see Rey and Tirole (2007), Section 2.1.4 and footnote 45.

We model the demand in each submarket d according to a Hotelling-type specification. 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 $\psi\geq0$ is a parameter describing the importance of the commercial services or the locational issues (horizontal product differentiation) for the client. Our model, therefore, includes perfect substitutability and homogeneous products ($\psi=0$) as a special case.

We consider two firms, that we label as the incumbent (I) and the competitor (C). Each firm $i=I,C$ is exogenously 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 $x^C=3/4$, i.e. the two firms have some (exogenous) difference in the service provided.[11] The firms do not observe the individual customer's tastes (her preferred service variety v) but know only the (uniform) distribution of the customers according to their tastes. Thus, if only one firm enters submarket d, its demand is given by:

$$D_D^{i}\left(p_d^i\right)=\begin{cases}1 & \text{for } p_d^i\leq u-\frac{9}{16}\psi\\ \frac{1}{4}+\sqrt[2]{\frac{u-p_d^i}{\psi}} & \text{for } u-\frac{9}{16}\psi\leq p_d^i\leq u-\frac{\psi}{16}\\ 2\sqrt[2]{\frac{u-p_d^i}{\psi}} & \text{for } u-\frac{\psi}{16}\leq p_d^i\leq u\end{cases}. \tag{1}$$

If instead both firms enter the market and all the consumers are served [12]the demand is:

$$D_d^i\left(p_d^i,p_d^j\right)=\frac{1}{2}+\frac{p_d^j-p_d^i}{\psi}. \tag{2}$$

We have described so far the demand in a specific submarket d of size 1. Since all submarkets are identical, total demand is not larger than D, and it is indeed equal to D if all the consumers are served in the D submarkets. According to the entry and pricing decisions of the retailers in each submarket, the consumers in the D submarkets may face no, one or two competing offers.

2.2. Costs

The vertically integrated firm's costs derive from the purchase, transport and sales of gas and from the marketing costs related to entering a given (set of) submarket(s). Since we assume that transport services are offered at non discriminatory terms with a linear access charge, the network access costs are the same for C and I and, w.l.o.g., are set equal to zero. Variable sales costs are assumed to be (linear and) zero as well. Purchase costs depend on the nature of the upstream contractual arrangements. Each firm $i=I,C$ has a portfolio of long term contracts with the producers or importers, where the unit cost of gas w^i and a TOP obligation $\overline{q}^i$ per unit of time are specified: the firm has to pay an amount $w^i\overline{q}^i$ no matter if the gas is taken or not. The firms can obtain additional supply from extensions of the main contract. In the early liberalization phase that we consider, instead, no domestic wholesale trade is organized and firms do not exchange gas between them. Hence, the marginal purchase price is zero up to the TOP obligations $\overline{q}^i$ and equal to w^i for additional supply.[13] Notice that in our model the firms have no absolute capacity constraint but a discontinuous marginal cost curve, that jumps from 0 to w^i once the TOP obligations are exhausted. For simplicity, we assume $w^C=w^I=w$.

We further assume that each firm pays a fixed cost f for any retail submarket (of size 1) where it decides to operate. These fixed outlays are due, for instance, to the set-up costs of commercial offices and the cost of the dedicated personnel that runs the marketing activity in the submarket.

The cost function of firm $i=I,C$ is therefore:

$$C^i\left(q^i\overline{q}^iD^i\right)=\begin{cases}w\overline{q}^i+fD^i & \text{for } 0\leq q^i\leq\overline{q}^i\\ w\left(q^i-\overline{q}^i\right)+w\overline{q}^i+fD^i & \text{for } q^i\geq\overline{q}^i\end{cases} \tag{3}$$

where D^i corresponds to the size (number) of the submarkets in which firm i has decided to enter.

Assumptions. There are four key parameters in the model, u, w, f and ψ, whose values affect the equilibrium outcomes. The first, u, defines the maximum willingness to pay for gas; the second (w) corresponds to the marginal price for gas provisions beyond the TOP obligations and determines the jump in the marginal cost; the third (f) is related to the entry costs in a submarket and determines the minimum gross profits needed to expand the activities in a new submarket, while the fourth (ψ) gives the degree of retail service differentiation across firms, influencing the equilibrium margins. Although in general one may admit many different ranges of values of these parameters, we think that when focusing on the gas industry a specific combination of values is particularly relevant. Qualitatively, we claim that gas is an important input in many activities (u is high), it is costly (w is large as well), it is a commodity, with limited opportunities to differentiate the offers (ψ is low) and submarkets are potentially competitive (f is low). We translate these qualitative claims in the following assumptions:

$$u\geq max\left\{\frac{57}{16}\psi,\frac{9}{16}\psi+w+f\right\}. \tag{4}$$

$$w>\frac{3}{4}\psi\geq0. \tag{5}$$

$$f<\frac{\psi}{4}. \tag{6}$$

Assumption (4) ensures that a monopolist prefers to cover the entire market at the highest possible price rather than further raise it and ration the market, and that its equilibrium profits are non negative. Assumption (5) guarantees that internal solutions give non negative prices in any duopoly subgame and that the firm with more TOP obligations is always willing to enter (see the Proofs of Propositions 1 and 2 for details). Finally, Assumption (6) is consistent with profitable entry when firms compete with symmetric marginal costs. After deriving our results under these assumptions we will discuss what changes if they do not hold.

[11] Since we already analyze an asymmetric model, with the incumbent selecting first the submarkets it is willing to serve, we do not endogenize the choice of variety, where the incumbent might obtain additional advantages by locating its variety more centrally.

[12] In the equilibrium analysis we shall see that the market is always completely covered both when one or two firms enter in a given submarket. Hence, we avoid discussing in detail the expression of the demand curve for prices such that not all the consumers buy.

[13] 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.

2.3. TOP obligations and capacities

We assume that the incumbent and the competitor have a portfolio of long term contracts such that total TOP obligations equal total demand:

$$\overline{q}^I + \overline{q}^C = D. \tag{7}$$

In Appendix II, we endogenize the competitor's choice of obligations $\overline{q}^C$, showing that indeed C selects obligations equal to the residual market $D - \overline{q}^I$ that is not covered by the incumbent's obligations.

Although Eq. (7) is all that is needed in our equilibrium analysis, from an empirical point of view it seems realistic to assume that the incumbent's obligations are larger than the competitor's, and they do not exceed the size of the market, $\overline{q}^C < \overline{q}^I \leq D$.

2.4. Entry, competition and timing

The market is decentralized, so that firms have to decide which submarkets to deal with, and propose a price to their potential customers. This marketing decision allows the firm targeting a particular group of customers, what we call a submarket, by deploying dedicated and specialized resources. For instance, a firm can set up a network of agents that cover a specific geographical area, or that develop relationships with certain industrial clients. We assume that the decision to serve a submarket is observable by the competitor and irreversible in the short run, as it requires to sink some resources (e.g. local distribution networks, local offices and dedicated personnel) paralleled by the fixed outlay f.

Given the marketing decisions of the two firms, a given submarket may thus face no active firm, one firm (acting as a monopolist for those customers), or two competing firms. Active firm(s) post (simultaneously) their price offer to all customers in the submarket. These latter, once received the offer(s) – if any – decide 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 further assume that the incumbent is always able to move first in approaching the customers, due to his pre-existing relationships with the clients, followed by the competitor. Submarkets are visited by the firms sequentially and, in each of them, once the marketing choices are taken, the active firms simultaneously propose their prices. In the Proof of Proposition 7, we show that our segmentation result still holds also under simultaneous entry (and simultaneous pricing in the second stage). Hence, sequential entry is not essential to our result, but allows us coping easily with the coordination problem that otherwise would arise in a simultaneous entry setting.

Since the incumbent moves first, the firms face similar strategic issues when entering and pricing in each of the first $D_1 = \overline{q}^I$ submarkets. In each of these submarkets, indeed, the incumbent has residual TOP obligations greater (or equal) than the submarket demand. Hence, if I decides to enter, C anticipates that by entering in its turn, it will face a competitor that can serve the submarket demand at zero marginal costs. Moreover, C anticipates that if it enters and competes for some customers, additional cross-market effects will arise, since I will not use all its TOP obligations in the first D_1 submarkets and will have incentives to enter and compete on the residual demand. The same strategic issues can be analyzed by grouping $D_1 = \overline{q}^I$ submarkets together, that is by assuming that the incumbent, and then the competitor, decide first whether to enter or not a set $\mathcal{D}_1$ of submarkets whose total (number and) size is $D_1 = \overline{q}^I$. Once entry and pricing in this set of submarkets, that we shall often call market 1, is chosen, the firms set their entry and price strategies in the residual submarkets, grouped in the set $\mathcal{D}_2$ (or market 2). This latter includes a number $D_2 = D - D_1 = \overline{q}^C$ of submarkets, whose total size equals the competitor's TOP obligations.[14] As this compact formulation lends itself to a shorter (but equivalent) equilibrium analysis, we will adopt it.

Summing up, we assume that the two firms decide sequentially at first whether or not to enter market 1 (the set $\mathcal{D}_1$), composed by submarkets $d = 1,\ldots,D_1$, and market 2 (the set $\mathcal{D}_2$), that includes submarkets $d = D_1 + 1,\ldots,D$.

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

t = 1 the incumbent decides whether to enter or not market 1; then, having observed whether or not I participates, the competitor chooses to enter or not market 1. Then the participating firm(s) (if any) set a price simultaneously.

t = 2 the firms observe the outcome of stage t = 1 and the incumbent decides whether to enter or not market 2; then, having observed whether or not I participates, the competitor chooses to enter or not market 2. Finally, the participating firm(s) (if any) set a price simultaneously.

When $\overline{q}^I = D$ (and therefore $\overline{q}^C = D_2 = 0$) the timing is restricted to the first bullet.

Before moving to the equilibrium analysis, it appears convenient to anticipate the main result of the benchmark model. The equilibrium of the game can be described as follows:

2.5. Result

In any equilibrium configuration all customers pay the monopoly price. If the incumbent's obligations are smaller than market demand, I and C enter as monopolists in different submarkets of size corresponding to their obligations, while if the incumbent's obligations are as large as total demand I monopolizes all submarkets.

3. The sequential entry game

In this section we analyze the subgame perfect equilibria in the sequential entry game, where competition in the first and then in the second market takes place. Although the two markets are separate, a strategic link between them remains, because the residual TOP obligations in the second market depend on the sales (i.e. entry and pricing decisions) in the first market. Hence, when the firms decide their entry and price strategies in the first market they take into account the impact on profits in the first market and on the residual obligations left, anticipating how these latter will affect entry and price decisions in the second market.

3.1. Pricing and entry in the second market

We start our equilibrium analysis, according to backward induction, with the pricing and marketing decisions in market 2. The profits in market 2, and in particular the relevant marginal costs, are affected by the amount (if any) of residual TOP obligations not already committed to sales in market 1. Hence, we can parameterize the second stage subgames to $(\overline{q}_2^I, \overline{q}_2^C)$, where $\overline{q}_2^i \leq \overline{q}^i$ is the residual TOP obligation of firm $i = I, C$ in the second market.

We proceed by identifying the best reply function when both firms enter the second market and compete in prices. First of all, notice that the profit functions are continuous and concave in the own price, but kinked along the locus $\overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$ that solves $D_2^i\left(p_2^i, p_2^j\right) = \overline{q}_2^i$. Hence, $\overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$ is the price p_2^i that, for given p_2^j,

[14] Hence, in our notation D_i corresponds to the *number* of submarkets (and to the total demand) included in the *set* $\mathcal{D}_i$, that we call market i.

makes firm i's demand equal to its residual obligations. For $p_2^i < \overline{p}_2^i$ firm i's demand exceeds its obligations and the marginal cost jumps up from 0 to w. Solving explicitly, we obtain:

$$\overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right) = p_2^j - \frac{\psi}{2D_2}\left(2\overline{q}_2^i - D_2\right).$$

Let $\widehat{p}_2^i\left(p_2^j, c\right)$ be the price that maximizes profits for given p_2^j when the marginal cost is $c\in\{0,w\}$. It is implicitly defined by the first order condition $\frac{\partial \Pi_2^i\left(p_2^i, p_2^j, c\right)}{\partial p^i} = 0$. Solving explicitly we get:

$$\widehat{p}_2^i\left(p_2^j, c\right) = \frac{p_2^j + c}{2} + \frac{\psi}{4}.$$

The following Lemma characterizes the best reply for firm i.

Lemma 1. *Let $BR_2^i(p_2^j)$ be firm i's best reply to p_2^j. Then*

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

Proof. See Appendix I.■

Fig. 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 $\widehat{p}_2^i\left(p_2^j, 0\right)$, the intermediate segment BC given by $\overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$ and the upper segment CD equal to $\widehat{p}_2^i\left(p_2^j, w\right)$. Notice that when the residual obligation $\overline{q}_2^i$ increases, $\overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$ decreases, shifting up the intermediate segment BC of the best reply.

We can now proceed analyzing the price equilibria that occur in the different subgames depending on the marketing decisions of the two firms in the second market. In most cases we obtain a unique price equilibrium. When instead the subgame entails multiple equilibria, we select the most profitable for the two firms, that is, the Pareto efficient equilibrium from the firms' perspective.

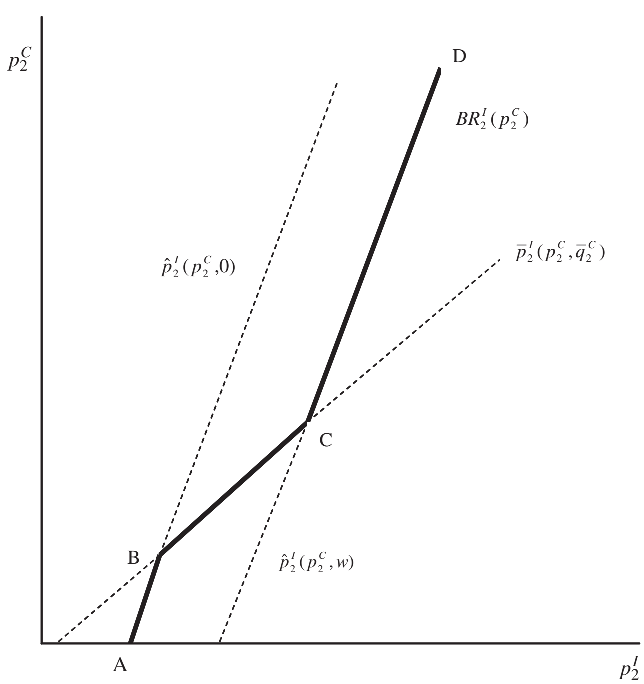

Fig. 1. Best reply: $BR_2^1(p_2^C)$.

The relevant subgames involve $\overline{q}_2^C + \overline{q}_2^I \geq D_2$, as the Proof of Proposition 1 shows in detail. This restriction derives from the condition that total sales in the first market cannot exceed total demand in this market. Since the residual obligations in the second market depend on the first market sales,[15] i.e. $\overline{q}_2^i = \overline{q}^i - q_1^i$, we can rewrite the initial inequality as $\overline{q}_2^C + \overline{q}_2^I = \overline{q}^C - q_1^C + \overline{q}^I - q_1^I \geq D_2 = \overline{q}^C$. Simplifying, we obtain $q_1^I + q_1^C \leq \overline{q}^I = D_1$, that is, the first market sales do not exceed market demand.

Proposition 1. *(Price equilibria)*

If only firm $i = I, C$ enters market 2, it sets price $p_2^{i*} = u - \frac{9}{16}\psi$ and serves the entire market for any residual obligation it has.

If both firms enter the second market, let us define firm i as the one with the fewer residual obligations, that is $\overline{q}_2^i \leq \overline{q}_2^j$ for $i \neq j \in \{I, C\}$. Given the marketing and price strategies in the first market, the residual obligations and the corresponding equilibrium prices fall in one of the three following cases:

a) *if $\overline{q}_2^I + \overline{q}_2^C = D_2$ the (Pareto efficient) equilibrium prices are*

$$p_2^{i*} = w + \psi\frac{\overline{q}_2^i}{D_2}, \qquad p_2^{j*} = w + \psi\frac{4\overline{q}_2^i - D_2}{2D_2}. \tag{8}$$

Each firm sells all its residual TOP obligation.

b) *if $\overline{q}_2^I + \overline{q}_2^C > D_2$ and $\overline{q}_2^i \leq D_2/2$, then the equilibrium prices are*

$$p_2^{i*} = \psi\frac{3D_2 - 4\overline{q}_2^i}{2D_2}, \qquad p_2^{j*} = \psi\frac{D_2 - \overline{q}_2^i}{D_2}. \tag{9}$$

Only firm i, with the fewer residual obligations, sells all of them while firm j, with the larger residual obligations, covers the residual demand.

c) *if $\overline{q}_2^I + \overline{q}_2^C > D_2$ and $\overline{q}_2^i > D_2/2$, then the equilibrium prices are*

$$p_2^{i*} = \frac{\psi}{2}, \qquad p_2^{j*} = \frac{\psi}{2} \tag{10}$$

and each firm serves half of the market.

Proof. See Appendix I.■

If only one firm decides to serve market 2, it will set the monopoly price covering the entire demand. If, however, both firms enter market 2, the prices set and the sales realized in equilibrium depend on the residual obligations, which in turn derive from the marketing and price decisions in the first market. In case (a) total residual obligations equal demand: each firm then sells exactly its residual obligations and the equilibrium prices never exceed $w + \frac{\psi}{2}$. In this case we select the prices that are Pareto efficient for firms. If residual TOP obligations are larger than D_2, we have two additional cases, labeled (b) and (c). In both of them, competition leads to prices lower than in case (a), but above the zero marginal cost due to product differentiation (parameter ψ). When one of the two firms has limited residual obligations (case (b)) it still sells all of them, while in case (c) both firms have very large residual obligations and they split evenly the market without exhausting them, and gaining a small margin over the marginal cost 0. In this latter case, TOP obligations do not affect the equilibrium prices and sales, and the market equilibrium

[15] To convey the basic intuition we just consider here the case when the competitor C sells in the first market an amount of gas not larger than its obligation, that is $q_1^C \leq \overline{q}^C$. A more general analysis that considers also the case $\overline{q}^C < q_1^C \leq \overline{q}^I = D_1$ is developed in the Proof of Proposition 1 in Appendix I.

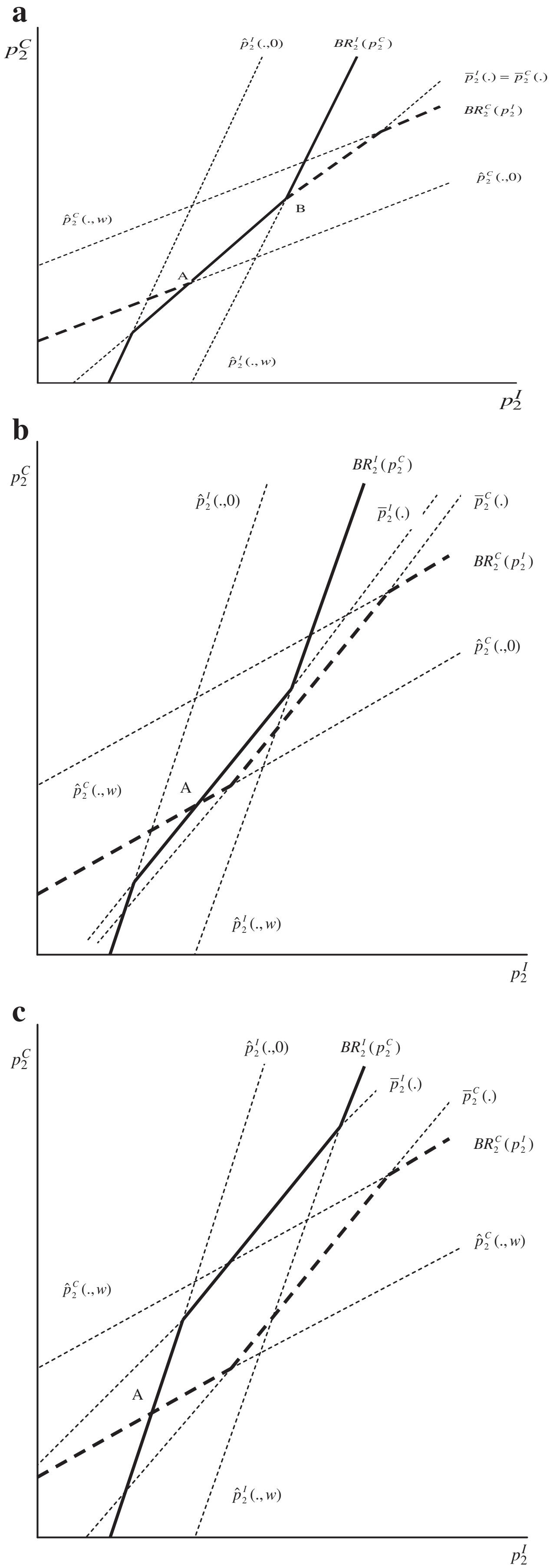

Fig. 2. Equilibrium prices: segment AB (case a).

corresponds to what emerges when two firms with zero marginal costs compete.[16]

Fig. 2 shows the three cases (a), (b) and (c) in which both firms are active in market 2 and the different points of intersection of the two best reply functions.

We can now move to the marketing decisions of the two firms in the second market, having characterized the equilibrium prices in any subgame. When choosing whether to serve market 2 or not, the firms compare the gross profits associated to the equilibrium prices and sales described in Proposition 1 with the fixed marketing costs fD_2 in case of entry in market 2.

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

Proposition 2. *(Entry equilibria) Let us define firm i as the one with the fewer residual obligations, that is* $\overline{q}_2^i \leq \overline{q}_2^j$ *for* $i \neq j \in \{I,C\}$. *The equilibrium marketing strategies of the two firms are:*

- *If* $\overline{q}_2^I + \overline{q}_2^C = D_2$, *then:*
  - *if* $\overline{q}_a < \overline{q}_2^i$, *where*

$$\overline{q}_a \equiv \frac{wD_2}{2\psi}\left(\sqrt[2]{1+4\frac{f\psi}{w^2}}\right)$$

  both firms enter market 2;
  - *if instead* $0 \leq \overline{q}_2^i \leq \overline{q}_a$ *only firm j enters market* 2;
- *If* $\overline{q}_2^I + \overline{q}_2^C > D_2$, *then:*
  - *if* $\overline{q}_b \leq \overline{q}_2^i$, *where*

$$\overline{q}_b \equiv \frac{3D_2}{8}\left(1-\sqrt[2]{1-\frac{32f}{9\psi}}\right)$$

  both firms enter market 2;
  - *if* $0 \leq \overline{q}_2^i \leq \overline{q}_b$ *only firm j enters market* 2.

Proof. See Appendix I.■

The intuition behind the equilibrium entry pattern is straightforward. At the second stage, the price equilibria give positive sales and gross profits as long as a firm has positive residual obligations; entry is then profitable if the gross profits cover the fixed marketing costs fD_2. Indeed, entry may become unprofitable for the firm with the smaller residual obligations (firm *i* in our notation). This firm in equilibrium sells exactly its residual obligations, and its gross profits therefore decrease the lower the obligations still pending. Then, there is a minimum level of residual obligations that allows repaying the fixed marketing costs once entered. When its residual obligations are larger than the threshold, then, the firm with the fewer residual obligations enters in equilibrium. At the same time, entry is the dominant strategy of the firm with more residual obligations. Notice that, when the marketing cost vanishes, i.e. $f \rightarrow 0$, the equilibrium marketing strategies boil down to a very simple rule: each firm enters as long as it retains positive residual obligations.

3.2. Equilibrium

We now turn our attention to the entry and price decisions in the first market. These choices determine the sales q_1^i in the first market and the residual obligations $\overline{q}_2^i = \overline{q}^i - q_1^i$, affecting the entry and

[16] Notice that the price configurations described in Proposition 1 include also the case of homogeneous offers: when the differentiation parameter ψ tends to zero. When we converge to the homogeneous products case ($\psi \rightarrow 0$), indeed, prices fall to w in case (a) and to 0 in cases (b) and (c), in line with the Bertrand result.

price decisions in the second market. These strategic implications make therefore the analysis more complex.[17]

These additional effects apply in case only one firm enters market 1 as well as when both firms compete for the first market's customers. In the first case we have to check whether the optimal price entails covering the entire demand D_1, or it prescribes to ration the first market (through a price higher than p_m) retaining some residual obligations that will induce entry in the second market. When instead both firms enter, each firm might have the incentive to price in such a way to leave a substantial part of the sales to the rival. This way the latter would indeed exhaust (almost) all its obligations, finding then unprofitable to enter market 2, that the former firm would then monopolize. The following proposition analyzes the different cases.

Proposition 3. *The following price equilibria occur in the first market:*

a) *If only firm i enters 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 the first market:*

1. *there is no price equilibrium in pure strategies,*
2. *an equilibrium in mixed strategies μ_1^{I*}, μ_1^{C*} exists.*
3. *in the mixed strategy equilibrium both firms obtain positive expected profits and the expected total profit of the competitor in the two markets is less than $(u - \frac{9}{16}\psi)D_2$.*

Proof. See Appendix I.■

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, indeed, giving up some monopoly rents by overpricing in the first market and shifting some obligations to the second (competitive) market is not profitable, and the firm sets the monopoly price and covers the entire market D_1 without entering market 2.

When both firms enter the first market, each firm tries to induce, through high prices, the rival to cover a significant part of the demand. This way, the rival exhausts its obligations and does not enter the second market. Being these strategies mutually inconsistent, no price equilibrium in pure strategies exists in this subgame.[18] In the mixed strategy equilibrium, the total expected profits that C can earn by competing with I in the first market (and then compete in market 2 as well) are below the monopoly profits that it can earn with certainty in market 2 by staying out of market 1. Hence, the competitor is better off by leaving the first market to the incumbent, monopolizing the second one.

We have concentrated so far our analysis on the case when the incumbent has TOP obligations short of total demand. Our analysis, however, allows us easily considering also the case of incumbent's obligations that match market demand. The following Proposition establishes our main segmentation result.

Proposition 4. *Depending on the amount of TOP obligations of the incumbent, we can have two possible outcomes:*

- *Segmentation: when $\overline{q}^I < D$, the incumbent enters the first market, while the competitor enters the second market. Both firms charge to their customers the monopoly price $p_m = u - \frac{9}{16}\psi$.*
- *Monopolization: when $\overline{q}^I = D$, the incumbent enters the whole market and charges the monopoly price $p_m = u - \frac{9}{16}\psi$, while the competitor does not enter.*

Proof. See Appendix I.■

3.3. Comments

Proposition 4 suggests two possible unsatisfactory outcomes of liberalization, depending on the amount of TOP obligations of the incumbent. If they fall short of market demand, segmentation occurs, that is entry without competition, while entry would be completely prevented if the incumbent can supply the entire market with its TOP obligations. In both cases, customers do not receive any benefit. Our result therefore suggests that third party access is a necessary but not a sufficient condition to create competition in the retail markets. In the next section we shall discuss possible solutions that allow one enriching the liberalization plans leading to competition in retailing.

The basic intuition behind our segmentation result (case $\overline{q}^I < D$) is quite simple: when a firm has to meet TOP clauses, its cost structure is characterized by zero marginal costs up to the obligations and higher marginal cost for larger quantities. If both firms enter the first market, they obtain competitive returns over marginal costs and do not exhaust their obligations, entering also the second market with low returns on their residual obligations. Conversely, leaving a fraction of the market to the rival turns out to be a mutually convenient and credible strategy. The other firm, indeed, 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. By leaving the rival in a monopoly position on a part of the market, a firm acquires a monopoly position on the residual customers.

The monopolization result (case $\overline{q}^I = D$) is easily explained as well: the asymmetry in marginal costs when only the incumbent has TOP obligations makes entry unattractive for the competitor, who would face an aggressive low cost incumbent and would obtain no sales and profits. We show in Appendix II that even endogenizing the competitor's choice of TOP obligations, it is always optimal for C to contract obligations $\overline{q}^C$ equal to the residual demand (if any) not covered by the incumbent's obligations. Hence, if the incumbent's obligations do cover the whole market, the competitor does not contract any gas provision and remains out of the market.

It is important to stress that the segmentation outcome is not just an example of the well known result that a market with intense price competition and high fixed costs becomes a monopoly in a free entry equilibrium, what is often labeled as blockaded entry. To clarify this point, let us define $\Pi^i(c^i,c^j;\psi)$ as firm i's profits when its own marginal cost is c^i and the rival's is c^j, with parameter ψ describing how much price competition is relaxed. In our setting the marginal cost can assume one of two relevant levels, 0 or w, creating an environment of symmetric or asymmetric costs. The key inequality that drives the equilibrium outcomes is then:

$$\Pi^i\left(c^i = c^j;\psi\right) > \Pi^i\left(c^i > c^j;\psi\right) \geq 0,$$

that holds in a wide set of oligopoly models including Cournot or Hotelling, the one we adopt in this paper.[19] Competing with a high marginal cost rival creates an advantage with respect to a symmetric cost setting, with the high marginal cost competitor worse off.

In this environment, we can have different outcomes of the entry process according to the level of the fixed costs f, that correspond in our model to the marketing costs. When $\Pi^i(c^i = c^j;\psi) > f > \Pi^i(c^i > c^j;\psi)$, entry occurs if firms are symmetric, while an inefficient competitor

[17] This different feature of the strategies in market 1 and market 2 would occur also in a more disaggregated setting, in which the firms would enter sequentially each of the D submarkets: the strategies in submarket $d = D$ would involve only the maximization of the (last) submarket profits while those taken in submarkets $d = 1,\ldots,D-1$ would depend on their impact on both the submarket profits and the continuation of the game.

[18] This sort of outcome would occur also in case of sequential entry in the different submarkets $d = 1,\ldots,D - \overline{q}^C$, whenever we do not aggregate all of them into a single market 1: if both firms enter in any of these submarkets, the pricing strategies may contribute to make the residual obligations of either firm insufficient to motivate its entry in the remaining submarkets. Leaving sufficient sales to the rival would therefore secure monopoly profits in some of the residual submarkets.

[19] The inequalities are consistent with the following effects: $\partial \Pi^i / \partial c^i < 0$, $\partial \Pi^i / \partial c^j > 0$ and $\partial \Pi^i / \partial \psi > 0$.

would not enter once a low cost firm is already in the market. Notice that the condition $\Pi^i(c^i=c^j;\psi)>f$ is consistent with the premise of a liberalization plan: the market can sustain more than one (equally efficient) firm. The case $f>\Pi^i(c^i=c^j;\psi)$ instead would imply that a duopoly with equally efficient firms would not be sustainable, a case of blockaded entry that makes the market unfit for liberalization.

Moreover, the inequality $f>\Pi^i(c^i>c^j;\psi)$ explains the entry pattern in the second market: a firm does not enter if residual obligations are (almost) exhausted, with a cost disadvantage for any relevant level of output. If a high cost competitor is strongly penalized by the intensity of competition, the profits $\Pi^i(c^i>c^j;\psi)$ may be very low (if any), and even a small entry cost f may be sufficient to prevent entry, leading to segmentation. In this case, therefore, monopoly prices occur for a range of entry costs much wider than those associated with the blockaded entry case.

Finally, some degree of imperfect competition ($\Pi^i(c^i=c^j;\psi)>0$) is still required to neatly obtain the segmentation result. Consider the limiting case of Bertrand competition ($\psi\rightarrow 0$), where $\Pi^i(c^i=c^j;0)=\Pi^i(c^i>c^j;0)=0$. In this setting, if $f>0$, only blockaded entry and pure monopolization may occur. If, alternatively, firms do not bear any entry cost ($f=0$), entering (with or without residual TOP obligations) or not entering at all would pay the same zero profits. The segmentation result would still be obtained, but the entry pattern, then, would depend entirely on the assumptions we make regarding the way these ties are broken, quite an artificial result.[20] With some degree of imperfect competition ($\psi>0$), instead, the entry choices are clearly determined.

A result close to our segmentation outcome can be found in Dudey (1992) on sequential pricing with (absolute) capacity constraints. Dudey's paper modifies the standard Edgeworth–Bertrand setting assuming that consumers enter the market sequentially and purchase during the period; the firms, endowed with a fixed capacity, compete simultaneously in prices in each period to attract the current consumer. In this setting, pricing in different periods is the key ingredient that allows firms avoiding cut-throat competition or Edgeworth-cycling, exhausting their capacity sequentially and serving consumers at monopoly prices. We obtain similar results with a more flexible technology, that exhibits discontinuous marginal cost rather than absolute capacity constraints, with product differentiation as well as with homogeneous product and also with simultaneous pricing in all submarkets (see the Proof of Proposition 7) rather than with sequential pricing. In our setting, indeed, the key ingredient is the different timing in entry and pricing decisions, rather than a sequence of price competition episodes.

4. Restoring retail competition

Our discussion suggests that segmentation can occur because the firms, when deciding which submarkets to enter, have discontinuous marginal costs due to TOP obligations. We have developed our benchmark model having in mind the institutional setting that we observe in the early stages of liberalization in European gas markets. In this section we want to explore alternative rules for the wholesale and retail activities, and in the contracts and market organization admitted, that may lead to generalized entry and genuine retail competition.

Before opening this discussion, however, it is useful to analyze two variations in the benchmark model that will be helpful to evaluate how specific reforms may affect the degree of retail competition. The first case entails the retailers having a flat marginal cost p_w for any amount of gas delivered to the market rather than the discontinuous marginal cost curve induced by TOP.

Lemma 2. *(Generalized entry and retail competition) When, in the same setting of the benchmark model, the incumbent and the competitor have a flat marginal cost p_w for any level of gas, in the subgame perfect equilibrium both firms enters each submarket $d=1,2$ and sets a price $p_d=p_w+\frac{\psi}{2}$.*

Proof. See Appendix I.■

To get the intuition for this result, we can notice that the basic mechanism of the benchmark model, such that leaving a submarket to the rival firm would secure to be monopolist on the residual demand, does not work anymore with flat marginal costs. In this latter case, indeed, the strategic link across submarket strategies, driven by the amount of residual obligations, is lost. By entering an additional submarket, each firm obtains positive net incremental profits $\frac{\psi}{4}-f>0$ without affecting in any way its and the rival's incentives to enter the other submarkets. Each firm, therefore, enters all markets and obtains positive profits.

The second case that helps evaluating the policies to improve retail competition is when the total TOP obligations of the incumbent and the competitor are lower than market demand, that is $\overline{q}^I+\overline{q}^C<D$.

Lemma 3. *(Competition in niche markets) When, in the same setting of the benchmark model, the total TOP obligations of the two firms fall short of market demand, that is $\overline{q}^I+\overline{q}^C<D$, the subgame perfect equilibrium is characterized by the incumbent entering market 1 of size $\overline{q}^I$ and setting the monopoly price $p_m=u-\frac{9}{16}\psi$, the competitor entering market 2 of size $\overline{q}^C$ and setting the monopoly price $p_m=u-\frac{9}{16}\psi$ and both firms entering market 3 of size $D-\overline{q}^I-\overline{q}^C$ and setting the price $p_3^I=p_3^C=w+\frac{\psi}{2}$.*

Proof. See Appendix I.■

Once the incumbent and the competitor have exhausted their TOP obligations, they have still the possibility of buying gas at a marginal price w drawing from the extension of their long term contract. Hence, in the third market both firms with a flat marginal cost w can enter. Since in the symmetric marginal costs equilibrium, as established in Lemma 2, each firm gains a positive net profit $\frac{\psi}{4}-f$ by entering each of the residual submarkets not yet served, both firms enter all the submarkets grouped into market 3. Hence, retail competition develops in the residual markets not covered by TOP obligations.

4.1. Gas release programs

We start our discussion by examining gas release programs, that Spain, UK and Italy, have included in their liberalization plans. This measure forces the incumbent to sell to the competitors certain amounts of gas. Similar commitments have been used in antitrust cases in Italy in 2004, 2007 and 2009.

Gas release programs, as long as they transfer the TOP obligations included in the original contracts, affect the allocation of TOP obligations in the market, reducing $\overline{q}^I$ and increasing $\overline{q}^C$ accordingly. However, the basic interaction as described in the setting of the benchmark model remains the same, and these transfers only modify the market shares of the two firms in equilibrium to the advantage of the competitor, without affecting the equilibrium prices. These measures, therefore, just create opportunities for entry (if initially $\overline{q}^I=D$) or increase the competitor's market share (if initially $\overline{q}^I<D$). By adding a new source of contracts for the provision of gas, these programs can even allow the entry of other retailers that were previously excluded due to the lack of connections with international producers or importers. In all cases, however, the entry pattern that leads to segmentation and monopoly pricing is unaffected, since the overall endowment of TOP

[20] For instance, to replicate the segmentation result in a homogeneous product setting we have to *assume* what instead would be strictly optimal with product differentiation, namely that firms enter (getting zero profits) when they have symmetric costs while they stay out (getting zero profits as well) if they have a cost disadvantage. Notice, however, that these assumptions may be justified considering the homogeneous product setting as the limiting case for $\psi\rightarrow 0$.

obligations still matches total demand, and each firm has the same discontinuous marginal cost schedule.

A different outcome may occur if gas release programs are coupled with additional restrictions that prevent the incumbent from transferring the TOP obligations to the buyer that eventually buys the gas released at linear wholesale price.

Suppose, for instance, that the gas release program imposes to sell a certain amount of gas $\hat{q}^I < \overline{q}^I$ at a linear wholesale price w. This measure leads to a reduction in the amount of TOP obligations that the incumbent has to cover in the retail market, $\overline{q}^I - \hat{q}^I$, and leaves unchanged the obligations held by the competitor, $\overline{q}^C$. In other words, this gas release program reduces the amount of TOP obligations that the incumbent and the competitor have to cover through sales in the retail market, creating an additional source of gas $\hat{q}^I$ that can be purchased by any other operator at a flat marginal cost equal to w. Then, the result in Lemma 3 applies, and the residual market $D - \left(\overline{q}^I - \hat{q}^I\right) - \overline{q}^C = \hat{q}^I$ is entered by operators that buy the gas released and charge the competitive price $w + \frac{\psi}{2}$. Hence, we can state the following:

Proposition 5. *If gas release programs allow transferring to the buyers the original TOP obligations, the segmentation result persists and the only effect of this measure is to decrease the market share of the incumbent, to the advantage of the competitor(s). If instead the gas is transferred at a linear price w, competition occurs in a residual market of size equal to the amount of gas released.*

4.2. Wholesale trade and retail competition

Our description of the natural gas market identifies a wholesale activity, corresponding to contracting gas upstream with the producers under TOP obligations and providing it downstream, and a retail activity, that entails obtaining gas from the wholesalers, entering retail submarkets and serving final customers. These two activities are run in the benchmark model within the same company, and no wholesale trade occurs between the two firms. In this setting, the amount of gas withdrawn from the producers, and the level of residual obligations, is determined by the strategies in the retail market that are therefore deeply affected by the existence of TOP obligations.

In this section, we explore alternative ways to enhance retail competition combining two complementary lines of intervention. On the one hand we consider different forms of wholesale trade between companies in the domestic market. Our analysis may therefore contribute to the discussion opened by the Third energy package on the development of wholesale markets. On the other hand, we analyze the effects of vertical separation of wholesale and retail activities, a line of business restriction that unbundles these activities and prevents the wholesalers from dealing directly with the final users.[21] In the First and Second directives, the European Commission has recommended unbundling of the infrastructure from the downstream or upstream activities. Here we are analyzing an additional restriction, the unbundling of wholesale and retail activities that should be run under different and independent companies. This combination of policy measures may help relaxing the link between TOP obligations and retail strategies, replacing market segmentation with generalized entry and monopoly margins with competitive ones.

The first solution entails creating a compulsory wholesale market where the wholesalers supply all the gas withdrawn from the producers and the retailers purchase it for their deliveries to final consumers. In this setting, even when companies are vertically integrated, their wholesale and retail units cannot deal with each other directly, but only through the wholesale market and according to the prescriptions of the market coordinator. More specifically, the amount of gas supplied by a wholesaler is not determined by an individual retailer's demand, but it is mandated by the market coordinator, the dispatcher, according to a market clearing rule that sets the wholesale price and allocates total retail demand given the wholesalers' bids. This institutional framework separates the incentives of the wholesalers and retailers even when they act within the same company. We show in the next subsection that, when firms participate in a compulsory wholesale market, generalized entry and retail competition occur in equilibrium under vertical separation as well as under vertical integration.

The second case involves bilateral contracting between companies with a restriction to linear and non discriminatory wholesale offers and a commitment to match all the retailers' orders. Wholesale trade, in this setting, occurs when firms are vertically separated, but also in case of vertical integration: in this latter case, indeed, the wholesale unit of a firm can sell gas to the competitor's retail unit as well as to its own. Under vertical separation, we show that generalized entry and competition characterize the equilibrium. However, in case of vertical integration, bilateral contracting leads to a very different outcome. In this latter case, indeed, the firms in equilibrium make the inter-firm wholesale trade collapsing by setting a sufficiently high wholesale price, and credibly committing this way to purchase gas only through the long term contracts with TOP. As a result, segmentation persists under vertical integration while competition is implemented under vertical unbundling.

4.2.1. Compulsory wholesale market

We analyze in this section the creation of a compulsory wholesale market, considering both the case of wholesale and retail activities run within a vertically integrated company, as in the benchmark model, and a separation of these businesses into different and independent companies.

To ease the discussion, in both the vertical separation and vertical integration cases we define as wholesalers and retailers the subjects in charge for the corresponding activity. Wholesalers I^W and C^W (burdened by TOP obligations $\overline{q}^I + \overline{q}^C = D$) have to sell the gas at linear wholesale price in the wholesale market, where the retailers I^R and C^R must buy the gas that they resell in the final markets. If wholesale and retail activities are unbundled, i^W and i^R $(i = I, C)$ are different and independent companies, while if the companies are vertically integrated, i^W and i^R are different units of the same company $i = I, C$. Moreover, since TOP obligations and wholesale bids and supplies are specific to the wholesale activities and varieties and final demand and prices refer only to the retail activities, when referring to these variables we omit the index W or R to ease the notation.

We maintain the same framework of the benchmark model concerning retailers and final customers' demand, with retailer I^R offering variety $x^I = \frac{1}{4}$ and retailer C^R offering variety $x^C = \frac{3}{4}$ in each submarket they serve.[22] The retailers i^R, $i = I, C$, decide which submarket to enter and set their price, collecting the orders. As in the benchmark model, the market can be decomposed into D submarkets of size equal to 1, and the retailers have to decide which submarkets to serve. Moreover, grouping these latter in two larger sets (market 1 and market 2), that greatly simplified the analysis in the benchmark model, is no longer useful. Retailer i^R expected demand in submarket d, D_d^i can be derived according to the same logic of the benchmark model. Total demand for retailer i^R is then $D^i(\mathbf{p}^I, \mathbf{p}^C) = \sum_{d=1}^{D} D_d^i(p_d^I, p_d^C)$ where $\mathbf{p}^I$ and $\mathbf{p}^C$ are the vectors of final

[21] Line-of-business restrictions were introduced in the US, for instance, on long-distance and local telephone service at the time of the ATT break-up. In 1996 the Telecom Act removed this prohibition.

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

prices set by the two retailers I^R and C^R in the D submarkets. Finally, $D(\mathbf{p}^I,\mathbf{p}^C)=D^I(\mathbf{p}^I,\mathbf{p}^C)+D^C(\mathbf{p}^I,\mathbf{p}^C)$ represents total demand from the retailers in the wholesale market. The two wholesalers I^W and C^W compete in prices to serve total wholesale demand $D(\mathbf{p}^I,\mathbf{p}^C)$ by submitting their bids p_w^I and p_w^C.

The wholesale market is coordinated by a dispatcher that collects the orders $D(\mathbf{p}^I,\mathbf{p}^C)$ from the retailers and the supply bids of the wholesalers p_w^I and p_w^C, sets the wholesale price p_w and the wholesalers' sales S^I and S^C, according to these rules:

i) each wholesaler i^W, $i=I,C$, has to submit a linear bid price p_w^i, and it has to supply whatever gas S^i is mandated by the dispatcher at that price;
ii) the dispatcher collects the wholesalers' offers and forms a merit order (in terms of the submitted prices p_w^I and p_w^C), sets the wholesale price p_w, and allocates the demand for gas $D(\mathbf{p}^I,\mathbf{p}^C)$ of the retailers to the wholesaler(s).
iii) the price setting and allocation rule used by the dispatcher are as follows:
   a) if $p_w^i<p_w^j$, $i\neq j\in\{I,C\}$, then $S^i=D(\mathbf{p}^I,\mathbf{p}^C)$ and $p_w=p_w^i$, that is if wholesaler i^W submits a lower bid, this latter is the wholesale price and the wholesaler serves all the demand;
   b) if $p_w^I=p_w^C$ the dispatcher sets the wholesale price $p_w=p_w^I=p_w^C$ and allocates total demand $D(\mathbf{p}^I,\mathbf{p}^C)$ proportionally to the TOP obligations of the wholesalers: $S^i=\frac{\overline{q}^i}{\overline{q}^I+\overline{q}^C}D(.)$, $i=I,C$.

The timing of the game is as follows: at time 1 the wholesalers submit their bids p_w^I and p_w^C; at time 2 the dispatcher sets the wholesale price p_w; at time 3 the retailers simultaneously decide whether to enter submarkets $d=1,\ldots,D$ having observed the wholesale price, and at time 4 the retailers observe the entries and simultaneously set their prices in the submarkets they entered; finally, at time 5 the dispatcher commands the wholesale supplies S^I and S^C.

The following Proposition establishes that when a compulsory wholesale market is introduced, generalized entry and competition characterize the market equilibrium.

Proposition 6. *(Compulsory wholesale market) Suppose that a compulsory wholesale market is introduced, in which the wholesalers I^W and C^W submit linear prices p_w^I and p_w^C, the dispatcher sets the wholesale price p_w and the wholesale deliveries S^I and S^C and from which the retailers I^R and C^R buy any amount they need and compete in the final markets. Then, in the subgame perfect equilibrium the wholesalers submit offers $p_w^I=p_w^C=w$, the dispatcher sets the wholesale price $p_w=w$, the retailers enter all submarkets, and set final prices $p_d^I=p_d^C=w+\frac{\psi}{2}$ and the dispatcher commands deliveries equal to the TOP obligations ($S^i=\overline{q}^i$, $i=I,C$). This equilibrium outcome holds under vertical integration (firms I and C) and vertical separation (independent wholesalers I^W and C^W and retailers I^R and C^R).*

Proof. See Appendix I.■

A wholesale market represents a particular institutional environment in which wholesalers and retailers trade at the same linear wholesale price. Under vertical separation, then, the retailers have a flat marginal cost equal to the wholesale price p_w and therefore, according to Lemma 2, they enter each submarket and price competitively. Interestingly, the same outcome occurs even under vertical integration, where each company runs both the retail and wholesale activities. When companies operate within a organized and compulsory wholesale market, indeed, the dispatcher deeply affects the way wholesale and retail choices interact.

In the benchmark model with vertically integrated firms, the retail unit, by entering and pricing in the final submarkets, determines the company retail demand, obtaining then the gas from the wholesale unit and delivering it to the clients. In this case, the amount of gas that the wholesale unit withdraws from the long term contract depends on the company's retail demand, and the marginal cost of the integrated company, in turn, shifts up from 0 to w when retail demand gets larger than TOP obligations.

In a compulsory wholesale market, instead, there is no direct link between the retail sales $D^i(\mathbf{p}^I,\mathbf{p}^C)$ and the wholesale deliveries S^i of the integrated company i, since S^i is mandated by the dispatcher according to the allocation rules and does not change when, for given entry pattern and total retail demand $D(\mathbf{p}^I,\mathbf{p}^C)$, the retail unit of an integrated company cuts its price and expands its sales displacing the other retailer. In this latter case, the wholesale equilibrium does not change and the retail unit has to buy additional gas in the wholesale market at the price p_w, that becomes the relevant company marginal cost when retail sales increase. Hence, the dispatcher creates a separation of the wholesale and retail activities even when these are run within the same company.[23]

In order to maintain the model as close as possible to the benchmark setting, we have considered a duopolistic retail market. However, one additional benefit of introducing a compulsory wholesale market is the possibility of making entry easier, since retailers can buy gas without establishing contractual relations with foreign producers. In this case, the retail margin would decrease in the number of retailers, which in turn would be determined, in a free entry equilibrium, by the fixed marketing cost f.[24]

It should be also borne in mind that competition in the upstream segment may not necessarily lead to a wholesale price equal to the unit cost of gas w. This Bertrand outcome occurs, as shown in Proposition 6, if the rules of the wholesale market require to submit offers in the form of linear prices with unbounded deliveries, that is as flat supply schedules. If instead the bids can be submitted as price–quantity pairs for additional deliveries, the outcome may differ. The literature on supply function equilibria[25] shows that the Bertrand equilibrium corresponds to the case when firms use a supply curve equal to their true marginal costs (that is w in our case); if firms are instead able to commit to a supply curve that includes a mark-up over marginal costs, the equilibrium wholesale prices may be much higher that the competitive ones. Even in this case, however, in the wholesale market the retailers purchase gas at a common price p_w, and therefore enter and compete in every submarket according to Lemma 2. Hence, if the wholesale market rules allow to submit non linear supply schedules, the retail margin is at the competitive level $\frac{\psi}{2}$, but the wholesale price p_w may remain higher than w, increasing accordingly the price for the final customers. Hence, in this setting the promotion of wholesale competition becomes a relevant issue.

The compulsory nature of the wholesale market is essential to our result. Indeed, if retailers (I^R and C^R) and wholesalers can trade either in the wholesale market or directly through bilateral contracts that include TOP obligations (non-compulsory wholesale market), the segmentation result is restored. Without developing a complete model, consider the case when retailer I^R has signed a bilateral contract with a wholesaler that includes TOP obligations equal to $\overline{q}^I<D$. Retailer C^R has to decide whether to sign a similar contract with TOP obligations $\overline{q}^C$ or, alternatively, to buy in the wholesale market at price p_w. In the latter case, Lemma 3 tells us (setting $\overline{q}^C=0$) that the equilibrium in the market is characterized by retailer I^R entering

[23] The pro-competitive effects of a compulsory wholesale market, indeed, may be hampered if third parties (e.g. financial intermediaries) provide hedging contracts that replicate the effect of TOP obligations. Hence, further restrictions on the kind of side contracts that the retailers can use may be needed.

[24] For instance, if we model the N-retailers case according to the circular version of the Hotelling model, the symmetric equilibrium prices are $p=p_w+\frac{\psi}{N^2}$ and the free entry condition determines the equilibrium number of retailers $N=\left(\frac{\psi}{f}\right)^{1/3}$.

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

a market of size $\overline{q}^I$ and charging the monopoly price, while the residual demand $D-\overline{q}^I$ is served at the competitive price $w+\frac{\psi}{2}$ by the two retailers. Alternatively, retailer C^R can sign a long term contract with obligations $\overline{q}^C \leq D-\overline{q}^I$ and monopolize a submarket of size $\overline{q}^C$ while competing with retailer I^R in the residual market (if any). Retailer C^R therefore obtains profits $\Pi^C=(u-\frac{9}{16}\psi-w-f)\overline{q}^C+(\frac{\psi}{4}-f)\left(D-\overline{q}^I-\overline{q}^C\right)$ that are clearly increasing in $\overline{q}^C$. Hence, retailer C^R will choose to sign contracts with TOP obligations with the wholesalers for $\overline{q}^C=D-\overline{q}^I$, rather than buying in the wholesale market, and then will replicate the outcome of vertical integration.

This discussion highlights that if bilateral TOP contracts are feasible, the retailers would opt for bilateral contracts with TOP obligations, reintroducing the same competitive distortions as in the benchmark model with vertical integration. Hence, when exploring solutions different from a compulsory wholesale market, as we do in the next section, restrictions on bilateral contracts will be essential.

4.2.2. Restrictions on bilateral contracts

Imposing the creation of a wholesale market can be complex and may also entail some specific organizational cost. It is therefore interesting to consider an alternative measure that, without establishing a compulsory wholesale market, may restore retail competition by imposing restrictions on bilateral contracting between retailers and wholesalers.

Taking Lemma 2 at face value, one may argue that, to improve retail competition, regulation should simply prohibit the adoption of TOP clauses in the contracts for the provision of gas. Still, in this very sketchy form, this would not be easy to implement since most of the gas imported by member countries comes from outside the European Union, and international contracts may be out of the jurisdiction of national (or even Community) authorities. We acknowledge that the European Commission has been able to impose some revisions of international contracts, for instance by abolishing the destination clauses. However, eliminating TOP obligations would be much harder, since these restrictions, beyond their impact on retail competition, have a genuine motivation of risk sharing between producers and users when huge transport infrastructures must be realized. If the contracts with the producers can be hardly affected, then, we have to carefully consider the other downstream stages and find solutions that avoid the mere transfer of upstream TOP obligations to the retail contracts.

We focus here on regulatory restrictions which allow the wholesalers i^W to offer contracts only in the form of a linear and non discriminatory wholesale price p_w^i, $i=I,C$, together with a commitment to deliver whatever quantity of gas is requested at that price. This restriction would force wholesalers to post a price that is publicly available to any retailer that can subscribe a provision contract accordingly. The linearity condition rules out TOP clauses in whatever form in the contract offered to the retailers.

We analyze the effects of this restriction both in the case of vertical separation, where retailers and wholesalers are independent companies, and in case of vertical integration, where each wholesaler is vertically integrated with one retailer, so that the activities are run by different units within the same company. In this latter case, if a retail unit signs a contract with the other company's wholesale unit, it adds to the internal source a second provider of gas. We maintain the same setting of the previous section regarding retail demand.

The timing of the game is as follows. At time 1 wholesalers post their offers p_w^I and p_w^C and commit to provide gas upon request; at time 2, the retailers decide simultaneously whether to enter submarkets $d=1,\ldots,D$; at time 3, the retailers post simultaneously the price vectors $\mathbf{p}^I$ and $\mathbf{p}^C$ and collect orders in the submarkets where they entered; finally, at stage 4 the retailers choose their wholesaler(s), sign the contract and withdraw the gas. After each stage the decisions become public information.

The following proposition shows that when retail and wholesale activities are vertically separated generalized entry and competition occur in equilibrium; in case of vertical integration, instead, the companies set wholesale prices at a level that prevents the development of cross-firm wholesale trade and the segmentation result of the benchmark model persists.

Proposition 7. *(Restrictions on bilateral contracts): Consider a market organization in which wholesalers and retailers trade through linear contracts for any amount of gas requested (linear prices and unbounded supply).*

- *If the retail firms are independent of wholesalers, wholesalers I^W and C^W offer gas at a price $p_w^I=p_w^C=w$ and retailers I^R and C^R enter all submarkets setting a price $p^I=p^C=w+\frac{\psi}{2}$.*
- *When instead all firms are vertically integrated, they set a wholesale price above w, no firm purchases gas from the competitor's wholesale unit and each firm enters different submarkets of size equal to their TOP obligations and sets the monopoly price $p^I=p^C=u-\frac{9}{16}\psi$.*

Proof. See Appendix I.■

Linear wholesale contracts allow one to promote retail competition when vertical separation of wholesale and retail activities applies. In this case, indeed, retailers purchase from the more convenient wholesale contract and share the same marginal cost, and wholesalers compete *à la* Bertrand to supply the retailers. Banning TOP obligations in the contracts with the retailers prevents the segmentation result, and linear contracts with unbounded deliveries promote generalized entry and retail competition.

A completely different outcome occurs when firms are vertically integrated. The retail units continue to buy the gas from the cheaper offer, as in the vertical separation case: for retail sales up to the TOP obligations, it is best to draw from the contract with the producer, while additional gas is purchased comparing the long term contract with the producer and the wholesale offer of the other company. If this latter is not higher than w, the retail unit buys from the other firm's wholesale unit the gas in excess of its obligations.

When, for instance, I posts a wholesale price $p_w^I=w$, company C, if its retail sales $D^C(\mathbf{p}^I,\mathbf{p}^C)$ exceed its obligations, buys the additional gas $D^C(.)-\overline{q}^C$ from I. Then, C's marginal cost for additional retail sales is the direct cost of purchasing gas from I at p_w^I. But this latter is also the opportunity marginal costs for I: this company, indeed, in this market configuration sells gas in two ways: retail to final users ($D^I(.)$) and wholesale to the other company ($D^C(.)-\overline{q}^C$). Then, when I expands its retail sales to the detriment of C's sales, it correspondingly reduces its wholesale deliveries to C at p_w^I. Therefore, p_w^I acts as the opportunity marginal cost for additional retail sales $D^I(.)$.

Summing up, when firms trade between them, they have the same marginal cost, equal to the wholesale price posted by the net supplier of gas. This outcome occurs when firms post wholesale prices not higher than w, that make it ex-post better for the retail units to buy from the rival rather than from the extension of the long term contract with the producer. In this case, generalized entry and small margins over the wholesale price characterize the equilibrium. In other words, when a company posts an attractive wholesale price, it becomes a competitive wholesaler and, at the same time, an accommodating retailer.

However, if the wholesale prices are set higher than w, each company prefers to purchase additional gas from the producer rather than from the rival's retail unit, and the cost structures of the vertically integrated companies are determined by the long term contracts with TOP obligations. By raising its wholesale price, a firm makes its wholesale offer unattractive. Then, it will have a zero marginal cost until its retail sales do not cover its obligations.[26] The equilibrium outcome, then, involves segmentation and monopoly pricing. In other words, by becoming a weak wholesaler the firm succeeds to be a tough retailer. When posting the wholesale price, the vertically integrated companies, then, opt for this outcome.

In a sense, the segmentation result in the benchmark model refers to an initial phase of liberalization when wholesale transactions occur only within the long term international contracts with the producers. When domestic wholesale trade develops and it is regulated to avoid the use of TOP obligations in the contracts with the retailers, generalized entry occurs as long as firms are vertically separated. Under vertical integration, instead, the companies are able to make wholesale trade collapsing by setting sufficiently high wholesale prices compared to the long term contracts with the producers. Hence, vertical separation is needed when no wholesale compulsory market is created and regulation works only through restrictions on bilateral contracts.

To conclude, we have designed two different solutions to enhance retail competition by developing wholesale trade. The first one is institutionally more complex, as it involves creating a compulsory wholesale market, but it does not need vertical separation of the wholesale and retail activities in different and independent companies. The second solution requires perhaps a simpler form of intervention, namely imposing regulatory restrictions on the bilateral contracts between wholesalers and retailers, but cannot work without vertical unbundling.

Appendix I. Proofs

Proof of Lemma 1. Notice at first that for given p_2^j any $p_2^i \leq \overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$ implies that the demand is not lower than the residual TOP obligations ($D_2^i\left(p_2^i, p_2^j\right) \geq \overline{q}_2^i$) and, in turn, that the marginal cost is $c = w$. Conversely, any $p_2^i > \overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$ is associated to a demand short of the residual obligations ($D_2^i\left(p_2^i, p_2^j\right) < \overline{q}_2^i$) and a marginal cost $c = 0$. Let us consider the three following cases:

- if for a given p_2^j we have $D_2^i\left(\widehat{p}_2^i\left(p_2^j, 0\right), p_2^j\right) < \overline{q}_2^i$, then, $BR_2^i\left(p_2^j\right) = \widehat{p}_2^i\left(p_2^j, 0\right)$. We have in fact $\overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right) < \widehat{p}_2^i\left(p_2^j, 0\right) < \widehat{p}_2^i\left(p_2^j, w\right)$. Then for $p_2^i \leq \overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$ the demand exceeds the obligations and the marginal cost is w. And since $\overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right) < \widehat{p}_2^i\left(p_2^j, w\right)$, the profits $\Pi_2^i(p_2^i, p_2^j, w)$ are increasing in p_2^i. For $p_2^i > \overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$ the demand falls short of the obligations and the marginal cost is 0. Then the profits are maximized at $p_2^i = \widehat{p}_2^i\left(p_2^j, 0\right)$. Hence $p_2^i = \widehat{p}_2^i\left(p_2^j, 0\right)$ is the global maximum in this region. Solving explicitly the condition $D_2^i\left(\widehat{p}_2^i\left(p_2^j, 0\right), p_2^j\right) = \overline{q}_2^i$ in terms of p_2^j gives us the boundary of this region. If $\frac{\psi}{2D_2}\left(4\overline{q}_2^i - D_2\right) > 0$ this region is non-empty.
- if for a given p_2^j we have $D_2^i\left(\widehat{p}_2^i\left(p_2^j, w\right), p_2^j\right) \geq \overline{q}_2^i$, that implies $\overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right) \geq \widehat{p}_2^i\left(p_2^j, w\right) > \widehat{p}_2^i\left(p_2^j, 0\right)$, then, $BR_2^i\left(p_2^j\right) = \widehat{p}_2^i\left(p_2^j, w\right)$. Indeed, for $p_2^i \leq \overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$ the demand exceeds the obligations and the marginal cost is w. Then the profits $\Pi_2^i(p_2^i, p_2^j, w)$ are maximized at $\widehat{p}_2^i\left(p_2^j, w\right) \leq \overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$. For $p_2^i > \overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$ the demand is lower than the obligations and the marginal costs are 0. Since $\overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right) > \widehat{p}_2^i\left(p_2^j, 0\right)$ in this region the profits $\Pi_2^i(p_2^i, p_2^j, 0)$ are decreasing in this region. Hence the global maximum is $p_2^i = \widehat{p}_2^i\left(p_2^j, w\right)$. Solving explicitly the condition $D_2^i\left(\widehat{p}_2^i\left(p_2^j, w\right), p_2^j\right) = \overline{q}_2^i$ in terms of p_2^j gives us the boundary of this region.
- for intermediate values of p_2^j we have $D_2^i\left(\widehat{p}_2^i\left(p_2^j, 0\right), p_2^j\right) > \overline{q}_2^i \geq D_2^i\left(\widehat{p}_2^i\left(p_2^j, w\right), p_2^j\right)$. In this case we have $\widehat{p}_2^i\left(p_2^j, 0\right) < \overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right) \leq \widehat{p}_2^i\left(p_2^j, w\right)$. Hence, for $p_2^i \leq \overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$ the demand exceeds the obligations and the marginal cost is w and the profits $\Pi_2^i(p_2^i, p_2^j, w)$ are increasing, since $\overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right) \leq \widehat{p}_2^i\left(p_2^j, w\right)$. When instead $p_2^i > \overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$ the demand falls short of the obligations and the marginal cost is 0. In this region, however, since $\widehat{p}_2^i\left(p_2^j, 0\right) < \overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$, the profits $\Pi_2^i(p_2^i, p_2^j, 0)$ are decreasing. Hence, the profits are kinked at $\overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$, that corresponds to the global maximum, that is $BR_2^i\left(p_2^j\right) = \overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$. If $\frac{\psi}{2D_2}\left(4\overline{q}_2^i - D_2\right) > 0$, when $p_2^j = \frac{\psi}{2D_2}\left(4\overline{q}_2^i - D_2\right)$ we have $\widehat{p}_2^i\left(p_2^j, 0\right) = \overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$, i.e. the best reply $BR_2^i(p_2^j)$ is continuous moving from the first to the second region. For $p_2^j = w + \frac{\psi}{2D_2}\left(4\overline{q}_2^i - D_2\right)$ we have $\widehat{p}_2^i\left(p_2^j, w\right) = \overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$ and the best reply $BR_2^i(p_2^j)$ is continuous moving from the second to the third region.

Proof of Proposition 1. Let us consider first the case when only one firm enters market 2. The demand is described above by (1). The highest price at which every consumer buys one unit of the good is $p_m = u - \frac{9}{16}\psi$. Since

$$\frac{\partial \Pi_1^I}{\partial p_1^I} = D_1\left\{\frac{1}{4} + \left(\frac{u - p_1^I}{\psi}\right)^{\frac{1}{2}} - \frac{p_1^I}{2\psi}\left(\frac{u - p_1^I}{\psi}\right)^{-\frac{1}{2}}\right\}$$

the first derivative at $p_1^I = p_m$ is negative as long as $u \geq \frac{33}{16}\psi$, as assumed. Moreover,

$$\frac{\partial^2 \Pi_1^I}{\partial p_1^{I2}} = -\frac{1}{\psi}\left(\frac{u - p_1^I}{\psi}\right)^{-\frac{1}{2}} - \frac{p_1^I}{4\psi}\left(\frac{u - p_1^I}{\psi}\right)^{-\frac{3}{2}} < 0$$

and Π_1^I is concave for $u - \frac{9}{16}\psi \leq p_1^I \leq u - \frac{\psi}{16}$. It is easy to check that the same conclusions hold for $u - \frac{\psi}{16} < p_1^I \leq u$ and the corresponding expression of the profit. Hence, any price above p_m implies a fall in the monopolist's profit and $p_1^I = p_m = u - \frac{9}{16}\psi$ is a global maximum. Moreover, we require that $p_m \geq w$. The two conditions are met under Assumption (4). The profits are maximized at p_m for any level of the marginal cost, and therefore, the equilibrium price if only one firm enters market 1 is $p_1^{i*} = p_m = u - \frac{9}{16}\psi$ for any possible level of the residual obligations of the competitor.

[26] Notice that this feature holds even if there are independent wholesalers competing with the vertically integrated firms. Since these latters use their internal source of gas until the TOP obligations are covered, their cost structure does not change if we add an independent source of gas at w that parallels the extensions of the long term contracts.

Turning to the case of both firms entering market 2, we start by identifying precisely the combinations of residual obligations $(\overline{q}_2^I, \overline{q}_2^C)$ 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 restricting our analysis of the equilibrium in the second market to the relevant cases that are described in the Proposition.

For each firm $i = I, C$ the residual obligations in the second market are $\overline{q}_2^i = max\{\overline{q}^i - q_1^i, 0\}$. Moreover, total sales in the first market cannot exceed total demand, i.e. $q_1^I + q_1^C \le D_1 = \overline{q}^I$. Then, $\overline{q}_2^I = max\{\overline{q}^I - q_1^I, 0\} \ge q_1^C$, that is the incumbent's residual obligations in the second market are at least as large as the competitor's sales in the first market, the equality sign corresponding to the case when the first market is completely covered. Taking this condition into account, we have $\overline{q}_2^C + \overline{q}_2^I \ge max\{\overline{q}^C - q_1^C, 0\} + q_1^C$ for $q_1^C \in [0, \overline{q}^I]$. It follows that for $q_1^C \in [0, \overline{q}^C]$ the inequality simplifies to $\overline{q}_2^I + \overline{q}_2^C \ge \overline{q}^C - q_1^C + q_1^C = \overline{q}^C = D_2$. For $q_1^C \in [\overline{q}^C, \overline{q}^I]$, instead, we have $\overline{q}_2^I + \overline{q}_2^C \ge q_1^C > \overline{q}^C = D_2$.

To further check, consider in detail the different cases, starting from those in which the firm(s) set a price that induce *all the consumers*in the first market to purchase. Since $\overline{q}^I + \overline{q}^C = D_1 + D_2$ if only I enters then $\overline{q}_2^I = 0$ and $\overline{q}_2^C = D_2$ (case a). If only C enters $\overline{q}_2^I = D_1 > D_2$ and $\overline{q}_2^C = 0$ (case b). If both enter the first market and $D_1^C(p_1^I, p_1^C) \le \overline{q}^C$ then $\overline{q}_2^I + \overline{q}_2^C = D_2$ (case a). If both enter and $D_1^C(p_1^I, p_1^C) > \overline{q}^C$ then $\overline{q}_2^I > D_2$ and $\overline{q}_2^C = 0$ (case b).

We turn now to all the cases in which the price(s) set by the firm(s) induce *only a fraction of consumers* in the first market to purchase. If only I enters then $\overline{q}_2^I + \overline{q}_2^C > D_2$ with $\overline{q}_2^I > 0$ and $\overline{q}_2^C = D_2$ (case b or c). If only C enters $\overline{q}_2^I = D_1 > D_2$ and $\overline{q}_2^C \ge 0$ (case b or c). If both enter the first market and $D_1^C(p_1^I, p_1^C) \le \overline{q}^C$ then $\overline{q}_2^I + \overline{q}_2^C > D_2$ with $\overline{q}_2^I > 0$ and $\overline{q}_2^C \ge 0$ (case b or c). If both enter and $D_1^C(p_1^I, p_1^C) > \overline{q}^C$ then $\overline{q}_2^I > D_2$ and $\overline{q}_2^C = 0$ (case b). Finally, if no firm enters the first market, both retain their initial obligations: $\overline{q}_2^I = D_1$ and $\overline{q}_2^C = D_2$ (case c).

We can now turn to identify the price equilibria when both firm enter the second market, falling in one of the three cases above. The best reply functions in these subgames differ for the position of the intermediate segments

$$\overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right) = p_2^j - \frac{\psi}{2D_2}\left(2\overline{q}_2^i - D_2\right), \overline{p}_2^j\left(p_2^i, \overline{q}_2^j\right) = p_2^i - \frac{\psi}{2D_2}\left(2\overline{q}_2^j - D_2\right).$$

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

In case (a), $\overline{q}_2^i + \overline{q}_2^j = D_2$, the two best reply functions overlap along the intermediate segments giving a continuum of Nash equilibria. Among them, we select the Pareto dominant (for firms) price pair. If $\overline{q}_2^i \le D_2/2$ the two best reply functions overlap below or at the locus $p_2^i = p_2^j$ and the Pareto dominant price pair is identified – Fig. 2a – by the intersection of $\overline{p}_2^j\left(p_2^i, \overline{q}_2^j\right)$ and $\widehat{p}_2^i\left(p_2^j, w\right)$, i.e. $p_2^{i*} = \widehat{p}_2^i\left(p_2^{j*}, w\right)$ and $p_2^{j*} = \overline{p}_2^j\left(p_2^{i*}, \overline{q}_2^j\right)$. 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 (5).

In case (b), we have $\overline{q}_2^i + \overline{q}_2^j > D_2$ and $\overline{q}_2^i \le D_2/2 < \overline{q}_2^j$. Hence, the intermediate segments of both best reply functions are below the locus $p_2^i = p_2^j$, with $\overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$ above $\overline{p}_2^j\left(p_2^i, \overline{q}_2^j\right)$. Then, the two best reply functions intersect – Fig. 2b – at $p_2^{i*} = \overline{p}_2^i\left(p_2^{j*}, \overline{q}_2^i\right)$ and $p_2^{j*} = \widehat{p}_2^j(p_2^{i*}, 0)$: the explicit solutions are in the statement. Notice that at the equilibrium prices only firm i, the one with the smaller residual obligations, sells all of them $(p_2^{j*} > \overline{p}_2^j(p_2^{i*}, \overline{q}_2^j))$.

In case (c), $\overline{q}_2^i + \overline{q}_2^j > D_2$ and $\overline{q}_2^i, \overline{q}_2^j > D_2/2$ the intermediate segment $\overline{p}_2^i\left(p_2^j, \overline{q}_2^i\right)$ lies above the locus $p_2^i = p_2^j$ while $\overline{p}_2^j\left(p_2^i, \overline{q}_2^j\right)$ lies below it. Then, the two best reply functions intersect – Fig. 2c – at $p_2^{i*} = \widehat{p}_2^i\left(p_2^{j*}, 0\right)$ and $p_2^{j*} = \widehat{p}_2^j(p_2^{i*}, 0)$ and in the symmetric equilibrium each firm covers half of the market.■

Proof of Proposition 2. According to Proposition 1, if only one firm enters market 2, it obtains monopoly profits and covers the fixed marketing costs fD_2. Hence, if C observes that I does not enter, it is always optimal to enter market 2. Proposition 1 has also identified the prices, sales and gross profits when both firms enter the second market, distinguishing case (a), when $\overline{q}_2^I + \overline{q}_2^C = D_2$, and cases (b) and (c), when $\overline{q}_2^I + \overline{q}_2^C > D_2$.

In case (a), if both firms enter they sell their residual obligations. In our notation firm i is the one with less residual obligations. The gross profits of the two firms in market 2 as a function of $\overline{q}_2^i \le D_2/2$ have the following pattern. $\Pi_2^i\left(\overline{q}_2^i\right) = \left(w + \psi\frac{\overline{q}_2^i}{D_2}\right)\overline{q}_2^i$ has a minimum equal to 0 when $\overline{q}_2^i = 0$ and it is increasing and convex for larger residual obligations, with a maximum equal to $\Pi_2^i = (w + \frac{\psi}{2})\frac{D_2}{2}$ at $\overline{q}_2^i = D_2/2$. Then, by direct calculations it is easy to check that the net profit $\Pi_2^i\left(\overline{q}_2^i\right) - fD_2$ is non negative as long as the residual obligations $\overline{q}_2^i$ are above $\overline{q}_a$. The gross profit of firm j, the one with more obligations, is $\Pi_2^j\left(\overline{q}_2^i\right) = \left(w + \psi\frac{4\overline{q}_2^i - D_2}{2D_2}\right)\left(D_2 - \overline{q}_2^i\right)$ and it is concave. The first derivative is $\frac{\partial \Pi_2^j}{\partial \overline{q}_2^i} = -w - \frac{4\psi\overline{q}_2^i}{D_2} + \frac{3}{2}\psi$. Since $w \ge \frac{3}{4}\psi$ by assumption, Π_2^j is always decreasing in $\overline{q}_2^i$ (if $w > \frac{3}{2}\psi$), with a minimum at $\overline{q}_2^i = D_2/2$, or initially increasing and then decreasing. It is easy to check that even at the lower bound $(w \to \frac{3}{4}\psi)$, when the minimum is at $\overline{q}_2^i = 0$, the gross profit of firm j is higher than the entry cost fD_2. Given these patterns, firm i enters market 2 if its residual obligations are above $\overline{q}_a$, and stays out otherwise, while firm j always enter.

Consider next case (b), where only the firm (firm i in our notation) with less residual obligations, covers them in equilibrium. Evaluating the gross profits of the two firms as a function of $\overline{q}_2^i$, we obtain the following patterns. $\Pi_2^i\left(\overline{q}_2^i\right) = \left(\psi\frac{3D_2 - 4\overline{q}_2^i}{2D_2}\right)\overline{q}_2^i$ is concave, initially increasing and then decreasing in $\overline{q}_2^i$, with a minimum equal to 0 at $\overline{q}_2^i = 0$. Then, firm i's net profit $\Pi_2^j\left(\overline{q}_2^i\right) - fD_2$ are positive as long as $\overline{q}_2^i > \overline{q}_b$, as direct calculations show. Firm j, endowed with more residual obligations, has gross profits equal to $\Pi_2^i\left(\overline{q}_2^i\right) = \left(\psi\frac{D_2 - \overline{q}_2^i}{D_2}\right)\left(D_2 - \overline{q}_2^i\right)$, decreasing and convex in $\overline{q}_2^i$ with a minimum equal to $\frac{\psi}{4}D_2$ at $\overline{q}_2^i = D_2/2$. Since $f < \frac{\psi}{4}$ by assumption, firm j's net profits are therefore always positive if entering market 2. Hence, if $\overline{q}_2^i$ are above $\overline{q}_b$ both firms enter market 2 while for smaller residual obligations firm i stays out while firm j enters.

In case (c) both firms obtain profits equal to $(\frac{\psi}{4} - f)D_2$ that are positive by assumption, and therefore both enter market 2.■

Proof of Proposition 3. In the following, we denote as Π^i, Π_1^i and Π_2^i, respectively, the overall profits of firm i and the profits it gains in the first and second markets.

Point (a)

We consider the incentives to overpricing of the incumbent when entering market 1 as a monopolist. I has two alternatives. The first one involves setting $p_m = u - \frac{9}{16}\psi$ and maximize the first market profit Π_1^I, covering market 1 and not entering market 2, having exhausted its obligations: in this case I obtains $\Pi^I = p_1^I D_1^I(p_1^I) = (u - \frac{9}{16}\psi)D_1$. Alternatively, firm I can set $p_1^I > p_m$ with lower first market profit Π_1^I, retain some obligations in market 2 and enter the second market competing with C, with profits $\Pi^I = p_1^I D_1^I(p_1^I) + \Pi_2^I$. The latter term, in turn, depends on the residual obligations $\overline{q}_2^I$ left once the first market sales are realized. Referring to Propositions 1 and 2, if only I enters the first market and does not cover all the demand, $\overline{q}_2^I \geq 0$ and $\overline{q}_2^C = \overline{q}^C = D_2$. Hence, we are in case (b) or (c) of Proposition 1 ($\overline{q}_2^I + \overline{q}_2^C > D_2$) and $\Pi_2^I = \overline{q}_2^I \psi \left(3D_2 - 4\overline{q}_2^I\right)/2D_2$ if $\overline{q}_2^I \leq D_2/2$ and $\Pi_2^I = \frac{\psi D_2}{4}$ otherwise. This function has a maximum at $\overline{q}_2^I = \frac{3D_2}{8} < \frac{D_2}{2}$, so, w.l.o.g. we can restrict attention to the former case. Since $\overline{q}_2^I = D_1 - D_1^I(p_1^I)$, substituting in Π_2^I we obtain for $u - \frac{9}{16}\psi \leq p \leq u - \left(\frac{3}{4} - \frac{D_2}{2D_1}\right)^2 \psi$ (corresponding to $\overline{q}_2^I \in [0, \frac{D_2}{2}]$), after rearranging:

$$\widehat{\Pi}_2^I\left(p_1^I\right) = D_1 \psi \left[\frac{3}{4} - \left(\frac{u - p_1^I}{\psi}\right)^{\frac{1}{2}}\right]\left[\frac{3}{2}\left(1 - \frac{D_1}{D_2}\right) + \frac{2D_1}{D_2}\left(\frac{u - p_1^I}{\psi}\right)^{\frac{1}{2}}\right].$$

Thus, $\widehat{\Pi}_2^I(p_1^I) = \Pi_2^I\left(p_2^{I*}\left(\overline{q}_2^I(p_1^I)\right), p_2^{I*}\left(\overline{q}_2^I(p_1^I)\right)\right)$ is firm I's second market profits evaluated at the equilibrium prices as a function of firm I's residual obligations that, in turn, depend on firm I's price p_1^I in the first market. Differentiating the second market profit we get, after rearranging:

$$\frac{\partial \widehat{\Pi}_2^I}{\partial p_2^I} = D_1 \left[\left(\frac{u - p_1^I}{\psi}\right)^{-\frac{1}{2}} \frac{3}{4}\left(1 - \frac{2D_1}{D_2}\right) + \frac{2D_1}{D_2}\right]$$

$$\frac{\partial^2 \widehat{\Pi}_2^I}{\partial p_2^{I2}} = D_1 \left[\frac{1}{2}\left(\frac{u - p_1^I}{\psi}\right)^{-\frac{3}{2}} \frac{3}{4}\left(1 - \frac{2D_1}{D_2}\right)\right] < 0.$$

$\widehat{\Pi}_2^I$ has a maximum at $p_1^I = u - \frac{9}{16}\left(1 - \frac{D_2}{2D_1}\right)\psi$, corresponding to $\overline{q}_2^I = \frac{3D_2}{8}$ while $\frac{\partial \widehat{\Pi}_2^I}{\partial p_2^I}$ is positive and equal to D_1 at $p_1^I = u - \frac{9}{16}\psi$.

Turning to the total profits in the two markets, $\Pi^I(p_1^I) = \Pi_1^I(p_1^I) + \widehat{\Pi}_2^I(p_1^I)$, it is the sum of two functions concave in p_1^I (see the Proof of Proposition 1 for the concavity of Π_1^I): evaluating Π^I in the interval $p_1^I \in [u - \frac{9}{16}\psi, u - \frac{9}{16}(1 - \frac{D_2}{2D_1})\psi]$, at the lower bound $p_1^I = u - \frac{9}{16}\psi$ we have $\frac{\partial \Pi^I}{\partial p_2^I} = \left(1 - \frac{u - \frac{9}{16}\psi}{3\psi}\right) 2D_1 < 0$ for $u > \frac{55}{16}\psi$ as assumed. For higher prices, $\frac{\partial \widehat{\Pi}_2^I}{\partial p_2^I} \geq 0$ decreases and is equal to 0 for $p_1^I = u - \frac{9}{16}(1 - \frac{D_2}{2D_1})\psi$ while $\frac{\partial \Pi_1^I}{\partial p_2^I}$ becomes more and more negative. Hence, $p_1^I = u - \frac{9}{16}\psi$ is the global maximum, implying that it is not profitable for firm I to sacrifice monopoly profits in the first market to gain competitive profits in market 2.

Point (b)

Let us define the following subsets of the strategy space $P = \{(p_1^I, p_1^C) \in [0, u]^2\}$:

$$P^I = \left\{\left(p_1^I, p_1^C\right) \middle| p_1^I \in [0, u], p_1^C \in \left[0, min\left\{p_1^I + \psi\,\widetilde{D}, u\right\}\right]\right\}$$
$$P^{IC} = \left\{\left(p_1^I, p_1^C\right) \middle| p_1^I \in \left[0, u - \psi\,\widetilde{D}\right], p_1^C \in \left(\left(p_1^I + \psi\,\widetilde{D}, min\left\{p_1^I + \psi\,\widehat{D}, u\right\}\right)\right)\right\}$$
$$P^C = \left\{\left(p_1^I, p_1^C\right) \middle| p_1^I \in \left[0, u - \psi\,\widehat{D}\right], p_1^C \in [p_1^I + \psi\,\widehat{D}, u]\right\} \tag{8}$$

where $\widetilde{D} = (D_1 - 2(D_2 - \overline{q}_a))/2D_1$ and $\widehat{D} = (D_1 - 2\overline{q}_a)/2D_1$. When $(p_1^I, p_1^C) \in P^I$ firm C exhausts at least $\overline{q}^C - \overline{q}_a$ obligations in the first market ($D_1^C(p_1^I, p_1^C) \geq D_2 - \overline{q}_a$ that implies $\overline{q}_2^I > D_2$ and $\overline{q}_2^C \leq \overline{q}_a$) and therefore C does not enter market 2, while firm I will enter as a monopolist. Conversely, when $(p_1^I, p_1^C) \in P^C$ firm I covers most of market 1 demand and almost exhausts its capacity ($D_1^I\left(p_1^I, p_1^I\right) \geq D_1 - \overline{q}_a$ that implies $\overline{q}_2^I \leq \overline{q}_a$); therefore only C will enter the second market. Finally, for $(p_1^I, p_1^C) \in P^{IC}$ both firms retain sufficient residual obligations and will enter also in the second market. Hence, the three sets imply different entry patterns in the second stage. Notice, for future reference, that P^I and P^C are closed sets while P^{IC} is open. From the previous discussion, the incumbent's profit jumps up at the boundary of P^I since the monopoly profit in market 2 is added, while the competitor's profit has a similar pattern at the boundary of P^C. Finally, the industry profits $\Pi = \Pi^I + \Pi^C$ are discontinuous at the boundaries of P^I and P^C, since the joint profits when the second market is a duopoly (region P^{IC}) are strictly lower than those obtained when it becomes a monopoly. Once introduced this notation we can prove part (b) proceeding in the three steps.

Step 1

We start proving that no price equilibrium in pure strategies exists if both firms enter the first market.

We shall show that firm I's optimal reply requires to choose always a price in P^I while firm C optimally selects a price at the boundary of P^C or, for low $\overline{q}^C$, internal to P^I when p_1^I is sufficiently high. In any case, the optimal replies never intersect.

Let us consider the incumbent's optimal reply. For $D_2 < \frac{3}{4}D_1$ and $p_1^C \leq \psi \frac{3D_1 - 4D_2}{2D_1}$ the price that maximizes firm I's profits in the first market producing at zero marginal cost, $\widehat{p}_1^I(p_1^C, 0) = \frac{p_1^C}{2} + \frac{\psi}{4}$, belongs to P^I. This is clearly the optimal reply for I: this price maximizes the incumbent's profit Π_1^I in the first market and, being consistent with competitor's sales not lower than $D_2 - \overline{q}_a$, it secures to the incumbent also the monopoly profit in the second market. For $p_1^C \geq \psi \frac{3D_1 - 4D_2}{2D_1}$, by moving along $\widehat{p}_1^I(p_1^C, 0)$ we enter region P^{IC} where both firms enter both markets. Then, for $p_1^C > \psi \frac{3D_1 - 4D_2}{2D_1}$, the optimal reply for the incumbent would be to corner firm C making it selling at least $\overline{q}^C - \overline{q}_a$ obligations and preventing its later entry, i.e. setting $p_1^I = p_1^C - \psi \widetilde{D}$, the price at the boundary of region P^I. That way the incumbent continues to sell (at increasing prices) $D_1 - D_2 + \overline{q}_a$ in the first market but secures the monopoly profits in the second market. For $D_1 > D_2 > \frac{3}{4}D_1$ the incumbent's optimal reply is at the boundary of P^I that is $p_1^I = \overline{p}_1^I(p_1^C) = p_1^C - \psi \widetilde{D}$ for any price of the competitor, since $\widehat{p}_1^I(p_1^C, 0)$ never belongs to P^I.

Hence, the best reply of the incumbent is always included in P^I and the incumbent maximizes always its profits by preventing firm C's entry in the second market.

Turning to firm C, for $p_1^I \geq w + \psi \frac{4(D_2 - \overline{q}_a) - D_1}{2D_1}$ firm C's optimal reply when maximizing market 1's profits, $\widehat{p}_1^C(p_1^I, w) = \frac{p_1^I}{2} + \frac{w}{2} + \frac{\psi}{4}$, lies in region P^I: firm C sells more than its obligations in market 1 and does not enter the second market. If market 2 is very small, this strategy may dominate that of letting the incumbent covering almost all market 1's demand and securing market 2's monopoly profits. For lower prices p_1^I, $\widehat{p}_1^C(p_1^I, w)$ would imply lower sales at lower prices in market 1 and entry and competitive prices in market 2, i.e. a fall in profits. At some point, before reaching the boundary of P^I, it becomes preferable to set a price at the boundary of P^C letting the incumbent covering almost all market 1's demand and securing market 2's monopoly profits. If instead firm C's obligations (and market 2) are sufficiently large, setting the price at the boundary of P^C is always the optimal reply. Hence, for large competitor's obligations each firm $i = I, C$ wants to corner the rival by picking up the price in P^i, while in case of small obligations and market 2's demand the incumbent finds it profitable to let the competitor sell more than its obligations (pick up a price inside P^I) for low prices p_1^C, while C find it profitable to follow the same pattern for high prices p_1^I. Hence, in both cases, the two best reply functions never intersect. Consequently, there is no price equilibrium in pure strategies. 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 is a compact and convex subset of R^+ and the discontinuity set for the incumbent is (using Dasgupta and Maskin notation)

$$P^{**}(I) = \left\{ \left(p_1^I, p_1^C\right) \middle| p_1^I \in \left[0, u - \psi\widetilde{D}\right], p_1^C = p_1^I + \psi\widetilde{D} \right\},$$

i.e. the boundary of P^I. Analogously, the discontinuity set for the competitor is

$$P^{**}(C) = \left\{ \left(p_1^I, p_1^C\right) \middle| p_1^I \in \left[0, u - \frac{\psi}{2}\widehat{D}\right], p_1^C = p_1^I + \frac{\psi}{2}\widehat{D} \right\},$$

i.e. the boundary of P^C. Hence, the discontinuities occur when the two prices are linked by a one-to-one relation, as required (see Eq. (2) in Dasgupta and Maskin (1986)), while $\Pi^i(p_1^I, p_1^C)$ is continuous elsewhere. Second, $\Pi = \Pi^I + \Pi^C$ is upper semi-continuous (see Definition 2 in Dasgupta and Maskin (1986)): since Π^I, Π^C and Π are continuous within the three subsets P^I, P^{IC} and P^C, for any sequence $\{p^n\} \subseteq P^j$ and $p \in P^j$, $j = I, IC, C$, such that $p^n \to p$, $lim_{n\to\infty}\Pi(p^n) = \Pi(p)$. 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^{IC}, i.e. $\{p^n\} \subseteq P^{IC}$ and $p \in P^{**}(i)$, $i = I, C$, such that $p^n \to p$, then $lim_{n\to\infty}\Pi(p^n) < \Pi(p)$, i.e. the joint profits jump up. Third, $\Pi^i(p_1^I, p_1^C)$ is weakly lower semi-continuous in p_1^i according to Definition 6 in Dasgupta and Maskin (1986). At $\left(\overline{p}_1^I, \overline{p}_1^C\right) \in P^{**}(I)$, if we take (see Dasgupta and Maskin (1986) $\lambda = 0$, $lim_{p_1^I \to^+ \overline{p}_1^I}\Pi^I\left(p_1^I, \overline{p}_1^C\right) = \Pi_1^I\left(\overline{p}_1^I, \overline{p}_1^C\right)$. Analogously, at $\left(p_1^I, \overline{p}_1^C\right) \in P^{**}(C)$, if we take $\lambda = 1$, $lim_{p_1^C \to^- \overline{p}}1^C\Pi^C\left(p_1^I, \overline{p}_1^C\right) = \Pi_1^C\left(\overline{p}_1^I, \overline{p}_1^C\right)$. Then all the conditions required in Theorem 5 are satisfied and a mixed strategy equilibrium (μ_1^{I*}, μ_1^{C*}) exists.

Point 3

Finally, we prove that $E\Pi^I(\mu_1^{I*}, \mu_1^{C*}) > 0$ and $E\Pi^C(\mu_1^{I*}, \mu_1^{C*}) < (u - \frac{9}{16}\psi)D_2$. The first inequality simply follows from the fact that $\Pi^i(p_1^i, p_1^j) > 0$ for any admissible price pair. To establish the second inequality we can proceed by contradiction. Suppose that the equilibrium mixed strategies μ_1^{I*}, μ_1^{C*} are such that $p \in P^C$ occurs with probability 1, with an expected profit for firm *C* equal to $E\Pi^C\ (\mu_1^{I*}, \mu_1^{C*}) = (u - \frac{9}{16}\psi)D_2$. From point 1, we know that the best reply of the incumbent is always included in P^I for any price $p_1^C \in [0, u]$; therefore, Π^I is always increasing in p_1^I moving from region P^C to P^{IC} to P^I. Then, the incumbent can profitably deviate by giving more weight μ_1^I (or choose with probability 1) to prices such that $p \in P^I$ and $p \in P^{IC}$ occur with positive probability. Hence, in a mixed strategy it cannot be that $p \in P^C$ occurs with probability 1, and P^I and P^{IC} have to occur with positive probability. The competitor obtains profits lower than $(u - \frac{9}{16}\psi)D_2$ when $p \in P^{IC}$ and, for D_2 sufficiently large, for $p \in P^I$, since its best reply is always at the boundary of region P^C. Hence, the expected profits in a mixed strategy equilibrium must be $E\Pi^C(\mu_1^{I*}, \mu_1^{C*}) <\ (u - \frac{9}{16}\psi)D_2$. When D_2 is small, for very high prices of the incumbent the competitor's optimal reply is in P^I: the competitor optimally sets $\widehat{p}_1^C(p_1^I, w)$ and covers a very large fraction of the (large) first market, renouncing to enter the (small) second market as a monopolist. However, it cannot be that in a mixed strategy equilibrium this outcome occurs with a probability sufficiently high to make $E\Pi^C(\mu_1^{I*}, \mu_1^{C*}) \geq\ (u - \frac{9}{16}\psi)D_2$. In this case, indeed, the incumbent, would induce the competitor to almost exhaust its obligations (obtaining to enter as a monopolist in the small second market) in a too generous way, by leaving a large fraction of the large first market to the competitor and making it selling more than its obligations. Remind that in the region where the competitor sets $\widehat{p}_1^C(p_1^I, w)$, the profits of the incumbent are decreasing in p_1^I. By putting more weight on lower prices the incumbent would be better off. Then, $E\Pi^C(\mu_1^{I*}, \mu_1^{C*}) < (u - \frac{9}{16}\psi)D_2$.■

Proof of Proposition 4. Let us analyze first the case when $\overline{q}^I < D$. 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:

- *I* and *C* enter the first market: in the mixed strategy equilibrium $E\Pi^I > 0$ and $0 < E\Pi^C < (u - \frac{9}{16}\psi)D_2$.
- Only *I* enters the first market: the incumbent uses all its obligations and stays out of the second market, that is monopolized by firm *C*. The profits are therefore $\Pi^I = (u - \frac{9}{16}\psi - w - f)D_1$ and $\Pi^C = (u - \frac{9}{16}\psi - w - f)D_2$ that are positive by assumption.
- Only *C* enters the first market: in this case it is the competitor that covers all the first market demand at the monopoly price staying out at the second stage that is monopolized by the incumbent. We have therefore $\Pi^I = (u - \frac{9}{16}\psi - f)D_2 - wD_1$ and $\Pi^C = (u - \frac{9}{16}\psi - w - f)D_1$.
- No firm enters the first market: if no firm enters the first market, both will enter the second with profits $\Pi^I = (\frac{\psi}{4} - f)D_2 - wD_1$ and $\Pi^C = (\frac{\psi}{4} - f - w)D_2$.

Since the incumbent moves first, and makes positive profits entering the first market for any reaction of the competitor, *I* enters. Since $E\Pi^C(\mu_1^{I*}, \mu_1^{C*}) < (u - \frac{9}{16}\psi)D_2$ the competitor is better off staying out of the first market and becoming a monopolist in the second market. Uniqueness simply follows by construction.

In the case $\overline{q}^I = D$ (and $\overline{q}^C = 0$) the incumbent has enough obligations to cover the entire demand. In this case we have to analyze the marketing and price decisions in just one market, and the firms are driven by the aim of maximizing the market profits, with no further strategic consideration, exactly as it was when we analyzed market 2 equilibria in Propositions 1 and 2. If *C* enters the price equilibrium corresponds to case a) in Proposition 1, and *C* sells nothing. Then, given the marketing costs fD_1, firm *C* has no incentive to enter.[27]

Proof of Lemma 2. We solve the same game as the benchmark model substituting the cost function (Eq. (3)) determined by the TOP obligations with a linear cost function $C_i(q_i) = wq_i$ for $i = I, C$ and any q_i. Hence, the marginal cost is *w* for any amount of gas delivered to the final market. This feature eliminates the strategic link between first and second market entry and pricing decisions that characterizes the benchmark model. Given the timing of the game we analyze the price game in the second market. If only one firm enters, the monopoly price $u - \frac{9}{16}\psi$ is set as in the benchmark model. If both firms enter the second market, market demand is given by Eq. (2) and the profit function is

$$\Pi_2^i = \left[\frac{1}{2} + \frac{p_2^j - p_2^i}{\psi}\right]\left(p_2^i - w\right).$$

Then the unique symmetric Nash equilibrium in prices is $p_2^I = p_2^C = w + \frac{\psi}{2}$ and each firm obtains profits $\Pi_2^i = D_2(\frac{\psi}{4} - f) > 0$. Hence, in the entry stage both firms decide to enter. Moving to the entry and price decisions in the first market, since the marginal costs are constant, the second market equilibrium is unaffected by the first

[27] Notice that the same outcome would occur also if we disaggregate the marketing and price decisions in the different submarkets $d = 1, \ldots, D$: given the incumbent obligations $\overline{q}^I = D$ there is no way for firm *C* to enter in an earlier submarket and price in such a way that the incumbent exhausts its residual obligations, creating room for entry in a later stage. Hence, the complete monopolization of the market by the incumbent occurs even in a disaggregated analysis.

market strategies. Hence, the same arguments developed for the second market apply: the price equilibrium is $p_1^I = p_1^C = w + \frac{\psi}{2}$, and both firms enter the first market as well.

Proof of Lemma 3. Maintaining the sequential contracting structure of the benchmark model, we can equivalently analyze the $d=1,\ldots,D$ submarkets sequentially or grouping them in *three* submarkets of sizes equal to $\overline{q}^I$, $\overline{q}^C$ and $D-\overline{q}^I-\overline{q}^C$. Hence, in each of the three submarkets, that are opened sequentially, I decides whether to enter, then C chooses as well and finally the active firms price simultaneously. In the first two submarkets the analysis of the benchmark model still applies: the incumbent enters a market of size $\overline{q}^I$ and the competitor stays out, then entering as a monopolist the second market of size $\overline{q}^C$. At this stage, both firms have exhausted their obligations and their marginal cost is w. Then, both firms enter the residual market of size $D-\overline{q}^I-\overline{q}^C$ for the same argument developed in the Proof of Lemma 2.

Proof of Proposition 6. Let us consider first the case of *vertical separation*, where the two wholesalers I^W and C^W and the two retailers I^R and C^R are independent companies. Since both retailers purchase gas in the wholesale market at the price p_w set by the dispatcher, Lemma 2 applies to stages 3 and 4: retailers I^R and C^R enter all submarkets and set the price $p^I = p^C = p_w + \frac{\psi}{2}$. Then, given the allocation rules of the dispatcher, the wholesalers I^W and C^W face a standard Bertrand game and set the prices $p_w^I = p_w^C = w$. Since the demand is completely covered, the dispatcher mandates deliveries $S^i = \overline{q}^i$, $i=I,C$.

Consider next the case of *vertically integrated companies*, where the wholesale and retail units i^W and i^R belong to the same company $i=I,C$. The profit of the integrated firm $i=I,C$ is

$$\Pi^i = p_w S^i - w\left[\overline{q}^i + max\left\{S^i - \overline{q}^i, 0\right\}\right] + \left(p^i - p_w\right)D^i$$

where S^i is mandated by the dispatcher according to the allocation rules, and D^i depends on the entry and pricing strategies of the retail unit i^R. Notice that S^i depends on the wholesale bids p_w^I and p_w^C and on total demand of the retailers. Since the retail markets are covered, any increase or decrease in firm i's demand is compensated by an opposite adjustment in firm j's demand, leaving total demand unchanged. Hence, the sales S^i of the upstream unit i^W do not depend on the retail demand D^i collected by the downstream unit i^R. Consequently, the company's marginal cost at stage 4, when the retail units set the final price p^i, is p_w, the cost of the gas purchased on the wholesale market, and the retail units set the prices $p^I = p^C = p_w + \frac{\psi}{2}$ and share the demand in each duopoly submarket. At stage 3, since the margin for entering an additional submarket is $\frac{\psi}{4} - f > 0$, they enter all submarkets as in Lemma 2. The wholesale units at stage 1 then face the same incentives as in the vertical separation case and set $p_w^I = p_w^C = w$.

Proof of Proposition 7. We start from the *vertical separation* case, where the two wholesalers I^W and C^W and the two retailers I^R and C^R are independent companies. At stage 4, whatever demand is collected in the previous stages, choosing the cheaper wholesaler is the dominant strategy for the retailers. Then, at stage 3, the firms set their prices in the markets they entered at stage 2; these latter are either monopolies or duopolies. In the monopoly markets the firm sets the maximum price that induces all the consumers to purchase, i.e. $p_m = u - \frac{9}{16}\psi$. In the duopoly markets the firms set the optimal price given their common marginal cost, equal to the price of the wholesaler selected at stage 4. Since firms obtain positive net profits in the duopolies they enter, at stage 2 both firms enter all submarkets. Finally, at stage 1 the wholesalers face the standard incentives of Bertrand competition, since they anticipate they are not selected at stage 4 if they offer a higher wholesale price, and they get all the contracts if they undercut the rival. The equilibrium wholesale prices are therefore $p_w^I = p_w^C = w$ while the retail prices are then $p_d^I = p_d^C = w + \frac{\psi}{2}$ in each of the d submarkets.

Let us now turn to the case of *vertical integration*, where the wholesale and retail units i^W and i^R belong to the same company $i=I,C$. In this setting, we may have internal transfers of gas from the wholesale to the retail unit of the same company, or a trade of gas between a company's wholesale unit and the competitor's retail unit. Firm i's profits depend on the amount of gas S^i withdrawn from the TOP contract with the producer, the cross-firms wholesale trade and the retail demand D^i. We have therefore

$$\Pi^i = p_w^i S^i - w\left[\overline{q}^i + max\left\{S^i - \overline{q}^i, 0\right\}\right] + p^i D^i - p_w^i min\left\{S^i, D^i\right\} - p_w^j max\left\{D^i - S^i, 0\right\}, \tag{9}$$

where the first two terms correspond to the revenues and costs of the wholesale unit, that purchases from the producer a volume S^i of gas under TOP obligations and sells it to the own and, possibly, competitor's retail units at price p_w^i, while the latter three terms are the revenues of the retail unit and the cost of the gas purchased from the internal wholesale unit and from the competitor's one. The expression above is simply describing the different sources of revenues and costs of the wholesale and retail units, while it is not yet considering the optimal strategies in the purchase of gas. Indeed, given the long term contract with the producer and the wholesale prices p_w^i and p_w^j, each company decides how to purchase the gas needed to serve the final demand D^i. These choices depend on the comparison of w, p_w^i and p_w^j. If, for instance, $w < p_w^i \leq p_w^j$, neither firm will buy from the rival's wholesale unit if it needs gas in excess to its TOP obligations, and $S^i = D^i$, $i=I,C$; if, instead, $w = p_w^i < p_w^j$ firm j would purchase the gas in excess to its obligations (if any) from the rival unit while firm i buys gas only through the contract with the producer. In this case $S^i \geq D^i$ and $S^j \leq D^j$. Hence, the amount of gas S^i that the wholesale unit withdraws from the contract with the producer reflects the optimal purchase of gas to be delivered to the final consumers.

At stage 4 each retail unit i^R selects the cheaper provider to cover the retail demand D^i. Since on the amount $\overline{q}^i$ the company has TOP obligations, if $D^i \geq \overline{q}^i$ the retail unit withdraws gas up to $\overline{q}^i$ from the long term contract through the company wholesale unit. If any additional gas $D^i - \overline{q}^i$ is needed, retail unit i at stage 4 buys from company j's wholesale unit if $p_w^j \leq w$, and from the long term contract at w otherwise. At stage 4 there are therefore four different outcomes: if $p_w^i > w$, $i=I,C$, both firms prefer to buy gas from the producer at w through the company wholesale unit; if $p_w^i > w$ and $p_w^j \leq w$ firm i buys the gas (if any) in excess to its TOP obligations from j and this latter buys all the gas from the producer; finally, if $p_w^i \leq w$, $i=I,C$, both firms buy the gas in excess of their obligations (if any) from the rival wholesale unit. Let us now consider the subgames indexed by the wholesale prices set at stage 1.

In the subgame when $p_w^i > w$, $i=I,C$, each firm buys gas only through the TOP contract with the producer. Then, each company's retail sales determine the amount of gas withdrawn from the upstream contract with the producer, i.e. $S^i = D^i$. Firm i's profits become $\Pi^i = p^i D^i - w\left[\overline{q}^i + max\left\{D^i - \overline{q}^i, 0\right\}\right]$ as in the benchmark model, with a discontinuous marginal cost jumping from 0 to w at $\overline{q}^i$. Then, the entry and price equilibrium is such that firm $i=I,C$ enters as monopolist submarkets of total size $\overline{q}^i$ and sets the monopoly price $p_m = u - \frac{9}{16}\psi$ with profits $\Pi^i = (p_m - w - f)\overline{q}^i$. To show this, suppose that firm I enters as a monopolist in a subset of submarkets of total size $\overline{q}^I$ and, deviating from the proposed equilibrium, further enters additional submarkets competing with C. In these duopolies, I's marginal cost is w since it has already covered its obligations in its monopoly submarkets, while firm C has a 0 marginal cost due to TOP. Hence, firm I in a duopoly price equilibrium does not obtain any sale, as Proposition 1 shows, and it has no incentive to enter additional submarkets in excess to $\overline{q}^I$. The same argument applies to C. Hence, we obtain segmentation and monopolization even in case of simultaneous entry and simultaneous pricing.

Consider next the case when $p^i_w \le w$, $i = I, C$: both firms anticipate they will sign at stage 4 a contract with the other company if retail demand exceeds the company's TOP obligations. Suppose that they enter each submarket and set a retail price configuration such that $D^i + D^j = D$ and $D^i > \overline{q}^i$, that implies $D^j < \overline{q}^j$. Since, firm i anticipates it will purchase the amount $D^i - \overline{q}^i$ from the rival at p^j_w, this latter is its marginal cost for additional retail sales. The wholesale price p^j_w is also firm j's marginal cost when $D^j < \overline{q}^j$. Indeed, firm j is selling in the retail market an amount $D^j < \overline{q}^j$ and to company i an amount $D^i - \overline{q}^i$ of gas. Its profits, then, are $\Pi^j = p^j D^j + p^j_w \left(D^i - \overline{q}^i\right) - w\overline{q}^j$. Since $D^i = D - D^j$ and $D - \overline{q}^i = \overline{q}^j$, substituting and rearranging we obtain $\Pi^j = \left(p^j - p^j_w\right) D^j - \left(p^j_w - w\right)\overline{q}^j$. Then, if firm j increases its retail sales by cutting the retail price p^j, it displaces company i in the retail market, reducing its wholesale sales to firm i at p^j_w: this latter, hence, acts as an opportunity marginal cost for firm j. For the same argument, at a price configuration such that $D^i < \overline{q}^i$, firm i sells gas to firm j. In this case, p^i_w is the direct marginal cost for firm j and the opportunity marginal cost for firm i. We conclude that when $p^i_w \le w$, $i = I, C$, both firms sign the contract for gas deliveries with the other company at stage 4 and they have the same marginal cost. Given Lemma 2, then, they enter each submarket. Since by assumption $\overline{q}^I > D^I = D^C = D/2 > \overline{q}^C$, at the equilibrium prices firm I sells to firm C, the relevant marginal cost is p^I_w and the equilibrium prices are $p^I = p^C = p^I_w + \frac{\psi}{2}$. The equilibrium profits in this subgame are therefore $\Pi^i = (\frac{\psi}{4} - f)D + (p^I_w - w)\overline{q}^i$.

This is the equilibrium outcome also when $p^C_w > w$ and $p^I_w \le w$. At stage 4, company I does not sign while C does. The entry and price equilibrium in the last two stages entails both firms entering all submarkets and covering half of total demand D; firm I sells gas to firm C and the (direct or opportunity) marginal cost of the two firms is p^I_w.

Finally, consider the subgame when $p^C_w \le w$ and $p^I_w > w$. In this case at stage 4 firm I signs the contract while firm C does not. Firm I's marginal cost is then 0 up to $\overline{q}^I$ and p^C_w for larger retail sales, while company C's marginal cost is p^C_w for retail sales short of $\overline{q}^C$, since in this range C is selling gas to I, and w for larger retail sales. Since in this latter range I is selling less than its obligations, its marginal cost is 0 while C's marginal cost is w, and, as shown in Proposition 1, there is no price equilibrium in which C has positive sales. Consequently, the only price and entry equilibrium can occur when $D^I > \overline{q}^I$: in this case I purchases gas from C, and the two firms have the same marginal costs p^C_w. The price and entry equilibrium, then, entails firm I entering as a monopolist the submarkets of size $\overline{q}^I$ and both firms entering the submarkets of size $\overline{q}^C$, each selling $\overline{q}^C/2$ at price $p^I = p^C = p^C_w + \frac{\psi}{2}$. The equilibrium profits are then $\Pi^I = (\frac{\psi}{4} - f)\overline{q}^C/2 + (p_m - w)\overline{q}^I$ and $\Pi^C = (p^C_w - w)\overline{q}^C - (\frac{\psi}{4} - f)\overline{q}^C/2$.

Turning to the choice of the wholesale prices, since retail profits are the same for any $p^i_w \le w$, if company i wants to induce the competitor to buy gas in excess of its obligations from i's wholesale unit, it is dominant to set $p^i_w = w$. The wholesale price choices at stage 1 are then summarized in the following payoff matrix:

C/I	$p^I_w = w$	$p^I_w > w$
$p^C_w = w$	$\Pi^I = (\frac{\psi}{4} - f)D$ $\Pi^C = (\frac{\psi}{4} - f)D$	$\Pi^I = (\frac{\psi}{4} - f)\overline{q}^C/2 + (p_m - w)\overline{q}^I$ $\Pi^C = (\frac{\psi}{4} - f)\overline{q}^C/2$
$p^C_w > w$	$\Pi^I = (\frac{\psi}{4} - f)D$ $\Pi^C = (\frac{\psi}{4} - f)D$	$\Pi^I = (p_m - w - f)\overline{q}^I$ $\Pi^C = (p_m - w - f)\overline{q}^C$

Comparing the profits in the different subgames, the equilibrium choice entails both firms setting a wholesale price above w, implementing the segmentation and monopolization outcome.■

Appendix II. The competitor's choice of TOP

In this Appendix, we show that if the competitor can choose its obligations $\overline{q}^C$, it will indeed choose exactly $\overline{q}^C = D - \overline{q}^I$. To prove this result we add an initial stage where the competitor signs its long term contract deciding the amount of TOP obligations.

We already know from Proposition 4 that if the competitor chooses TOP obligations equal to the residual demand, $\overline{q}^C = D - \overline{q}^I$, in equilibrium its profit can be written as $\left(u - \frac{9}{16}\psi - w - f\right)\left(D - \overline{q}^I\right)$. Lemma 3 has established that if the competitor selects $\overline{q}^C < D - \overline{q}^I$, then its profit amounts to $\left(u - \frac{9}{16}\psi - w - f\right)\overline{q}^C + \left(\frac{\psi}{4} - f\ \right)\left(D - \overline{q}^I - \overline{q}^C\right)/2$. Finally, if obligations in excess to the residual demand are chosen, that is $\overline{q}^C > D - \overline{q}^I$, the equilibrium entry and price decisions are the same as in Proposition 4, with I entering the first market, and C the second one, with sales $D_2 < \overline{q}^C$. Although the competitor C has TOP obligations exceeding residual demand $D - \overline{q}^I$, it prefers not to enter until the incumbent has exhausted its own obligations. Indeed, if C decides to enter the first market, it would share D_1 with the incumbent and, as a consequence, I would not exhaust its obligations $\overline{q}^I$ in the first market. Hence, the incumbent would enter the second market as well, destroying the monopoly profits that C would gain otherwise. Hence, the competitor would prefer to maintain its residual obligations idle, although it is paying for it.[28] The competitor's profits are therefore $\left(u - \frac{9}{16}\psi - f\right)\left(D - \overline{q}^I\right) - w\overline{q}^C$. Hence, the competitor will choose $\overline{q}^C = D - \overline{q}^I$. We summarize this discussion in the following Proposition.

Proposition 8. *If the competitor chooses its obligations $\overline{q}^C$ at time 0, given the incumbent's obligations $\overline{q}^I$, and then the game follows as in the benchmark model, C chooses obligations equal to the residual demand,* i.e. $\overline{q}^C = D - \overline{q}^I$.

The discussion on the different configurations developed above highlights also the outcomes of an alternative situation in which the firms are still endowed with exogenous TOP obligations $\overline{q}^I$ and $\overline{q}^C$, but market demand D may be larger or smaller than their obligations, for instance due to cyclical fluctuations. If total obligations fall short of total demand, i.e. $\overline{q}^C + \overline{q}^I < D$ we obtain segmentation for a relevant part of the market $\overline{q}^I + \overline{q}^C$ and generalized entry in the residual part $D - \overline{q}^I - \overline{q}^C$ as shown in Lemma 3. If instead the two firms have obligations in excess of market demand, $\overline{q}^C + \overline{q}^I > D$, the segmentation result occurs, with some obligations that are not matched by actual deliveries as discussed above. Hence, we can conclude that when demand fluctuates and firms have exogenous obligations, as it is with short run demand shocks and firms committed to long term TOP contracts, segmentation would involve volumes of gas corresponding to $min\left\{\overline{q}^C + \overline{q}^I, D\right\}$.

References

Allaz, B., Villa, J.-L., 1993. Cournot competition, forward markets, and efficiency. Journal of Economic Theory 59, 1–16.

Bushnell, J., 2008. Oligopoly equilibria in electricity contract markets. Journal of Regulatory Economics 32, 225–245.

Cretì, A., Villeneuve, B., 2004. Long term contracts and take-or-pay clauses in national gas markets. Energy Studies Review 13 (1), 75–94.

[28] The case of simultaneous entry and obligations in excess to market demand is more complex and we leave it to future research.

Crocker, K.J., Masten, S.E., 1985. Efficient adaptation in long-term contracts: take-or-pay provisions for natural gas. American Economic Review 75, 1083–1093.
Dasgupta, P., Maskin, E., 1986. The existence of equilibrium in discontinuous economic games, I: theory. Review of Economic Studies LIII, 1–26.
Davidson, C., Deneckere, R., 1986. Long term competition in capacity, short term competition in prices, and the Cournot model. Rand Journal of Economics 17, 404–415.
Dixit, A., 1980. The role of investment in entry deterrence. Economic Journal 90, 95–106.
Dudey, M., 1992. Dynamic Edgeworth–Bertrand competition. Quarterly Journal of Economics 107, 1461–1477.
Ergeg, 2008. ERGEG 2008 Status Review of the Liberalisation and Implementation of the Energy Regulatory Framework. European Regulators Group for Electricity and Gas, Brussels.
Escosa, 2006. Monitoring the Development of the Energy Retail Competition in South Australia. The Essential Services Commission of South Australia, Adelaide.
European Commission, 2005. Report on Progress in Creating the Internal Gas and Electricity Market, COM(2005) 568. Competition DG, Bruxelles.
Ghemawat, P., McGaham, A., 1998. Order backlogs and strategic pricing: the case of the US large turbine generator industry. Strategic Management Journal 19, 255–268.
Green, R., Newbery, D., 1992. Competition in the British electricity spot market. Journal of Political Economy 100, 929–953.
Hubbard, G., Weiner, R., 1986. Regulation and long-term contracting in US natural gas markets. Journal of Industrial Economics 35, 71–79.
Klemperer, P., Meyer, M., 1989. Supply function equilibria in oligopoly under uncertainty. Econometrica 57, 1243–1277.
Kreps, D., Scheinkman, J., 1983. Capacity constraints and Bertrand competition yield Cournot outcomes. Bell Journal of Economics 14, 326–337.
Maggi, G., 1996. Strategic trade policies with endogenous mode of competition. American Economic Review 86, 237–258.
Mahenc, P., Salanié, F., 2004. Softening competition through forward trading. Journal of Economic Theory 116 (2), 282–293.
Polo, M., Scarpa, C., 2003. The Liberalization of Energy Markets in Europe and Italy. IGIER . (w.p. n. 230).
Rey, P., Tirole, J., 2007. A primer on foreclosure. In: Armstrong, M., Porter, R. (Eds.), Handbook of Industrial Organization, vol. III. North Holland, pp. 2145–2220.
Salop, S., 1979. Monopolistic competition with outside goods. Bell Journal of Economics 10, 141–156.
Vives, X., 1986. Commitment, flexibility and market outcomes. International Journal of Industrial Organization 4, 217–229.