Gas release and transport capacity investment as instruments to foster competition in gas markets

C. Chaton
University of Alberta (CABREE)

F. Gasmi
Université de Toulouse I (GREMAQ, IDEI)

M.L. Guillerminet
Hamburg University (FNU)

and

J.D. Oviedo
Universidad del Rosario, Bogotá

Abstract

This paper develops a simple model for examining the interaction between gas-release and capacity investments programs as tools to improve the performance of imperfectly competitive natural gas markets. We first study the "artificial" duopoly effect created by a regulator who introduces a gas-release program under both a partial and a global budget-balance constraint imposed on an incumbent. We then assume that the gas-release measure is complemented by a program of investment in transport capacity dedicated to the shipping of gas from a competitive market by a marketer at a regulated transport charge. Calibration and simulation techniques are used to compare these two scenarios under different assumptions on the way regulation is conducted.

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1 Introduction

To establish competitive conditions in natural gas markets, new entrants need to have fair and efficient access to customers, delivery networks, gas supplies, and flexibility services. Release programs are typically designed to overcome the problem of inadequate access to supplies or capacity. Recently, the European Parliament has proposed amendments to the gas directive at first reading to ensure that there can be release of gas when this appears to be necessary for the development of sustainable competition. To reduce the likelihood that incumbent operators exercise their market power and to facilitate competition, the regulator may, at least in the short term, advise incumbents to release gas from their long-term contracts to new entrants. Such initiatives may then be complemented by investments programs in transport capacity with the goal of integrating regional markets and promoting competition for the benefit of consumers. This paper provides a simple modeling framework within which these alternative policies can be analyzed.

Gas release programs have been conducted in many European countries including Austria, France, Germany, Italy, Spain, and the UK. These programs have often been imposed by governments following the application of the 98/30 CE directive or by competition authorities as a condition for approbation of mergers involving the incumbent (historical) operator. Auctions have typically been the means by which the released gas has been allocated although bilateral contracting has also been used in some circumstances. This type of asymmetric regulation was first implemented in the UK in 1988 and since then has proven to be an instrument for opening the door to competition widely used in Europe.

In 1988, the Monopolies and Merger Commission (MMC) considered that the monopsony position of British Gas (BG) upstream of the UK gas industry constituted an important entry barrier downstream and allowed BG to enjoy a monopoly position in the supply of eligible customers. The British government, in charge of implementing the recommendations of the MMC, obtained voluntary commitments from BG to comply with the “90/10 rule” under which BG could contract for no more than 90% of new fields, hence leaving at least 10% to other companies.

Following a review of the effectiveness of the MMC recommendations, the Office of Fair Trading (OFT) has decided in 1991 that BG's market share should be decreased steadily to reach a limit of no more than 40% by 1995. To achieve this objectif, a gas-release program implying a retrocession by BG of 5 billion cubic meters (bcm) was implemented during the period 1992-1995. This program was coupled with a prohibition for BG to sign contracts with the North Sea producers on new sources of gas. Each year, the released gas was allocated on a pro-rata basis to successful applicants at a price reflecting BG's (weighted) average cost. By 1994, the UK spot market emerged, wholesale prices dropped, and so did BG's market share.

As a condition for the approval of the OMV merger with the gas activities of Energie Allianz that led to the creation of EconGas, the Austrian competition authority launched a gas-release program in 2002. In July 2003, EconGas auctioned off 250 million cubic meters (MMcm) of natural gas. EconGas held its second online auction for the same volume of gas in July 2004 and its third for a volume of 270 MMcm in July 2005. An important aspect of the Austrian gas regulatory policy is that although the incumbent has to release 20% of its long-term import contracts until 2008, the price of released gas is determined solely by the auction and EconGas has no obligation to sell if such a price is below cost.

Concerned with limited competition in France, in particular in the Southern part of the country, approval by the Commission de Régulation de l'Energie (CRE) made the approval of the restructuring of Total and Gaz de France (GDF) partly conditional on these two companies following a three-year gas-release program that started in January 2005. Under this program, GDF has to auction off 1.42 bcm of gas each year. Although the released volume represents only 3.5% of GDF and Gaz du Sud Ouest domestic sales, CRE has argued that these temporary supplies should allow new marketers to enter the Southern market where the current situation is simply ".. no competition." Moreover, CRE trusts that by 2008 the latest, new infrastructures, such as the Fos-2 Liquefied Natural Gas (LNG) terminal, and more pipeline interconnections to the Spanish transport network should enable these new entrants to secure their own longer-term supplies.

The German gas-release program was launched in July 2003 and the first deliveries went through in October of the same year. As a condition for approval of the merger of E.ON and Ruhgas, the German government obtained a commitment from E.ON Ruhrgas to release 18.6 bcm of gas in six annual auctions. The system of retrocession is a bidding mechanism with a reserve price equal to 95% of the imported gas cost.

In Italy, starting in January 2002 and until December 2010, Snam/Eni (the incumbent operator) has to release 39% of gas contracted out under long-term conditions. This gas-release program is coupled with additional measures of market share reduction. So, for example, no operator can sell gas (through its parent companies or its subsidiaries) to customers representing more than 50% of the annual domestic gas consumption net of own consumption. In 2004, the Italian regulatory and competition authorities unveiled an abuse of dominant position by Eni and as a result these authorities set a program whereby Eni would release 9.2 bcm gas per year during the period 2004-2008.

The Spanish government conducted a gas-release program for 25% of gas imports from Algeria that started in October 2001 and ended in January 1, 2004. Then, the contracts were turned over to Gas Natural/Enagas. The total retrocession amounted to 4.24 bcm representing 11% of total supplies to the Spanish market and 15% of the eligible market. Participation to the auctions was made conditional on submission of sales forecasts and plans for securing diversified gas supplies once the gas-release program had came to an end. The average price was set equal to the gas purchasing cost (the oil-indexed price of gas) plus a fixed management fee.

Despite the large popularity of gas-release programs as a means to trigger competition in the natural gas industry, as shown by this brief examination of some representative European experiences, it is striking that the academic literature that analyzes their economic impact is rather thin.[1] For the purpose of our paper and to the best of our knowledge, the only paper that is worth mentioning here is Clastres and David (2005). These authors examine the behavior of an incumbent subject to asymmetric regulation of the gas-release measures type discussed above. Gasmi and Oviedo (2005) focus on transport capacity as an instrument to enhance competition and security of supply. While both of these papers are concerned with the important policy

[1] In contrast, there exists a quite large institutional litterature on the subject that has essentially emanated from the European Union.

issue of what the proper instruments to promote competition in the natural gas industry are for the regulator, they only consider one instrument at a time, namely, exclusively gas release or capacity investments. The objectif of our paper is to examine the economic impact of these two instruments when the regulator can use them simultaneously. A particular effort will be devoted to highlighting the way these alternative instruments interact.

This paper is organized as follows. The next section presents the basic theoretical ingredients of our model and considers the case where gas release is the only instrument used by the regulator to foster competition. As a preliminary step, we examine the private incentives of the incumbent to engage in gas release. Then, we assume that the price at which gas is released is under the control of the regulator. We derive the optimal regulatory policies under the incumbent's balanced-budget constraint when accounting separation between sales to final consumers and sales to the marketer is imposed and when it is not. Section 3 introduces transport capacity as an additional instrument to promote competition by allowing imports of gas produced under competitive conditions. Again, we first consider the case where the gas-release decision is decentralized to the incumbent and then the case where both the gas-release and investment activities are regulated. Section 4 presents some calibration and simulations exercises. Section 5 summarizes the main arguments of the paper and points to some policy implications.

2 Gas release as the only instrument to foster competition

Consider a regional market dominated by a monopolist with a profit function[2]

$$\Pi_m = \quad p(q_m) \times q_m - C_m(q_m) - F_m \tag{1}$$

where $p(.)$ is the inverse demand function, $C_m(.)$ is the variable cost function and F_m is the fixed cost. This incumbent profit-maximizing firm exercises its market power according to the inverse-elasticity rule

$$\frac{p - C_m'}{p} = \frac{1}{\varepsilon(q_m)} \tag{2}$$

[2]Throughout, we assume for the sake of simplicity that market demand is linear and costs are convex.

Assuming the functional forms $p(q_m) = \gamma - q_m$ and $C_m(q_m) = \theta q_m$, $\gamma > \theta$, we obtain $q_m = (\gamma - \theta)/2$ and $\Pi_m = (\gamma - \theta)^2/4 - F_m \geq 0$ which requires $F_m \leq (\gamma - \theta)^2/4$ for the firm to be active.

In order to improve the efficiency of this regional market, the social planner "artificially" creates a duopoly by requiring that this regional monopolist, hereby called the incumbent I, release to an entrant, hereby called the marketer R, a fraction α of its production at a unit price p_R. Under this gas-release measure, we have then

$$q_I + q_R = q_m \tag{3}$$

$$q_I = (1 - \alpha) q_m \tag{4}$$

$$q_R = \alpha q_m \tag{5}$$

where q_I and q_R are the quantities sold by the incumbent to consumers and the marketer respectively.

Under these circumstances, the profit function of the incumbent is

$$\Pi_I = p(q_I + q_R) \times q_I + p_R \times q_R - C_I^I(q_I) - C_I^R(q_R) - F_I \tag{6}$$

where $(C_I^I(q_I) + C_I^R(q_R))$ and F_I are the incumbent's variable and fixed costs respectively. Note that the incumbent's technology allows for separability between the costs of gas to be released to the marketer and that for final consumption. The profit function of the marketer is

$$\Pi_R = [p(q_I + q_R) - p_R] q_R \tag{7}$$

and the net consumer surplus is

$$CS = S(q_I + q_R) - p(q_I + q_R) \times (q_I + q_R) \tag{8}$$

As a preliminary step, we briefly examine the question of whether or not gas release can be a market outcome. We assume that competition takes place sequentially, namely, that the incumbent first sets the gas-release charge p_R and then the marketer and the incumbent compete à la Cournot. The market equilibrium is found by first solving the quantity game in which the incumbent maximizes its profit (6) with respect to q_I and the marketer maximizes its profit (7) with respect to q_R.[3] The first-order conditions of this game are:[4]

$$\frac{\partial \Pi_I}{\partial q_I} = p + q_I p' - C_I^{I'}(q_I) \quad = 0 \tag{9}$$

$$\frac{\partial \Pi_R}{\partial q_R} = p + q_R p' - p_R \quad = 0 \tag{10}$$

and these conditions implicitly define the supply functions $q_I(p_R)$ and $q_R(p_R)$. The next lemma gives some useful expressions for the slopes of these supply functions.

Lemma 1 *The supply functions $q_I(p_R)$ and $q_R(p_R)$ satisfy*

$$\begin{aligned} \frac{dq_I}{dp_R} &= -\frac{1}{3p' - 2C_I^{I''}} & \frac{d^2 q_I}{dp_R^2} &= \frac{2C_I^{I'''}}{3p' - 2C_I^{I''}} \left[\frac{dq_I}{dp_R}\right]^2 \\ \frac{dq_R}{dp_R} &= \frac{2p' - C_I^{I''}}{p'[3p' - 2C_I^{I''}]} & \frac{d^2 q_R}{dp_R^2} &= -\frac{C_I^{I'''}}{3p' - 2C_I^{I''}} \left[\frac{dq_I}{dp_R}\right]^2 \end{aligned} \tag{11}$$

and

$$\alpha = \frac{p - p_R}{(p - p_R) + (p - C_I^{I'})} \tag{12}$$

This lemma says that an increase in the release charge leads to an increase in incumbent's output and a decrease in marketer's output with a net negative effect on aggregate output. It also says that the higher the incumbent's opportunity cost of releasing gas to the marketer as reflected in a higher relative marginal profit of the marketer, $(p - p_R)/(p - C_I^{I'})$, the smaller the release fraction α.

These supply functions are substituted back into the incumbent profit function and the latter is maximized with respect to p_R. This yields the

[3] Existence and uniqueness of this equilibrium is guaranteed by our assumptions of linear demand and convex costs.

[4] The second-order conditions are always satisfied under our demand and cost assumptions.

following first-order condition:

$$\frac{d\Pi_I}{dp_R} = q_R + \frac{(p_R - C_I^{R'})(2p' - C_I^{I''}) - (p - C_I^{I'})p' + q_I p'(p' - C_I^{I''})}{p'[3p' - 2C_I^{I''}]} = 0 \quad (13)$$

which together with conditions (9) and (10) yield the equilibrium level of α given in the next proposition.

Proposition 1 *Under decentralized gas release, the fraction of gas released by the incumbent is given by*

$$\alpha = \frac{(C_I^{I'} - C_I^{R'})(2p' - C_I^{I''})}{(p - C_I^{R'})(2p' - C_I^{I''}) + (p - C_I^{I'})(3p' - 2C_I^{I''})} \quad (14)$$

To illustrate this proposition, let

$$p(q_I + q_R) = \gamma - q_I - q_R, \; C_I^I(q_I) = \theta_I q_I, \; C_I^R(q_R) = \theta_R q_R, \; \gamma > \theta_I, \theta_R \quad (15)$$

In this case, the following solution obtains:

$$q_I = \frac{(\gamma - \theta_R)}{2} - \frac{7(\theta_I - \theta_R)}{10} \quad (16)$$

$$q_R = \frac{2(\theta_I - \theta_R)}{5} \quad (17)$$

$$p_R = \frac{(\gamma + \theta_R)}{2} - \frac{(\theta_I - \theta_R)}{10} \quad (18)$$

$$\alpha = \frac{4(\theta_I - \theta_R)}{5(\gamma - \theta_R) - 3(\theta_I - \theta_R)} \quad (19)$$

provided that $F_I \leq \frac{(\gamma-\theta_I)^2}{4} + \frac{(\theta_I-\theta_R)^2}{5}$. Observe that in the special case where $\theta_I = \theta_R$, one obtains $\alpha^m = 0$ as there are no incentives for the incumbent to engage in gas release.

Let us now assume that it is the regulator (and not the incumbent) who controls the gas-release charge p_R. As far as timing, we assume that the regulator first sets the release charge and then the incumbent and the marketer compete in output. Using (6)-(8), the utilitarian social welfare function W is given by

$$W(p_R) = S(q_I(p_R) + q_R(p_R)) - C_I^I(q_I(p_R)) - C_I^R(q_R(p_R)) - F_I \quad (20)$$

where the pair of supply functions is already substituted for. The regulator needs then to maximize social welfare (20) with respect to p_R, subject to the participation constraint of the regulated incumbent. We consider two versions of the incumbent participation constraint associated with the regulatory framework under which the gas-release program is developed.[5]

One possibility is to assume that regulation does not require accounting separation between the incumbent sales to final consumers and its (intermediate) sales to the marketer. In this case, the participation constraint can be written as

$$\Pi_I = \quad p(q_I + q_R) \times q_I + p_R \times q_R - C_I^I(q_I) - C_I^R(q_R) - F_I \geq 0 \quad (21)$$

Letting ϕ_I designate the Lagrange multiplier associated with (21) and using the fact that $\frac{\partial S(\cdot)}{\partial q_I} = \frac{\partial S(\cdot)}{\partial q_R} = p(\cdot)$, we obtain the following first-order conditions:

$$\begin{aligned} \phi_I q_R + \frac{dq_I}{dp_R}&\left[(1+\phi_I)(p - C_I^{I'}) + \phi_I q_I p'\right] \\ +\frac{dq_R}{dp_R}&\left[(1+\phi_I)(p - C_I^{R'}) - \phi_I(p - p_R - q_I p')\right] = 0 \quad (22) \\ &\phi_I[p q_I + p_R q_R - C_I^I(q_I) - C_I^R(q_R) - F_I] = 0 \quad (23) \end{aligned}$$

Alternatively, one could assume that accounting separation is required and that the regulator has only to guarantee that the revenues stemming from the gas-release activity allow the incumbent to just recover the "stand-alone" cost of this activity. In this case, the relevant participation constraint is

$$\Pi_I^R = \quad p_R \times q_R - C_I^R(q_R) - F_I^R \geq 0 \quad (24)$$

where $F_I^R = \delta F_I$ with $0 \leq \delta \leq 1$. Letting ϕ_I^R designate the Lagrange multiplier associated with (24), the following first-order conditions obtain is this case:

$$\phi_I^R q_R + \frac{dq_I}{dp_R}(p - C_I^{I'}) + \frac{dq_R}{dp_R}\left[(p - C_I^{R'}) + \phi_I^R(p_R - C_I^{R'})\right] = 0 \quad (25)$$

$$\phi_I^R[p_R q_R - C_I^R(q_R) - F_I^R] = 0 \quad (26)$$

Substituting the slopes $\frac{dq_I}{dp_R}$ and $\frac{dq_R}{dp_R}$ from Lemma 1 into (22)-(23) allows us to state the next proposition that characterizes the optimum when no accounting separation is required.

[5] The "local" participation constraint considered here can be viewed as reflecting the fact that the gas is typiquement released through auctions (see the introduction).

Proposition 2 *With no accounting separation, the optimal release charge, output levels, price, and shadow cost of the incumbent's global participation constraint satisfy the following conditions:*

$$\phi_I q_R + \frac{(2p' - C_I^{I''})\left[(1+\phi_I)(p - C_I^{R'}) - \phi_I(p - p_R - q_I p')\right]}{p'[3p' - 2C_I^{I''}]} = \frac{\left[(1+\phi_I)(p - C_I^{I'}) + \phi_I q_I p'\right]}{3p' - 2C_I^{I''}} \tag{27}$$

$$p - C_I^{I'} + q_I p' = 0 \tag{28}$$

$$p - p_R + q_R p' = 0 \tag{29}$$

To illustrate this proposition let us assume the functional forms given in (15) and no fixed cost. We obtain two solutions. When

$$-\frac{(\gamma - \theta_R)}{3} \leq (\theta_I - \theta_R) < 0 \tag{30}$$

the following solution obtains:

$$q_I = -2(\theta_I - \theta_R) \tag{31}$$

$$q_R = (\gamma - \theta_R) + 3(\theta_I - \theta_R) \tag{32}$$

$$p_R = -(\gamma - 2\theta_R) - 4(\theta_I - \theta_R) \tag{33}$$

$$\phi_I = 0 \tag{34}$$

$$\alpha = 1 + \frac{2(\theta_I - \theta_R)}{(\gamma - \theta_R) + (\theta_I - \theta_R)} \tag{35}$$

When $(\theta_I - \theta_R) \geq 0$, the solution is

$$q_I = \frac{\gamma - \theta_R}{2} - \left[\frac{7(\theta_I - \theta_R) + \sqrt{G}}{10}\right] \tag{36}$$

$$q_R = \frac{2(\theta_I - \theta_R)}{5} + \frac{\sqrt{G}}{5} \tag{37}$$

$$p_R = \frac{\gamma + \theta_R}{2} - \left[\frac{(\theta_I - \theta_R) + 3\sqrt{G}}{10}\right] \tag{38}$$

$$\phi_I = \frac{1}{10}\left[-1 + \frac{5(\gamma - \theta_R) + 13(\theta_I - \theta_R)}{\sqrt{G}}\right] \tag{39}$$

$$\alpha = -\frac{1}{2} + \frac{3(\theta_I - \theta_R) + \sqrt{G}}{2(\gamma - \theta_R)} \tag{40}$$

where $G \equiv [5(\gamma - \theta_I)^2 + 4(\theta_I - \theta_R)^2] \geq 0$. In the particular case where $\theta_I = \theta_R$ $(\equiv \theta)$, provided that the condition $\theta < \frac{\gamma}{2}$ holds, there is a unique solution given by

$$q_I = \frac{(5 - \sqrt{5})(\gamma - \theta)}{10} \tag{41}$$

$$q_R = \frac{\sqrt{5}(\gamma - \theta)}{5} \tag{42}$$

$$p_R = \frac{\gamma + \theta}{2} - \frac{3\sqrt{5}(\gamma - \theta)}{10} \tag{43}$$

$$\phi_I = \frac{-1 + \sqrt{5}}{10} \tag{44}$$

$$\alpha = \frac{\sqrt{5} - 1}{2} \tag{45}$$

Substituting the slopes $\frac{dq_I}{dp_R}$ and $\frac{dq_R}{dp_R}$ from Lemma 1 into (25)-(26) allows us to state the next proposition that characterizes the optimum when accounting separation is imposed by the regulator.

Proposition 3 *With accounting separation, the optimal release charge, output levels, price and shadow cost of the incumbent's partial participation constraint satisfy the following conditions:*

$$\phi_I^R q_R + \frac{(2p' - C_I^{I''})\left[(p - C_I^{R'}) + \phi_I^R(p_R - C_I^{R'})\right]}{p'[3p' - 2C_I^{I''}]} = \frac{(p - C_I^{I'})}{3p' - 2C_I^{I''}} \tag{46}$$

$$p - C_I^{I'} + q_I p' = 0 \tag{47}$$

$$p - p_R + q_R p' = 0 \tag{48}$$

Assuming zero fixed cost and the functional forms given in (15), we obtain three solutions in this case. When

$$(\theta_I - \theta_R) < -\frac{(\gamma - \theta_R)}{3} \tag{49}$$

the following solution is obtained:

$$
\begin{aligned}
q_I &= \frac{\gamma-\theta_R}{2} - \frac{(\theta_I-\theta_R)}{2} &(50)\\
q_R &= 0 &(51)\\
p_R &= \frac{\gamma+\theta_R}{2} + \frac{(\theta_I-\theta_R)}{2} &(52)\\
\phi_I^R &= -\frac{1}{2} - \frac{(\theta_I-\theta_R)}{(\gamma-\theta_R)+(\theta_I-\theta_R)} &(53)\\
\alpha &= 0 &(54)
\end{aligned}
$$

When

$$
-\frac{(\gamma-\theta_R)}{3} \leq (\theta_I-\theta_R) < 0 \qquad (55)
$$

we obtain

$$
\begin{aligned}
q_I &= -2(\theta_I-\theta_R) &(56)\\
q_R &= (\gamma-\theta_R)+3(\theta_I-\theta_R) &(57)\\
p_R &= -(\gamma-2\theta_R)-4(\theta_I-\theta_R) &(58)\\
\phi_I^R &= 0 &(59)\\
\alpha &= \frac{(\gamma-\theta_R)+3(\theta_I-\theta_R)}{(\gamma-\theta_R)+(\theta_I-\theta_R)} &(60)
\end{aligned}
$$

Finally, when $(\theta_I-\theta_R) \geq 0$, the following solution obtains:

$$
\begin{aligned}
q_I &= \frac{\gamma-\theta_R}{3} - \frac{2(\theta_I-\theta_R)}{3} &(61)\\
q_R &= \frac{\gamma-\theta_R}{3} + \frac{(\theta_I-\theta_R)}{3} &(62)\\
p_R &= \theta_R &(63)\\
\phi_I^R &= \frac{1}{3} + \frac{(\theta_I-\theta_R)}{(\gamma-\theta_R)+(\theta_I-\theta_R)} &(64)\\
\alpha &= \frac{(\gamma-\theta_R)+(\theta_I-\theta_R)}{2(\gamma-\theta_R)-(\theta_I-\theta_R)} &(65)
\end{aligned}
$$

In the special case where $\theta_I = \theta_R = \theta$, provided that the condition $\theta < \frac{\gamma}{2}$

holds, there is a unique solution given by

$$q_I = q_R = \frac{(\gamma - \theta)}{3} \tag{66}$$

$$p_R = \theta \tag{67}$$

$$\phi_I^R = \frac{1}{3} \tag{68}$$

$$\alpha = \frac{1}{2} \tag{69}$$

3 Gas release and capacity investment as instruments to foster competition

We now assume that the regulator seeks to further foster competition by complementing the gas-release program with dedicated investments in transport capacity K used to ship natural gas from a competitive market. More specifically, the marketer can now supply gas from two alternative sources, namely, the gas released by the incumbent in quantity q_R at a charge p_R, and imported gas in quantity K at a cost $(c + p_K)$, where c is the (competitive) price of gas to be shipped and p_K is the transport charge of this gas which is regulated. The levels of output now satisfy

$$q_I + q_R + K = q_m \tag{70}$$

$$q_I = (1 - \alpha)(q_m - K) \tag{71}$$

$$q_R = \alpha(q_m - K) \tag{72}$$

The profit functions of the incumbent, the marketer, and the transporter are respectively given by

$$\Pi_I = p(q_I + q_R + K) \times q_I + p_R \times q_R - C_I^I(q_I) - C_I^R(q_R) - F_I \tag{73}$$

$$\Pi_R = p(q_I + q_R + K) \times (q_R + K) - p_R \times q_R - (c + p_K) \times K \tag{74}$$

$$\Pi_T = p_K K - C_T(K) - F_T \tag{75}$$

where the technology of the transporter is represented by the cost function $C_T(K) + F_T$. The net consumers surplus CS is now given by

$$CS = S(q_I + q_R + K) - p(q_I + q_R + K) \times (q_I + q_R + K) \tag{76}$$

where $S(\cdot)$ represents gross consumer surplus. Finally, the utilitarian social welfare function is obtained as the unweighed sum of Π_I, Π_R, Π_T, and CS given by (73)-(76).

If the gas-release activity is not regulated while capacity is, the regulator determines only the level of transport capacity K subject to equilibrium behavior in the gas commodity market. As done earlier in this case, we assume that market competition is sequential. The incumbent sets the gas-release charge p_R anticipating output competition in q_I as its control variable and q_R as the marketer's.[6] Hence, the incumbent maximizes its profit (73) with respect to q_I while the marketer maximizes its profits (74) with respect to q_R, yielding the following first-order conditions:

$$\frac{\partial \Pi_I}{\partial q_I} = p + q_I p' - C_I^{I'}(q_I) \quad = 0 \tag{77}$$

$$\frac{\partial \Pi_R}{\partial q_R} = p + (q_R + K)p' - p_R \quad = 0 \tag{78}$$

The outcome of this output interaction is a couple of functions $q_I(p_R, K)$, $q_R(p_R, K)$. Lemma 1 shows the slopes of these functions with respect to p_R, whereas those with respect to K are given by

$$\frac{\partial q_I}{\partial K} = 0 \qquad\qquad \frac{\partial q_R}{\partial K} = -1 \tag{79}$$

These functions are substituted back into the incumbent profit function to obtain the latter as a function of p_R and K. The incumbent then maximizes this "reduced form" profit function with respect to p_R, which results in the first-order condition (13). The result of this maximization problem is a gas-release charge as a function of K, $p_R(K)$. Replacing this gas-release charge function into the first-order conditions (77) and (78) yields the triple $\{q_I(K), q_R(K), p_R(K)\}$. The next lemma provides some information on the relationship between these output and release-charge functions and the level of transport capacity K.

[6] Recall that capacity investments are dedicated to the marketer.

Lemma 2 *The equilibrium output and release-charge levels* $\{q_I(K), q_R(K), p_R(K)\}$, *provided that* $C_I^{I'''}(q_I) = 0$, *satisfy*

$$\frac{dq_I}{dK} = -\frac{p'[3p'^2 + C_I^{I''}C_I^{R''} - 2p'(C_I^{I''} + C_I^{R''})]}{(2p' - C_I^{I''})[5p'^2 + C_I^{I''}C_I^{R''} - 2p'(2C_I^{I''} + C_I^{R''})]} \tag{80}$$

$$\frac{dq_R}{dK} = -\frac{2p'(p' - C_I^{I''})}{5p'^2 + C_I^{I''}C_I^{R''} - 2p'(2C_I^{I''} + C_I^{R''})} \tag{81}$$

$$\frac{dp_R}{dK} = \frac{p'(3p' - 2C_I^{I''})[3p'^2 + C_I^{I''}C_I^{R''} - 2p'(C_I^{I''} + C_I^{R''})]}{(2p' - C_I^{I''})[5p'^2 + C_I^{I''}C_I^{R''} - 2p'(2C_I^{I''} + C_I^{R''})]} \tag{82}$$

and

$$\alpha = \frac{[(C_I^{I'} - C_I^{R'}) + Kp'](2p' - C_I^{I''})}{[(p - C_I^{R'}) + Kp'](2p' - C_I^{I''}) + (p - C_I^{I'})(3p' - 2C_I^{I''})} \tag{83}$$

Finally, social welfare is in turn written as a function only of K, namely as

$$W(K) = S(q_I(K) + q_R(K) + K) - C_I^I(q_I(K)) - C_I^R(q_R(K)) \\ -(c + p_K)K - F_I - F_T \tag{84}$$

and is maximized with respect to K subject to the transporter's participation constraint

$$\Pi_T = \ p_K K - C_T(K) - F_T \geq 0 \tag{85}$$

Letting ϕ_T denote the Lagrange multiplier associated with the transporter's participation constraint we obtain the following first-order conditions:

$$\phi_T[p_K - C_T'(K)] + [p - c - C_T'(K)] + \frac{dq_I}{dK}[p - C_I^{I'}] + \frac{dq_R}{dK}[p - C_I^{R'}] = 0 \tag{86}$$

$$\phi_T[p_K K - C_T(K) - F_T] = 0 \tag{87}$$

Substituting $\frac{dq_I}{dK}$ and $\frac{dq_R}{dK}$ from Lemma 2 into (86)-(87) allows us to characterize the optimum level of transport capacity when both release-gas and imports are available to the marketer.

So far, we haven't been able to obtain a general characterization of the optimum when both the gas-release charge and the capacity are regulated.

However, such a characterization has been obtained with specific functional forms that turn out to be useful in the calibration and simulation exercise performed in the next section. Let us assume that

$$p(q_I + q_R + K) = \gamma - q_I - q_R - K,\ C_I^I(q_I) = \theta_I q_I,\ C_I^R(q_R) = \theta_R q_R,$$
$$C_T(K) = \omega K,\ \gamma > \theta_I, \theta_R \tag{88}$$

When the gas-release charge is not regulated, we obtain two types of solutions provided that $F_T \leq \frac{(\gamma-\theta_R)(p_K-\omega)}{2}$. First, when either

$$-\frac{5(\gamma-\theta_R)}{13} - \frac{100(\theta_R - c - \omega)}{39} + \frac{3F_T}{13(p_K-\omega)} \leq$$
$$(\theta_I - \theta_R) \leq -\frac{5(\theta_R - c - \omega)}{3} \tag{89}$$
$$-\frac{3(\gamma-\theta_R)}{7} + \frac{9F_T}{35(p_K-\omega)} \leq (\theta_R - c - \omega) \leq -\frac{3(\gamma-\theta_R)}{10} \tag{90}$$

or

$$-\frac{5(\gamma-\theta_R)}{13} - \frac{100(\theta_R - c - \omega)}{39} + \frac{3F_T}{13(p_K-\omega)} \leq$$
$$(\theta_I - \theta_R) \leq -\frac{10(\theta_R - c - \omega)}{3} - \frac{(\gamma-\theta_R)}{2} \tag{91}$$
$$-\frac{3(\gamma-\theta_R)}{10} \leq (\theta_R - c - \omega) \leq -\frac{3(\gamma-\theta_R)}{20} - \frac{3F_T}{10(p_K-\omega)} \tag{92}$$

hold, the solution to the constrained welfare maximization program is given by

$$q_I = -2(\theta_I - \theta_R) - \frac{10(\theta_R - c - \omega)}{3} \tag{93}$$
$$q_R = \frac{2}{9}\Big[-3(\gamma-\theta_R) - 6(\theta_I - \theta_R) - 20(\theta_R - c - \omega)\Big] \tag{94}$$
$$K = \frac{1}{9}\Big[15(\gamma-\theta_R) + 39(\theta_I - \theta_R) + 100(\theta_R - c - \omega)\Big] \tag{95}$$
$$p_R = \theta_R - (\gamma-\theta_R) - 4(\theta_I - \theta_R) - 10(\theta_R - c - \omega) \tag{96}$$
$$\phi_T = 0 \tag{97}$$
$$\alpha = \frac{4}{7} + \frac{9[(\gamma-\theta_R) - 2(\theta_I - \theta_R)]}{7[3(\gamma-\theta_R) + 15(\theta_I - \theta_R) + 35(\theta_R - c - \omega)]} \tag{98}$$

Second, when

$$\frac{F_T}{(p_K-\omega)} \leq (\theta_I-\theta_R) \leq -\frac{15(\gamma-\theta_R)+100(\theta_R-c-\omega)}{39}+\frac{3F_T}{13(p_K-\omega)} \quad (99)$$

$$-\frac{3(\gamma-\theta_R)}{7}+\frac{9F_T}{35(p_K-\omega)} \leq (\theta_R-c-\omega) \leq -\frac{3(\gamma-\theta_R)}{20}-\frac{3F_T}{10(p_K-\omega)} \quad (100)$$

we obtain,

$$q_I = \frac{(\gamma-\theta_R)}{2}-\frac{7(\theta_I-\theta_R)}{10}-\frac{3F_T}{10(p_K-\omega)} \quad (101)$$

$$q_R = \frac{2}{5}\left[(\theta_I-\theta_R)-\frac{F_T}{(p_K-\omega)}\right] \quad (102)$$

$$K = \frac{F_T}{(p_K-\omega)} \quad (103)$$

$$p_R = \frac{(\gamma+\theta_R)}{2}-\frac{(\theta_I-\theta_R)}{10}-\frac{9F_T}{10(p_K-\omega)} \quad (104)$$

$$\alpha = \frac{4[(\theta_I-\theta_R)(p_K-\omega)-F_T]}{5[(\gamma-\theta_R)-3(\theta_I-\theta_R)]-7F_T} \quad (105)$$

When the gas-release is regulated, the regulator sets both the capacity and the release charges anticipating the market equilibrium in output levels. Hence, the regulator first solves for the equilibrium functions $q_I(p_R,K)$ and $q_R(p_R,K)$ from (77) and (78), and substitutes them back into the social welfare function which is expressed as

$$W(p_R,K) = S(q_I(p_R,K)+q_R(p_R,K)+K) - C_I^I(q_I(p_R,K)) - C_I^R(q_R(p_R,K)) - (c+p_K)K - F_I - F_T \quad (106)$$

Social welfare given in (106) is then maximized with respect to p_R and K subject to the transporter's participation constraint (85) to obtain the following first-order conditions:

$$\frac{dq_I}{dp_R}[p-C_I^{I'}]+\frac{dq_R}{dp_R}[p-C_I^{R'}]=0 \quad (107)$$

$$\phi_T[p_K-C_T'(K)]+[p-c-C_T'(K)]+\frac{dq_I}{dK}[p-C_I^{I'}]+\frac{dq_R}{dK}[p-C_I^{R'}]=0 \quad (108)$$

$$\phi_T[p_K K-C_T(K)-F_T]=0 \quad (109)$$

Substituting $\frac{dq_I}{dp_R}$ and $\frac{dq_R}{dp_R}$ from Lemma 1 and $\frac{dq_I}{dK}$ and $\frac{dq_R}{dK}$ from (79) into (107)-(109) allows us to characterize the optimum level of transport capacity when both release-gas and imports are regulated. As an illustration, let us assume the functional forms in (88). In this case, when the conditions

$$-\frac{(\gamma-\theta_R)}{3}+\frac{F_T}{(p_K-\omega)} \leq (\theta_I-\theta_R)<0 \tag{110}$$

$$(\theta_R-c-\omega)<0 \tag{111}$$

hold, we obtain

$$q_I=-2(\theta_I-\theta_R) \tag{112}$$

$$q_R=(\gamma-\theta_R)+3(\theta_I-\theta_R)-\frac{F_T}{(p_K-\omega)} \tag{113}$$

$$K=\frac{F_T}{(p_K-\omega)} \tag{114}$$

$$p_R=-(\gamma-2\theta_R)-4(\theta_I-\theta_R) \tag{115}$$

$$\phi_T=-\frac{(\theta_R-c-\omega)}{(p_K-\omega)} \tag{116}$$

$$\alpha=\frac{[(\gamma-\theta_R)+3(\theta_I-\theta_R)](p_K-\omega)-F_T}{[(\gamma-\theta_R)+(\theta_I-\theta_R)](p_K-\omega)-F_T} \tag{117}$$

Finally, when the conditions

$$-\frac{(\gamma-\theta_R)}{3} \leq (\theta_I-\theta_R)<0 \tag{118}$$

$$(\theta_R-c-\omega)=0 \tag{119}$$

hold, we obtain

$$q_I=-2(\theta_I-\theta_R) \tag{120}$$

$$q_R+K=(\gamma-\theta_R)+3(\theta_I-\theta_R) \tag{121}$$

$$p_R=-(\gamma-2\theta_R)-4(\theta_I-\theta_R) \tag{122}$$

$$\phi_T=0 \tag{123}$$

$$\alpha=1+\frac{2(\theta_I-\theta_R)}{(\gamma-\theta_R)+(\theta_I-\theta_R)-K} \tag{124}$$

4 Calibration and Simulation

The objective of this section is to compare the various scenarios considered in the previous sections on the basis of welfare by means of calibration and simulation techniques. These empirical exercises will be performed having in mind the French situation. We first present the way we calibrate the demand and cost functions and then discuss some preliminary simulations.[7]

The first function that is needed in order to perform simulations is the demand function for natural gas, more precisely the inverse demand function $p(q) = \gamma - q$. Ideally, one would hope to use time-series or cross-sectional data to estimate such a linear relationship. However, given the scarcity of data and the relatively recent history of the industry reforms, we choose to draw on existing econometric studies of demand. Indeed, since the middle 70s a large econometric literature has developed following the need to save energy and to target the objectives of energy policies. Even though this literature has examined demand for various energy sources both in the residential and industrial sectors, it was mainly concerned with household demand for electricity and to a lesser extent for natural gas.[8] Krichene (2005) has found that in recent years demand for natural gas has substantially varied and price-elasticity has dropped markedly after 1974.

Based on the more recent surveys by Dahl (2004) and Liu (2004), we have taken as the price-elasticity of demand for gas in France equal to 0.56. Given this value of the elasticity, we have calculated three values for the intercept of the inverse demand function γ corresponding to three different levels of the price of 100kWh PCS in Euros, namely, 2.058944109, 2.225140329, and 2.35968605. The values found for the intercept term are, respectively, 0.0573563, 0.061986052, and 0.065734111. These three values will be used in the simulations.

Let us now turn to the calibration of the gas commodity cost function $C_I(q) = \theta q + F_I$ and the transport cost function $C_T(K) = \omega K + F_T$. We assume that the incumbent obtains gas solely through long-term contracts

[7]While the simulations presented in this first draft of the paper need to be completed, they serve the important purpose of testing the internal coherence of our scenarios.

[8]For a review of this literature, see Bohi and Zimmerman (1984). Madlener (1996) reviews the literature concerned with European markets.

as the spot market is not well developed yet. Hence, θq can be seen as the variable cost of purchasing gas trough long-term contracts plus the transport cost of this gas from the source to the French boarder. It follows that θ can be seen as the boarder-price of gas for the historical operator. We also distinguish between the cost for the operator of gas for its own usage, θ_I, from the cost for the operator of gas made available to the marketer (the entrant), θ_R. The discrepancy between these two costs depends on the relative bargaining power of the operator and the gas suppliers. We have retained as value of θ_I the average of the border-prices corresponding to the long-term contracts binding the French historical operator with The Netherlands, Norway, and Russia from 1988 to 2000. This lead us to assume that $\theta_I \in \{0.006793312, 0.007735521, 0.009429732\}$. As to θ_R, we assume that $\theta_R \in \{0.9\theta_I, \theta_I, 1.1\theta_I\}$. The cost F_I represents the transport cost of gas from the boarder to the final consumer, i.e., the access charge to the transport network. This lead us to assume that $F_I \in \{0.000402411, 0.00044542, 0.000478721\}$.[9]

A typical functional form for the transport cost function is $C_T(K) = (a + bK^{\beta})L$ where L is the length of the pipeline. We have normalized L to 1 and approximated this cost function by the linear cost function used in the model $C_T(K) = \omega K + F_T$. Note that the transport capacity between the producer and the incumbent is linked to the existing long-term contracts. Consequently, without new investments in transport infrastructure an entrant wouldn't have access to the same gas sources as the incumbent. Moreover, if it obtains gas from another market (a competitive market as in our model), such an entrant would't be able to supply the market already supplied by the incumbent. Hence, in order for the entrant to have access to gas sources and compete with the incumbent, programs of investment in transport capacity and/or gas-release measures need to be implemented. Our investigation of the French situation has led us to assume that $10^4\omega = 1.01$ and $10^8 F_T = 1.47723$.

The simulations that we have been able to obtain results for so far concern the case where gas-release is the only regulatory instrument. In the benchmark situation where gas release is not regulated, we obtain a high

[9] F_I is given in Euros per kWh.

fraction of gas release of the order of 90 per cent. Introducing regulation of gas release with accounting separation diminishes this gas release fraction to around 62 per cent and increases social welfare relative to the decentralized case by 36 to 52 per cent When accounting separation is added the release fraction attains 51 per cent. While gas release is found to be optimal in these exercises, it is worth emphasizing that these results were obtained under a quite strong condition on the relative efficiency of the entrant, namely, $\theta_I \geq \theta_R$.

5 Conclusion

This paper has been motivated by the recent efforts of governments within the European Union to introduce gas-to-gas competition. It is fear to say that, broadly speaking, Europe has been largely dependent on a few suppliers, most importantly, Algeria, Russia, and Norway. Moreover, national industries have been historically organized as monopolies that integrated the import, transport, storage, and final distribution activities. This very concentrated structure of the European gas industry made the liberalization reforms look more like what can be characterized as active asymmetric regulation aimed at establishing a more balanced share of of markets. Two prominent instruments used to achieve such a goal are undoubtedly gas-release measures and capacity investment programs.

In this paper, we have offered a simple model for examining the interaction between gas-release and capacity investments programs as tools to improve the performance of imperfectly competitive natural gas markets. We have first studied the "artificial" duopoly effect created by a regulator who introduces a gas-release program. We then have assumed that the gas-release measure is complemented by a program of investment in transport capacity dedicated to the shipping of gas from a competitive market by a marketer at a regulated transport charge. Calibration and simulation techniques have then been used to compare these two scenarios under different assumptions on the way regulation is conducted. Besides allowing us to assess the sensitivity of the relative merits of these scenarios to technological efficiency, this empirical exercise has revealed that gas-release measures should be primarily viewed as intermediary policies of promoting gas-to-gas competition.

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