TSE working paper series

09-121

Research Group: *Development*

November, 2009

Investment in Transport Infrastructure, Regulation, and Gas-Gas Competition

FARID GASMI AND JUAN DANIEL OVIEDO

Ecole d'économie de Toulouse (TSE) - Manufacture des Tabacs
Aile Jean-Jacques Laffont - 21, allée de Brienne - 31000 TOULOUSE
Tél : +33 (0) 5 61 12 85 89 - Fax : +33 (0) 5 61 12 86 37 - **www.TSE-fr.eu** - contact@TSE-fr.eu

Investment in transport infrastructure, regulation, and gas-gas competition*

Farid GASMI
Toulouse School of Economics (ARQADE & IDEI)
Université Toulouse 1 Capitole

and

Juan Daniel OVIEDO
Universidad del Rosario

Abstract

This paper develops a simple model in which a regulated (upstream) transporter provides capacity to a marketer competing in output with an incumbent in the (downstream) gas commodity market. The equilibrium outcome of the firms' interaction in the downstream market is explicitly taken into account by the regulator when setting the transport charge. We consider various forms of competition in this market and derive the corresponding optimal transport charge policies. We then run simulations that allow us to perform a comparative welfare analysis of these transport infrastructure investment policies based on different assumptions about the intensity of the competition that prevails in the gas commodity market.

JEL-code: L51, L95
Key words: Transport capacity investment, Regulation, Natural gas, Imperfect competition.

November 2009

*Part of this material was presented at the CSSA Conference on "Security of Supply in Europe: Policy for Gas and Nuclear Power," Cambridge University, UK, December 13-15, 2007. We thank participants to this conference for useful comments. We also thank P. Sotkiewicz, C. Waddams, an anonymous referee, and the editor of this journal for suggestions on a previous draft. All remaining errors are ours only.

1 Introduction

The last two decades have witnessed a marked interest worldwide for the introduction of competition in the natural gas industry. In the European Union, the gas market has experienced since the second half of the nineties a large-scale complex liberalization/deregulation process.[1] The European Commission (EC), under the terms of the 2003 EC gas directive, has committed to the establishment of a single market throughout Europe scheduled to be fully open by July 2007.[2] Although a large number of gas consumers in Europe are now able to choose their suppliers and many steps have been taken towards the harmonization of national legislation following the EU directives, barriers to competition still remain. These primarily relate to market structure, national attitudes towards liberalization, access to gas supplies, and access to key infrastructure facilities.[3]

Historically, natural gas has payed an important role in the European energy economy. Various factors including high population density, extensive urbanization, and availability of local gas production have contributed to the development of intensive gas use within western Europe. This phenomenon is reinforced by the fact that natural gas has a great potential for being the most preferred choice of input for power generation in the European Union since it is a "clean" fuel with higher efficiency levels than those of its close competitors such as coal or fuel oil. However, in most European countries, gas production is expected to significatively decline over the next decade as existing gas fields are reaching maturity and new discoveries are generally small. Thus, the European gas market will most probably become increasingly dependent on imports from outside the region.[4]

[1] For an overview of these reforms, see Cremer et al. (2003).

[2] European Union Member States have all, except when specifically exempt from the liberalization requirements, similar levels of market opening targets. Note, however, that security of supply, an issue of great importance for the EU, might affect the rhythm at which the liberation policies should be implemented.

[3] Overall, by the end of 2004, no less than 56% of gas consumed within Europe was supplied to end-users who were legally able to choose their suppliers.

[4] Almost all European countries are net exporters of gas and many, including major users such as France or Spain, are close to being totally independent on gas imports. Moreover, Europe is expected to be the largest world market for imported natural gas

Norway is Europe's only major gas exporter supplying about 14% of European gas consumption. Russia supplies more than 60% of the gas imported into Europe and is expected to remain its largest external supplier for decades. Algeria supplies more than 25% of the gas imported into Europe by pipeline to southern Europe and as liquefied natural gas (LNG) to several countries including France, Belgium, Greece, and Portugal. The need for supply diversification is thus strong and European gas importers are indeed willing to diversify their sources and LNG provides a way to accomplish this.[5] LNG imports currently represent 11% of total imports into the region and are expected to steadily grow in the future.

Recently made demand and supply projections for Europe, even when based on moderate expectations of future demand for natural gas, have shown the existence of a substantial gap between demand and the potential supply from outside Europe. The network extensions and new gas connections that need to be put in place in order to meet demand in 2020 mainly involve new pipelines from Russia, Algeria, and the Caspian sea Area as well as new LNG terminals to receive LNG from Egypt and the Middle East.[6]

Given these specific features of demand and supply, the European gas system raises important "investment" questions that might not be found in the US. Although the European Union has clearly set an objective of introducing competition, the market is likely to remain for some time dominated by a few large producers. Thus, the issue of the impact of transport capacity on market structure and market power certainly deserves some attention. While a great number of papers has analyzed the way upstream transport networks affect the working of downstream markets, to the best of our knowledge, the major part of this literature has taken as given the capacity of the transport network and the charge applied for its use.[7] In this paper, both of these factors are considered as endogenous.

between 2000 and 2020 (Cayrade, 2004).

[5]Note that while the LNG solution is feasible, it is relatively costly.

[6]A rough estimate of the bill for these infrastructure projects lies between 150 and 200 billion US dollars. See Sagen and Aune (2004) for more details.

[7]See, among others, De Vany and Walls (1994), Doane and Spulber (1994) in gas, and Borenstein et al. (2000), Léautier (2001) in electricity.

The plan of this paper is as follows. The next section discusses some related literature. In section 3, we develop a model of an upstream firm providing a marketer with transport capacity at a regulated price. The regulator sets the transport charge taking as given competition in output between an incumbent and the marketer in a downstream gas commodity market. The outcome of the downstream firms' interaction is synthesized by generic equilibrium output responses to changes in the transport charge.[8] Section 4 applies this general setting to specific forms of market conduct with a varying degree of competition. Section 4 performs a comparative analysis of the various regulatory policies considered, in particular, an attempt is made to assess their relative welfare performance. The last section summarizes the main lessons to be drawn from the analysis and gives some directions for further research. The appendix contains technical proofs.

2 Transport network and market structure - an overview of the literature

The issue of the impact of transport capacity on market structure and market power has been addressed in both the institutional/empirical and the theoretical literature on energy. In the electricity sector, competitive strategies in deregulated markets have become a very active area of research. Most of the published literature (see, e.g., Green and Newbery, 1992, Von der Fehr and Harbord, 1993, Borenstein and Bushnell, 1999, Rudkevich et al., 1998, and Green, 1999) examines strategic behavior in a static setting. Concerning imperfect competition in generation, many authors have proposed models in which generators take advantage of transmission constraints to exert local market power (Oren, 1997, Cardell et al. 1997, Borenstein et al., 2000, and Nasser, 1998). These studies have either abstracted from the details of transmission or used a variant of a standard transportation model to describe the geographic differences among markets. The choice of possible strategies follows the common Cournot quantity approach. A general finding is that the role of the transmission segment goes beyond that of simply bringing power

[8] In this paper, we abstract away from information problems.

from competitive sources.

More relevant to the European power market, Smeers and Wei (1999) propose an oligopoly model where both power generators and consumers are spatially dispersed. The generators compete à la Cournot in a context where transmission prices are regulated, i.e., they take their rivals' output and the prices for transmission services as fixed when deciding about profit-maximizing output. The transmission firm takes the quantities of transmission services demanded by the generators as fixed when it determines the transmission prices according to certain regulatory rules. In this framework, they analyze the impact of the market power retained by the generators after the restructuring of the electricity industry. They also assess the effect of pricing of transmission services on the generation segment and the investment in ransmission assets. A similar issue was analyzed in Smeers and Wei (1997) where they consider two-stage models for the electricity industry where the second stage (the energy market) and the first stage (investment) behaviors obey different competition paradigms.

From a regulatory perspective, Nasser (1998) describes how generation and transmission of power have been unbundled to foster the introduction of competition in the electricity industry. The author identifies the importance of designing institutions that lead to "optimal" network expansion. He describes alternative arrangements that have been proposed which can be classified as follows: planning by a government entity, regulation of the network operator, and decentralization of investment decisions supported by pricing of congestion of the network.[9] He shows that the socially optimal network expansion is such that the marginal cost of capacity equals its social marginal value. This value is given in terms of the congestion reduction brought about by a marginal increase of capacity.

Léautier (2000) highlights the importance of the optimal design of regulatory contracts for the operators of power transmission networks in the United States. He examines the regulation of a for-profit transmission company in charge of bringing competitive power to wholesale power markets. Such con-

[9]Brazil has opted for the first solution, the UK for the second, and Argentina for the third.

tracts should ensure financial viability of the transmission activity, promote adequate usage of the service, induce productive efficiency, and encourage optimal expansion of the network. This last feature is considered by the author as critical for the development of efficient wholesale power markets.[10]

Similarly, Léautier (2001) identifies two important effects of transmission expansion. First, part of market demand will be met by cheap power instead of expensive local power, the so-called "substitution effect." Second, competition among power generators is increased, the so-called "strategic effect." The author finds that while the substitution effect is always welfare improving, the welfare impact of the strategic effect is not unambiguous, i.e., it might be the case that consumers pay a lower price but generators earn lower profits.

In the natural gas sector, for the case of the US gas industry and mainly on the empirical front, a large stream of the literature has examined the impact of interconnecting sub-networks on the degree of market integration and competition (see, e.g., Doane and Spulber, 1994, and De Vany and Walls, 1994).[11] Some of the earlier efforts at characterizing various aspects of the European natural gas market include Tzoannos (1977) and Haurie et al. (1987). Mathiesen et al. (1987) screen the European market with respect to three scenarios, namely, perfect competition, Cournot competition, and collusion among producers. Other applications of the Cournot-type competitive framework have since been developed for the purpose of analyzing the European gas market. A three-level Stackelberg game has been developed by Grais and Zheng (1996) to study the transport of natural gas from Russia to Western Europe.

The potential impact of the possible introduction of open access in the European gas system was also studied by means of a Cournot framework in Golombek et al. (1995). The authors explore the impact of open access on

[10] Léautier (2000) argues that insufficient transmission capacity creates four costs: higher than optimal congestion, higher than optimal power losses, lower than optimal reliability, and imperfect competition in generation.

[11] For a review of the literature related to the impact of third-party access to pipelines in the natural gas industry see Cremer et al. (2003).

market power exerted by natural gas producers through the development of marketers. Using a numerical model where producers behave in a Cournot fashion and face a competitive fringe of marketers, they show that this competitive effect is indeed significant. In a more elaborated model, Golombek et al. (1998) study the impact on the imperfectly competitive supply side of the natural gas industry of policies that introduce competition in the demand side. They show that these pro-competitive demand measures will generate incentives to break up national gas producers into several independent domestic producers.

De Wolf and Smeers (1997) adopt a Stackelberg game perspective for their work on the European natural gas market. Breton and Zaccour (2001) concentrate on analyzing a duopoly of producers under a security constraint but in a somewhat abstract form. More recently, Boots et al. (2004) model a successive oligopoly applied to the European natural gas market. In this numerical model, Cournot producers are also Stackelberg leaders with respect to traders, who may be Cournot oligopolists or price takers. They obtain that successive oligopoly yields higher prices and lower consumer welfare than an oligopoly with only one level. Moreover, due to the high concentration of traders, prices are distorted more by market power in trading than in production. Finally, they show that when traders increase in number, prices approach competitive levels.[12]

Even though the literature shows the abundance of models supposed to represent the European natural gas market, these models are meant to be short-term models where there is no place for capacity expansion decisions. This constitutes a severe handicap when it comes to analyzing the normative implications of capacity expansion and its impact on market structure. Recently, an approach has been followed in which capacity expansion is explicitly considered as a means to improve the efficiency of gas markets.[13] One of the objectives of this stream of the literature is to explore the possibility of having to build “excess” transport capacity when the latter is an instru-

[12] Egging and Gabriel (2005) extend the model of Boots et al. (2004) by considering the role of storage and transmission both assumed to be perfectly competitive.

[13] See Cremer and Laffont (2002), Cremer et al. (2003), Gasmi et al. (2005), and Gasmi and Oviedo (2005).

ment among a set of others available to control regional market power. The question of interest is then what types of policies, including imports, are to be implemented by network operators concerned by the exercise of market power by incumbent local monopolies. The basic theoretical setting used to analyze this issue consists of a simple model in which a "local" market is dominated by a single firm and is linked to an alternative competitive market by a transport line.

Gas produced in the competitive market at some relatively low marginal cost can be imported to the regional market through the transport line. The capacity of this line is under the control of the network owner/operator whose objectives are assumed to coincide with those of a social planner. Within this basic framework, capacity control can be motivated in two ways. First, it can act as a remedy to any possible productive inefficiency due to the incumbent monopolist's use of a low efficiency technology by allowing for access to a more efficient source of natural gas. Second, by the mere fact that the building of capacity allows to import cheaper gas into the regional market, competitive pressure can be put on the local firm in order to mitigate the exercise of its market power and hence to alleviate the allocative inefficiency it entails.

In addition to capacity, Gasmi et al. (2005) introduce the possibility for the social planner to set price and use transfers between consumers and the firm. However, in the simplest framework considered, price control and transfers are both intended to exclusively deal with the allocative inefficiency associated with the exercise of market power. The goal then is to study the degree to which transport capacity and the two alternative control instruments substitute or complement each other as instruments to maximize social welfare in this second-best environment. The authors seek to investigate this substitutability relationship under complete information and both for a fixed and a variable set of control instruments available to the network operator.[14]

A natural extension of this complete information analysis is to introduce

[14]In particular, the authors consider a progressive reduction of the set of control instruments available to the social planner to account for the progresses achieved in the deregulation of the gas industry.

incomplete information, and this is undertaken in Gasmi and Oviedo (2005). There are various ways to incorporate information incompleteness in the simple framework considered and the authors choose to introduce adverse selection by assuming that the local monopoly privately knows its marginal cost and that the regulator has only some beliefs on it described by a probability that it takes on either a low or a high value. The authors investigate then how this asymmetric information affects capacity planning for a given control scheme.

While Gasmi et al. (2005) and Gasmi and Oviedo (2005) analyze the role of transport capacity as an instrument available to the regulator to mitigate the effect of gas suppliers' market power, in this paper we take a step further and study the case where, because of the advances made in the liberalization/deregulation process, the regulator looses the ability of himself building transport capacity. Since the natural gas industry combines activities possessing natural monopoly characteristics (pipeline transport and distribution) with those that are potentially competitive (production and commodity supply), it is natural to see a combination of regulation of price and non-price behavior coexisting with competition. We assume that transport capacity is provided by a vertically separated private firm (upstream) and used in the commodity gas market by a trading agent, the marketer (downstream), which competes in quantities with an incumbent firm. However, since pipeline transportation and distribution have natural monopoly characteristics, regulation of price and non-price behavior is required. In this paper, we focus on the impact of the regulation of the upstream transport charge on the competitive performance of the downstream gas commodity market.

We assume that a perfectly informed regulator sets the transport charge taking as given competition in output between an incumbent and the marketer in a downstream gas commodity market. The outcome of the downstream firms' interaction is synthesized by generic equilibrium output responses to changes in the transport charge. We then apply this general setting to specific forms of market conduct with a varying degree of competition, namely, no competition, Stackelberg competition, Cournot competition, and competition exercised by a fringe of gas traders. Once we have studied the impact of price regulation on the alternative downstream equilibria considered, we proceed to perform a comparative analysis of the optimal transport charge policies with the objective of assessing their relative welfare performance by means of simulations. While the simulations confirm the general wisdom that more competition is preferred to less from the consumers and the social welfare points of view, they also show some less expected results about the ordering of key policy variables, such as the capacity of pipelines and its price, across different competitive scenarios that reveal some redistribution conflicts.

3 Transport charge regulation for a general downstream market equilibrium

Consider a regional natural gas commodity market, market B, in which an incumbent firm, firm I, produces gas with a technology described by a cost function $C_I(q_I)$ where q_I is output. We assume that the institutional framework allows a marketer M to import gas from an alternative market, market A, at a constant unit commodity price c provided a regulated transport charge p_K is paid to a transporter T that builds a pipeline of capacity K linking the two markets at cost $C_T(K) + F_T$.[15] Consumption takes place in market B according to an inverse demand function $p(\cdot)$ assumed to be linear. Figure 1 pictures this simple industry structure.[16]

[15]The incumbent's cost function is assumed to be increasing, strictly convex, and twice continuously differentiable with $C_I^{'''} = 0$. The transporter's variable cost function is increasing convex.

[16]Although this framework shares some features with that typically used to study access to an essential facility such as the local loop in telecommunications, two important aspects specific to the case of natural gas considered here are worth mentioning. First, the essential facility (the pipeline) is used only by the entrant (the marketer). Second, the incumbent supplier of the final good (natural gas) is completed separated from the owner of the essential facility (the capacity builder).

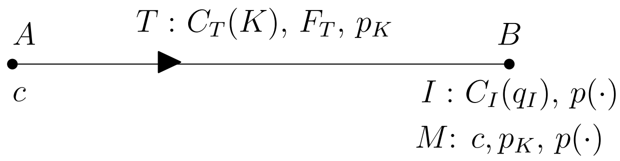


Figure 1: Industry configuration

We assume that the transporter is regulated. More specifically, the regulator determines the transport charge p_K anticipating equilibrium behavior in the downstream gas commodity market B. Our main objective then is to investigate the relationship between the level of this transport charge (and of the implied social welfare) and firms' conduct in this market.

Let us analyze the regulator's problem of setting the price of transport capacity p_K. Total supply in the downstream gas commodity market Q, composed of q_I units produced locally by the incumbent and K units imported by the marketer, brings consumers a net surplus CS given by

$$CS = S(q_I + K) - p(q_I + K)[q_I + K] \tag{1}$$

where $S(\cdot)$ represents gross consumer surplus. The profit function of the upstream firm T, the transporter, is given by[17]

$$\Pi_T = p_K K - C_T(K) - F_T \tag{2}$$

In the downstream market, firms I and M compete in output and their profit functions are respectively given by[18]

$$\Pi_I = p(q_I + K)q_I - C_I(q_I) \tag{3}$$

$$\Pi_M = [p(q_I + K) - p_K - c]K \tag{4}$$

Since capacity is an input for the marketer, equilibrium levels of output (and hence price) in this downstream market are going to depend on the level of the transport charge set by the regulator. This is formalized by

[17] The cost structure of this upstream firm reflects the fact that natural gas transportation is highly capital-intensive and typically considered as a natural monopoly.

[18] We assume that in equilibrium both firms are active.

writing downstream levels of output as functions $q_I(p_K)$ and $K(p_K)$, where the specific forms of these functions will be determined by the precise nature of the interaction between firms. So, as far as timing, first the regulator sets p_K, second the transporter builds K, and third the marketer uses K to compete with the incumbent.

Using (1)-(4), the utilitarian social welfare function W is given by[19]

$$\begin{aligned} W(p_K) = & S(q_I(p_K) + K(p_K)) \\ & -C_I(q_I(p_K)) - cK(p_K) - C_T(K(p_K)) - F_T \end{aligned} \tag{5}$$

The regulator's program consists in maximizing (5) under the participation constraint of the transporter[20]

$$\Pi_T(p_K) = p_K K(p_K) - C(K(p_K)) - F_T \geq 0 \tag{6}$$

Letting ϕ_T designate the Lagrange multiplier associated with (6) and using the fact that $\frac{\partial S(\cdot)}{\partial q_I} = \frac{\partial S(\cdot)}{\partial K} = p(\cdot)$, we obtain the following first-order conditions:

$$\begin{aligned} (p - C_I')\frac{dq_I}{dp_K} + (p - c - C_T')\frac{dK}{dp_K} & \\ +\phi_T\left[K + (p_K - C_T')\frac{dK}{dp_K}\right] &= 0 \end{aligned} \tag{7}$$

$$\phi_T[p_K K - C_T(K) - F_T] = 0 \tag{8}$$

When the transporter's participation constraint is not binding, ($\phi_T = 0$), the second-order conditions which are necessary and sufficient for a unique local maximum are given by

$$\begin{aligned} (p - c - C_T')\frac{d^2K}{dp_K^2} + (p - C_I')\frac{d^2q_I}{dp_K^2} & \\ +(p' - C_T'')\left(\frac{dK}{dp_K}\right)^2 + (p' - C_I'')\left(\frac{dq_I}{dp_K}\right)^2 &< 0 \end{aligned} \tag{9}$$

When it is binding ($\phi_T > 0$), second-order conditions are always satisfied. Rewriting the first-order conditions (7)-(8), we obtain:

[19] This social welfare is merely the unweighted sum of net consumer surplus and firms' profits.

[20] We assume that the set defined by this participation constraint is convex which insures that the regulatory program is concave. A sufficient condition is concavity of the profit function (2), obtained if $2\frac{dK}{dp_K} + (p_K - C_T')\frac{d^2K}{dp_K^2} - C_T''(\frac{dK}{dp_K})^2 \leq 0$.

Proposition 1 *For a given equilibrium in the downstream market described by the six-tuple* $(K(p_K), q_I(p_K), \frac{dK}{dp_K}, \frac{dq_I}{dp_K}, \frac{d^2K}{d^2p_K}, \frac{d^2q_I}{d^2p_K})$*, at the optimum, transport charge, outputs, price and shadow cost of the transporter's participation constraint satisfy the following condition:*

$$(1+\phi_T)(p_K - C_T')\frac{dK(p_K)}{dp_K} + \phi_T K(p_K) = \\ -\left((p - p_K - c)\frac{dK(p_K)}{dp_K} + (p - C_I')\frac{dq_I(p_K)}{dp_K}\right) \quad (10)$$

When the transporter's participation constraint is binding, $\phi_T > 0$, we obtain standard average-cost transport pricing $p_K = \frac{C_T(\cdot)+F_T}{K(\cdot)}$ satisfying (10). When this constraint is not binding, $\phi_T = 0$, we obtain that the transport charge is distorted away from marginal cost with a bounded distortion, $p_K - C_T'(\cdot) \leq (p - C_I')(-\frac{dq_I/dp_K}{dK/dp_K})$. The interpretation of this distortion becomes easier if one assumes that $|\frac{dK}{dp_K}| > |\frac{dq_I}{dp_K}|$, in which case an interior solution satisfies $C_I' < c + C_T'$, i.e., the cost of a marginal unit produced by the incumbent is less than the net cost of a marginal imported unit, $(c + p_K) - (p_K - C_T')$.[21]

The equation stated in Proposition 1 shows at the left-hand side the social marginal effect in the upstream market of an increase in the transport charge. More precisely, this is the impact on both the marginal and infra marginal units of capacity built by the regulated transporter. At the right-hand side, it shows the effect of this increase of p_K in the downstream market, namely, on the marginal profitability of both the marketer and the incumbent. At the optimum, these two effects should be balanced. Clearly, their respective magnitude will depend on the specific nature of the downstream firms' interaction. The next section considers capacity pricing policies under various assumptions about this interaction.

[21] The condition $|\frac{dK}{dp_K}| > |\frac{dq_I}{dp_K}|$ holds in all of our formal representations of downstream competition.

4 Transport charge regulation for specific downstream market equilibria

We consider four scenarios of downstream firms' behavior with a decreasing degree of competition, namely, no competition between firms I and M, Stackelberg competition, Cournot competition, and the case in which the incumbent faces a competitive fringe represented by firm M.

4.1 No downstream competition

In this section, we consider the polar case in which there is no competition in the downstream market, i.e., the incumbent and the marketer behave as if they were a single entity.[22] These firms maximize then joint profits given by

$$\Pi_I + \Pi_M = p(q_I + K)(q_I + K) - C_I(q_I) - (p_K + c)K \tag{11}$$

For a given transport charge p_K, solving the joint profit-maximization problem yields the following first-order conditions:[23]

$$[p(q_I + K) - p_K - c] + (q_I + K)p' = 0 \tag{12}$$

$$[p(q_I + K) - C_I'] + (q_I + K)p' = 0 \tag{13}$$

The profit-maximizing levels of output $(K^m(p_K), q_I^m(p_K))$ in this market are found by solving the system of first-order conditions (12)-(13).[24] How these outputs respond to changes in the transport charge p_K set by the regulator can be seen from the formulas provided in the next lemma.

[22] Alternatively, one can think of the marketer as being an affiliate of the incumbent and although the firms maximize joint profits, they have to comply with some strict accounting separation rule.

[23] The second-order condition is $2p'C_I'' < 0$ and is satisfied for our linear demand and convex cost function.

[24] Note that (12) and (13) imply $p_K = C_I' - c$. Existence and uniqueness of the maximum of the joint profit function for $K, q_I > 0$ is guaranteed in our industry configuration by the strict convexity of the incumbent's cost function.

Lemma 1 *The no downstream competition profit-maximizing outputs* $(K^m(p_K), q_I^m(p_K))$, *satisfy:*

$$\begin{aligned} \frac{dK^m}{dp_K} &= \frac{1}{2p'} - \frac{1}{C_I''} \qquad & \frac{d^2K^m}{dp_K^2} &= \frac{C_I'''}{C_I''}\left(\frac{dq_I^m}{dp_K}\right)^2 \\ \frac{dq_I^m}{dp_K} &= \frac{1}{C_I''} & \frac{d^2q_I^m}{dp_K^2} &= -\frac{C_I'''}{C_I''}\left(\frac{dq_I^m}{dp_K}\right)^2 \end{aligned} \tag{14}$$

An increase in the transport charge leads to a decrease in transport capacity and an increase in incumbent's output. However, the reduction in transport capacity dominates the increase in incumbent's volume, and the net effect is a reduction of total output and hence an increase in market price. Substituting $\frac{dK^m}{dp_K}$ and $\frac{dq_I^m}{dp_K}$ from this lemma into Proposition 1 allows us to characterize the optimum when there is no competition in the downstream gas commodity market.[25]

Proposition 2 *Assuming no competition in the downstream market, at the optimum, transport charge, outputs, price and shadow cost of the transporter's participation constraint satisfy the following conditions:*

$$-\frac{(1+\phi_T^m)(p_K^m - C_T'^m)(2p' - C_I''^m)}{2p'C_I''^m} + \phi_T^m K^m = \left(\frac{(p^m - p_K^m - c)(2p' - C_I''^m) - 2(p^s - C_I'^m)p'}{2p'C_I''^m}\right) \tag{15}$$

$$[p^m - p_K^m - c] + (q_I^m + K^m)p' = 0 \tag{16}$$

$$\left[p^m - C_I'^m\right] + (q_I^m + K^m)p' = 0 \tag{17}$$

When the transporter's participation constraint is binding, we obtain standard average-cost transport pricing $p_K^m = \frac{C_T(\cdot)+F_T}{K^m}$ satisfying (15)-(17). When

[25] The regulator's maximization program is well behaved since the participation constraint of the transporter when there is no downstream competition defines a convex set. Indeed, replacing the results shown in Lemma 1 into the condition guaranteeing the concavity of the transporter's profit function (see footnote 20) yields that it is always true since we assume $C_I''' = 0$.

this constraint is not binding, $\phi_T^m = 0$, we obtain that $p_K^m < C_T^{\prime m}(\cdot) + \frac{2(p^m - C_I^{\prime m})p'}{(2p' - C_I^{\prime\prime m})}$ and $C_I^{\prime m} < c + C_T^{\prime m}$.[26] The detailed argument behind the existence of this bound is presented at the end of the proof of Proposition 2 in the appendix.[27] Let us now study transport capacity policies when downstream competition prevails.

4.2 Stackelberg downstream competition

In this section, we assume that competition in the downstream market is à la Stackelberg where the incumbent and the marketer are respectively the leader and the follower. For a given transport charge p_K, solving the marketer's profit-maximization problem yields the following first-order condition:[28]

$$[p(q_I + K) - p_K - c] + Kp' = 0 \tag{18}$$

This first-order condition is solved for K to yield the marketer's reaction function. The latter is substituted into the incumbent's profit function which is then maximized with respect to q_I. The first-order condition of this maximization problem is

$$[p - C_I'] + \frac{q_I p'}{2} = 0 \tag{19}$$

The equilibrium $(K^{s_I}(p_K), q_I^{s_I}(p_K))$ of this Stackelberg game is obtained as the solution to the system of first-order conditions (18) and (19).[29] Some

[26]From Lemma 1, $|\frac{dK^m}{dp_K}| > |\frac{dq_I^m}{dp_K}|$, which as discussed in section 2, implies $C_I^{\prime m} < c + C_T^{\prime m}$. Given this condition, second-order conditions are always satisfied. Indeed, when $\phi_T = 0$, replacing the results obtained in this lemma into condition (9), yields $-C_T'' C_I''^3 + p' C_I''^2 [4C_T'' + C_I''] - 4p'^2 C_I'' [C_T'' + C_I''] - 4p'^2 C_I''' [c + C_T' - C_I'] < 0$, which is true.

[27]This is done for all of the other propositions corresponding to the competitive scenarios considered in this paper.

[28]The second-order condition is $2p' < 0$, which is true given our linear demand. It is well known that log-concavity of demand and convexity of the cost function of the incumbent imply that the best response function of the marketer is monotone and decreasing with slope belonging to the interval (-1,0). In our case, since demand is linear this slope is equal to $-\frac{1}{2}$.

[29]Existence and uniqueness of this equilibrium is guaranteed by our assumptions on demand and incumbent's cost function. It corresponds to the tangency point between the marketer's reaction function and a level curve of the incumbent's profit function in the positive quadrant.

formulas that allow us to see how these equilibrium outputs vary with the regulated transport charge p_K are presented in the next Lemma.

Lemma 2 *The Stackelberg equilibrium (with the incumbent as a leader) in the downstream market, $(K^{s_I}(p_K), q_I^{s_I}(p_K))$, satisfies:*

$$\frac{dK^{s_I}}{dp_K} = \frac{1}{2}\left[\frac{1}{p'} + \frac{1}{2(p' - C_I'')}\right] \qquad \frac{d^2K^{s_I}}{dp_K^2} = -\frac{C_I'''}{2(p' - C_I'')}\left(\frac{dq_I^{s_I}}{dp_K}\right)^2$$
$$\frac{dq_I^{s_I}}{dp_K} = -\frac{1}{2(p' - C_I'')} \qquad \frac{d^2q_I^{s_I}}{dp_K^2} = \frac{C_I'''}{(p' - C_I'')}\left(\frac{dq_I^{s_I}}{dp_K}\right)^2 \tag{20}$$

Lemma 2 shows that under Stackelberg competition, an increase in the transport charge leads to a decrease in transport capacity and an increase in incumbent's output. However, the reduction in transport capacity more than offsets the increase in incumbent's volume, yielding a reduction of total output and hence an increase in market price. Substituting $\frac{dK^{s_I}}{dp_K}$ and $\frac{dq_I^{s_I}}{dp_K}$ from this lemma into Proposition 1 allows us to characterize the optimum when there is downstream Stackelberg competition with the incumbent as a leader.

Proposition 3 *Assuming downstream Stackelberg competition with the incumbent as a leader, at the optimum, transport charge, outputs, price and shadow cost of the transporter's participation constraint satisfy the following conditions:*

$$\frac{(1+\phi_T^{s_I})(p_K^s - C_T^{'s_I})(3p' - 2C_I^{''s_I})}{4p'(p' - C_I^{''s_I})} + \phi_T^{s_I} K^s = -\left(\frac{(p^{s_I} - p_K^{s_I} - c)(3p' - 2C_I^{''s_I}) - 2(p^s - C_I^{'s_I})p'}{4p'(p' - C_I^{''s_I})}\right) \tag{21}$$

$$[p^{s_I} - p_K^{s_I} - c] + K^{s_I} p' = 0 \tag{22}$$

$$[p^{s_I} - C_I^{'s_I}] + \frac{q_I^{s_I} p'}{2} = 0 \tag{23}$$

When the transporter's participation constraint is binding, we obtain standard average-cost transport pricing $p_K^{s_I} = \frac{C_T(\cdot)+F_T}{K^{s_I}}$ satisfying (21)-(23). When this constraint is not binding, we obtain that $p_K^{s_I} < C_T^{'s_I}(\cdot) + \frac{2(p^{s_I} - C_I^{'s_I})p'}{(3p' - 2C_I^{''s_I})}$ and $C_I^{'s_I} < c + C_T^{'s_I}$.

The case with the marketer as a leader is treated as follows. The Stackelberg equilibrium $(K^{s_M}(p_K),\, q_I^{s_M}(p_K))$ is obtained by solving the first-order conditions

$$[p(q_I + K) - C_I'] + q_I p' \qquad = 0 \tag{24}$$

$$[p(q_I + K) - p_K - c] + K\left(1 - \frac{p'}{2p' - C_I''}\right)p' \quad = 0 \tag{25}$$

The next lemma provides useful information on the relationship between this equilibrium and the transport charge.

Lemma 2' *The Stackelberg equilibrium (with the marketer as a leader) in the downstream market,* $(K^{s_M}(p_K), q_I^{s_M}(p_K))$*, satisfies:*

$$\begin{aligned} \frac{dK^{s_M}}{dp_K} &= \frac{1}{2}\left[\frac{1}{p'} + \frac{1}{(p' - C_I'')}\right] & \frac{d^2K^{s_M}}{dp_K^2} &= 0 \\ \frac{dq_I^{s_M}}{dp_K} &= -\frac{1}{2(p' - C_I'')} & \frac{d^2 q_I^{s_M}}{dp_K^2} &= 0 \end{aligned} \tag{26}$$

Cross-examining Lemmas 2 and 2', we see that when leadership is transferred to the marketer, the slope of the incumbent's equilibrium output function remains unchanged. This is so because the transport charge has only a second-order effect on the incumbent's profits which is zero given our assumption of linear demand. As to the marketer, because the transport charge has a first-order effect on its profits, switching from the role of a follower to that of a leader, it sees the slope of its equilibrium output (capacity) function increased in absolute value.

Lemma 2' shows that an increase in transport charge has opposite effects on capacity and incumbent's output but the net effect on aggregate output is negative. Substituting $\frac{dK^{s_M}}{dp_K}$ and $\frac{dq_I^{s_M}}{dp_K}$ from this lemma into Proposition 1 allows us to characterize the optimum when there is downstream Stackelberg competition with the marketer as a leader.

Proposition 3' *Assuming downstream Stackelberg competition with the marketer as a leader, at the optimum, transport charge, outputs, price and shadow cost of the transporter's participation constraint satisfy the following conditions:*

$$\frac{(1+\phi_T^{s_M})(p_K^{s_M}-C_T^{'s_M})(2p'-C_I^{''s_M})}{2p'(p'-C_I^{''s_M})}+\phi_T^{s_M}K^{s_M} = -\left(\frac{(p^{s_M}-p_K^{s_M}-c)(2p'-C_I^{''s_M})-(p^{s_M}-C_I^{'s_M})p'}{4p'(p'-C_I^{''s_M})}\right) \quad (27)$$

$$[p^{s_M}-p_K^{s_M}-c]+K^{s_M}\left(1-\frac{p'}{2p'-C_I^{''s_M}}\right)p'=0 \quad (28)$$

$$[p^{s_M}-C_I^{'s_M}]+q_I^{s_M}p'=0 \quad (29)$$

When the transporter's participation constraint is binding, we obtain standard average-cost transport pricing $p_K^{s_M}=\frac{C_T(\cdot)+F_T}{K^{s_M}}$ satisfying (27)-(29). When this constraint is not binding, we obtain that $p_K^{s_M}<C_T^{'s_M}(\cdot)+\frac{(p^{s_M}-C_I^{'s_M})p'}{(2p'-C_I^{''s_M})}$ and $C_I^{'s_M}<c+C_T^{'s_M}$.

4.3 Cournot downstream competition

In this section, we assume that competition in the downstream market is à la Cournot. For a given transport charge p_K, the marketer and the incumbent simultaneously maximize own profits yielding the following first-order conditions:[30]

$$[p(q_I+K)-p_K-c]+Kp' = 0 \quad (30)$$

$$[p(q_I+K)-C_I']+q_Ip' = 0 \quad (31)$$

[30]The second-order conditions for the marketer's and incumbent's problem are respectively $2p'<0$ and $2p'-C_I''<0$, which are always satisfied under our demand and cost assumptions.

Solving these first-order conditions yields the Cournot equilibrium ($K^c(p_K)$, $q_I^c(p_K)$) and the next lemma provides useful information on the relationship between this equilibrium and the transport charge.[31]

Lemma 3 *The Cournot equilibrium* $(K^c(p_K), q_I^c(p_K))$ *in the downstream market, satisfies:*

$$\begin{aligned} \frac{dK^c}{dp_K} &= \frac{1}{2}\left[\frac{1}{p'} + \frac{1}{3p' - 2C_I''}\right] & \frac{d^2K^c}{dp_K^2} &= -\frac{C_I'''}{3p' - 2C_I''}\left(\frac{dq_I^c}{dp_K}\right)^2 \\ \frac{dq_I^c}{dp_K} &= -\frac{1}{3p' - 2C_I''} & \frac{d^2q_I^c}{dp_K^2} &= \frac{2C_I'''}{3p' - 2C_I''}\left(\frac{dq_I^c}{dp_K}\right)^2 \end{aligned} \tag{32}$$

Assuming Cournot competition, an increase in the transport charge leads to a decrease in transport capacity and an increase in incumbent's output with a net negative effect on aggregate output.[32] Substituting $\frac{dK^c}{dp_K}$ and $\frac{dq_I^c}{dp_K}$ from this lemma into Proposition 1 allows us to characterize the optimum when there is downstream Cournot competition.

Proposition 4 *With Cournot competition in the downstream market, at the optimum, transport charge, outputs, price and shadow cost of the transporter's participation constraint satisfy the following conditions:*

$$\begin{aligned} \frac{(1+\phi_T^c)(p_K^c - C_T'^c)(2p' - C_I''^c)}{p'(3p' - 2C_I''^c)} &+ \phi_T^c K^c = \\ &- \left(\frac{(p^c - p_K^c - c)(2p' - C_I''^c) - (p^c - C_I'^c)p'}{p'(3p' - 2C_I''^c)}\right) \end{aligned} \tag{33}$$

$$[p^c - p_K^c - c] + K^c p' = 0 \tag{34}$$

$$[p^c - C_I'^c] + q_I^c p' = 0 \tag{35}$$

[31] Existence and uniqueness of this equilibrium is guaranteed by our assumptions on demand and incumbent's cost function. It corresponds to the crossing point of the firm's reaction functions derived from (30) and (31).

[32] This corresponds to the general result in Industrial Organization saying that with strategic substitutes and a unique Cournot equilibrium, a firm's output decreases with its marginal cost and increases with its competitor's (Tirole, 1988, p. 220). In this paper, we find that this result also holds for the other forms of imperfect competition considered. Moreover, we find that an increase in one firm's marginal cost decreases industry output.

When the transporter's participation constraint is binding, we obtain standard average-cost transport pricing $p_K^c = \frac{C_T(\cdot)+F_T}{K^c}$ satisfying (33)-(35). When this constraint is not binding, we obtain that $p_K^c < C_T'^c(\cdot) + \frac{(p^c - C_I'^c)p'}{(2p' - C_I''^c)}$ and $C_I'^c < c + C_T'^c$.

4.4 Downstream competitive fringe

Now, assume that the incumbent faces a competitive fringe of gas traders represented by the marketer M. For a given transport charge p_K, this competitive fringe maximizes profits taking market price as given by ordering from the transporter capacity K such that its marginal cost is equal to market price:

$$p(q_I + K) - p_K - c \quad = 0 \tag{36}$$

The incumbent maximizes own profits over the residual demand and hence sets its marginal revenue equal to its marginal cost:

$$[p(q_I + K) - C_I'] + q_I p' \quad = 0 \tag{37}$$

The market equilibrium $(K^f(p_K), q_I^f(p_K))$ is obtained by solving (30) and (31) and useful information on this equilibrium are provided in the next Lemma.

Lemma 4 *The equilibrium $(K^f(p_K), q_I^f(p_K))$ obtained when the incumbent faces a competitive fringe in the downstream market satisfies:*

$$\begin{aligned} \frac{dK^f}{dp_K} &= \frac{1}{p'} + \frac{1}{p' - C_I''} & \frac{d^2K^f}{dp_K^2} &= -\frac{C_I'''}{p' - C_I''}\left(\frac{dq_I^f}{dp_K}\right)^2 \\ \frac{dq_I^f}{dp_K} &= -\frac{1}{p' - C_I''} & \frac{d^2q_I^f}{dp_K^2} &= \frac{C_I'''}{(p' - C_I'')}\left(\frac{dq_I^f}{dp_K}\right)^2 \end{aligned} \tag{38}$$

Again, we see from this lemma that an increase in transport charge has opposite effects on capacity and incumbent's output but the net effect on aggregate output is negative. Substituting $\frac{dK^f}{dp_K}$ and $\frac{dq_I^f}{dp_K}$ from this lemma into Proposition 1 allows us to characterize the optimum when there is a competitive fringe of gas traders in the downstream market.

Proposition 5 *when the incumbent faces a competitive fringe, at the optimum, transport charge, outputs, price and shadow cost of the transporter's participation constraint satisfy the following conditions:*

$$\frac{(1+\phi_T^f)(p_K^f - C_T'^f)(2p' - C_I''^f)}{p'(p' - C_I''^f)} + \phi_T^f K^f = - \left(\frac{(p^f - p_K^f - c)(2p' - C_I''^f) - (p^f - C_I'^f)p'}{p'(p' - C_I''^f)} \right) \quad (39)$$

$$p^f - p_K^f - c = 0 \quad (40)$$

$$[p^f - C_I'^f] + q_I^f p' = 0 \quad (41)$$

When the transporter's participation constraint is binding, we obtain standard average-cost transport pricing $p_K^f = \frac{C_T(\cdot)+F_T}{K^f}$ satisfying (39)-(41). When this constraint is not binding, we obtain that $p_K^f = C_T'^f(\cdot) + \frac{(p^f - C_I'^f)p'}{(2p' - C_I''^f)}$ and $C_I'^f < c + C_T'^f$.

5 A comparative analysis through simulations

So far, we have characterized individual transport charge policies associated with various assumptions about the competitive behavior of firms in the downstream market. Our objective is to compare these policies. While the complete analytical comparison of these second-best policies is beyond the scope of this paper, this is however possible with specific functional forms and simulations. Let us then assume that

$$p(q_I + K) = \gamma - (q_I + K), \quad C_I(q_I) = \frac{\theta}{2} q_I^2, \quad C_T(K) = \omega K + F_T \quad (42)$$

A straight application of Lemmas 1-5 allows us to derive the slopes of the equilibrium output functions under the corresponding assumptions about downstream competition. The results are shown in Table 1 where the indices m, s_I, s_M, c, and f designate the five forms of competition considered.

Table 1: Slopes of equilibrium output functions

Market Assumption	$\frac{dK}{dp_K}$	$\frac{dq_I}{dp_K}$	$\frac{dQ}{dp_K}$
m	$-\frac{2+\theta}{2\theta}$	$\frac{1}{\theta}$	$-\frac{1}{2}$
s_I	$-\frac{3+2\theta}{4(1+\theta)}$	$\frac{1}{2(1+\theta)}$	$-\frac{1+2\theta}{4(1+\theta)}$
s_M	$-\frac{2+\theta}{2(1+\theta)}$	$\frac{1}{2(1+\theta)}$	$-\frac{1}{2}$
c	$-\frac{2+\theta}{3+2\theta}$	$\frac{1}{3+2\theta}$	$-\frac{1+\theta}{3+2\theta}$
f	$-\frac{2+\theta}{1+\theta}$	$\frac{1}{1+\theta}$	-1

These slopes convey information on the downstream firms' output responses to changes in p_K. The magnitude of these responses are ranked as follows:

For $0 < \theta < 1$, we have

$$\left|\frac{dK^c}{dp_K}\right| < \left|\frac{dK^{s_I}}{dp_K}\right| < \left|\frac{dK^{s_M}}{dp_K}\right| < \left|\frac{dK^f}{dp_K}\right| < \left|\frac{dK^m}{dp_K}\right| \tag{43}$$

and for $\theta > 1$, we have

$$\left|\frac{dK^c}{dp_K}\right| < \left|\frac{dK^{s_I}}{dp_K}\right| < \left|\frac{dK^{s_M}}{dp_K}\right| < \left|\frac{dK^m}{dp_K}\right| < \left|\frac{dK^f}{dp_K}\right| \tag{44}$$

Whereas for any θ, we obtain

$$\left|\frac{dq_I^c}{dp_K}\right| < \left|\frac{dq_I^{s_I}}{dp_K}\right| = \left|\frac{dq_I^{s_M}}{dp_K}\right| < \left|\frac{dq_I^f}{dp_K}\right| < \left|\frac{dq_I^m}{dp_K}\right| \tag{45}$$

$$\left|\frac{dQ^{s_I}}{dp_K}\right| < \left|\frac{dQ^c}{dp_K}\right| < \left|\frac{dQ^{s_M}}{dp_K}\right| = \left|\frac{dQ^m}{dp_K}\right| < \left|\frac{dQ^f}{dp_K}\right| \tag{46}$$

With the functional forms described in (42), we see from Table 1 that the equilibrium output functions are linear in the transport charge. The equilibrium capacity functions are negatively sloped across the five forms of competition considered while those of the incumbent's output are positively sloped. However, as stated in section 3, the net effect on aggregate output is always negative, i.e., an increase in p_K will be accompanied by an unambiguous increase in gas commodity price.

From (43) and (44) we see that irrespective of the degree of convexity of the incumbent's cost function, θ, when competition prevails, i.e., under market assumptions s_I, c, s_M, and f, the response of equilibrium capacity to an increase in p_K are unambiguously ranked as $|\frac{dK^c}{dp_K}| < |\frac{dK^{s_I}}{dp_K}| < |\frac{dK^{s_M}}{dp_K}| < |\frac{dK^f}{dp_K}|$. This says that the more rigorous the level of competition is in the downstream market, the more responsive capacity is to changes in p_K.[33] As mentioned above, since this (negative) capacity effect dominates the (positive) effect on the incumbent's output, aggregate output decreases. From (46), we see that under market assumptions m (no competition) and s_M (marketer as a Stackelberg leader), an increase in p_K leads to decreases in aggregate output of the same magnitude. This result is driven by the fact that p_K has a direct effect on the marketer's profits (it directly affects its marginal cost) and our demand and cost assumptions.[34]

While these slopes of the equilibrium outputs are instructive by themselves, recall from the theory presented in the previous sections that they feed the regulator's decision. More specifically, these slopes need to be substituted into the conditions that characterize the optimal capacity pricing rules derived in Propositions 2-5. Let us state next these rules for each of the five forms of downstream competition in turn.

$$p_K^m - \omega = \left(\frac{\phi_T^m}{1+\phi_T^m}\right)\frac{2\theta K^m}{(2+\theta)} - \left(\frac{1}{1+\phi_T^m}\right)\frac{\theta Q^m}{(2+\theta)} \tag{47}$$

[33]We view Stackelberg leadership by the marketer as representing more vigorous competition than Stackelberg leadership by the incumbent.

[34]The indirect effect corresponds to the impact of p_K on equilibrium output levels and the subsequent effect on profits.

$$p_K^{s_I} - \omega = \left(\frac{\phi_T^{s_I}}{1+\phi_T^{s_I}}\right)\frac{4(1+\theta)K^{s_I}}{(3+2\theta)} + \left(\frac{1}{1+\phi_T^{s_I}}\right)\frac{[q_I^{s_I} - (3+2\theta)K^{s_I}]}{(3+2\theta)} \tag{48}$$

$$p_K^{s_M} - \omega = \left(\frac{\phi_T^{s_M}}{1+\phi_T^{s_M}}\right)\frac{2(1+\theta)K^{s_M}}{2+\theta} + \left(\frac{1}{1+\phi_T^{s_M}}\right)\frac{[q_I^{s_M} - (1+\theta)K^{s_M}]}{(2+\theta)} \tag{49}$$

$$p_K^{c} - \omega = \left(\frac{\phi_T^{c}}{1+\phi_T^{c}}\right)\frac{(3+2\theta)K^{c}}{(2+\theta)} + \left(\frac{1}{1+\phi_T^{c}}\right)\frac{[q_I^{c} - (2+\theta)K^{c}]}{(2+\theta)} \tag{50}$$

$$p_K^{f} - \omega = \left(\frac{\phi_T^{f}}{1+\phi_T^{f}}\right)\frac{(1+\theta)K^{f}}{(2+\theta)} + \left(\frac{1}{1+\phi_T^{f}}\right)\frac{q_I^{f}}{(2+\theta)} \tag{51}$$

In order to compare the performance of these five policies we ran simulations with the following parameters values: $\gamma = 1$, $\theta = 0.67$, c normalized to zero, ω and F_T continuously varying in $[0, 0.13]$ and $[0, 0.012]$ respectively. Figures 2(a-b), 3, 4(a-b), and 5(a-b) exhibit regions in the $\{F_T, \omega\}$-space within which we obtained different ranking of K, q_I, p_K, Π_I, Π_M, CS, $\Pi_I + \Pi_M$, and W. The region with dashed lines contours represents the (F_T, ω) pairs for which there does not exist a real root to the regulator's maximization program when there is no competition in the downstream market.

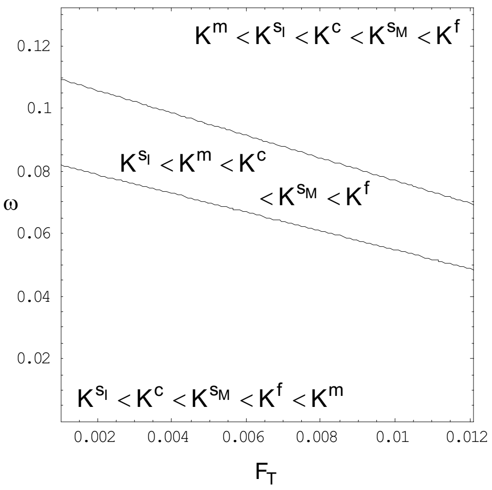


Figure 2a: Ranking of K

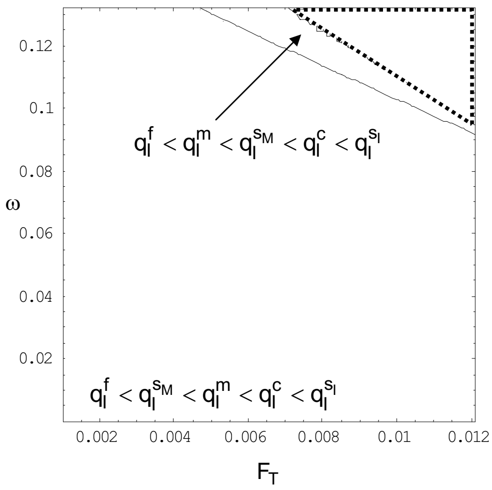
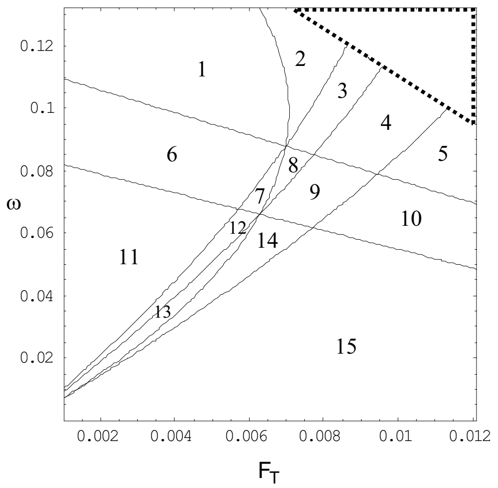


Figure 2b: Ranking of q_I

Figures 2a and 2b show the ranking of optimal capacity and incumbent's output, respectively, in the $\{F_T, \omega\}$-space. We see that when the downstream market is competitive, the more rigorous the level of competition, the higher (the lower) the capacity (the incumbent's output). Hence, competition "demands" transport capacity. The capacity levels without downstream competition cannot be unambiguously ranked relative to those achieved with some downstream competition. As to the incumbent's output, an unambiguous ranking is obtained when we restrict ourselves to market assumptions f, m, and c. In such a case, going from either no competition or Cournot competition to a competitive fringe market structure lowers the incumbent's output. However, moving from no competition to Cournot competition increases it. This suggests that a high level of competition in trading might be an effective means of reducing the incumbent's market share.



1 :	$p_K^{s_M}$	<	p_K^{c}	<	$p_K^{s_I}$	<	p_K^{m}	<	p_K^{f}
2 :	$p_K^{s_M}$	<	p_K^{c}	<	$p_K^{s_I}$	<	p_K^{f}	<	p_K^{m}
3 :	$p_K^{s_M}$	<	p_K^{c}	<	p_K^{f}	<	$p_K^{s_I}$	<	p_K^{m}
4 :	$p_K^{s_M}$	<	p_K^{f}	<	p_K^{c}	<	$p_K^{s_I}$	<	p_K^{m}
5 :	p_K^{f}	<	$p_K^{s_M}$	<	p_K^{c}	<	$p_K^{s_I}$	<	p_K^{m}
6 :	$p_K^{s_M}$	<	p_K^{c}	<	p_K^{m}	<	$p_K^{s_I}$	<	p_K^{f}
7 :	$p_K^{s_M}$	<	p_K^{c}	<	p_K^{m}	<	p_K^{f}	<	$p_K^{s_I}$
8 :	$p_K^{s_M}$	<	p_K^{c}	<	p_K^{f}	<	p_K^{m}	<	$p_K^{s_I}$
9 :	$p_K^{s_M}$	<	p_K^{f}	<	p_K^{c}	<	p_K^{m}	<	$p_K^{s_I}$
10 :	p_K^{f}	<	$p_K^{s_M}$	<	p_K^{c}	<	p_K^{m}	<	$p_K^{s_I}$
11 :	$p_K^{s_M}$	<	p_K^{m}	<	p_K^{c}	<	$p_K^{s_I}$	<	p_K^{f}
12 :	$p_K^{s_M}$	<	p_K^{m}	<	p_K^{c}	<	p_K^{f}	<	$p_K^{s_I}$
13 :	$p_K^{s_M}$	<	p_K^{m}	<	p_K^{f}	<	p_K^{c}	<	$p_K^{s_I}$
14 :	$p_K^{s_M}$	<	p_K^{f}	<	p_K^{m}	<	p_K^{c}	<	$p_K^{s_I}$
15 :	p_K^{f}	<	$p_K^{s_M}$	<	p_K^{m}	<	p_K^{c}	<	$p_K^{s_I}$

Figure 3: Ranking of p_K in regions 1-15

Figure 3 shows that if there is competition in the downstream market but it is not excessive (hence, market assumptions m and f are excluded), the transport charge decreases as the marketer plays a more important competitive role in the downstream market, $p_K^{s_I} > p_K^c > p_K^{s_M}$. This result is consistent with the unambiguous ordering $K^{s_I} < K^c < K^{s_M}$ of the marketer's output which suggests that as the marketer's ability to compete becomes stronger (going from s_I to c and to s_M) society finds it worthwhile to provide it with more capacity. When the two excluded market structures are put back as possible options, the optimal transport charges achieved cannot be unambiguously ranked between them and relative to market assumptions s_I, c, and s_M.[35] Despite this somewhat unstable behavior of the optimal transport charge and corresponding output levels across the various assumptions about the downstream market structure, it turns out that the ordering of social welfare and its components, i.e., consumer surplus and firms' profits, is much less surprising as we now show.

[35] One would have expected the general result that as competition becomes more aggressive, the optimal transport charge would be lower (and optimal capacity would be higher). Our simulations do not, however, support this conjecture. Even more surprising is the result that p_K^f and p_K^m cannot be unambiguously ordered.

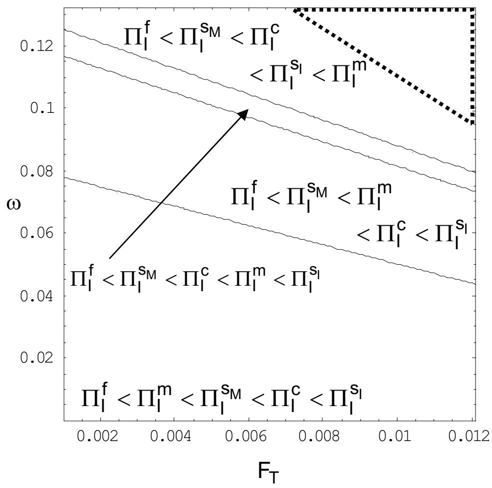


Figure 4a: Ranking of Π_I

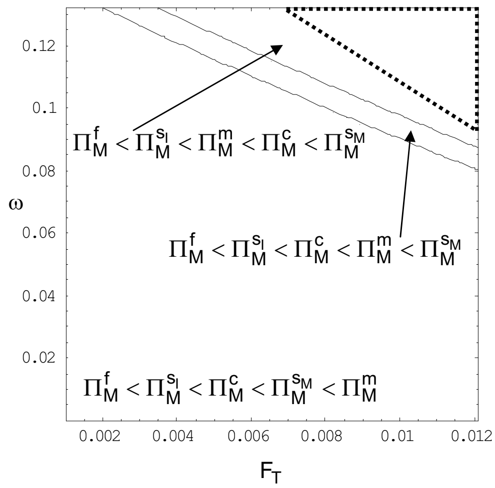


Figure 4b: Ranking of Π_M

Figure 4a shows that under some competition, the incumbent is always better off being a Stackelberg leader than a Cournot competitor, a Stackelberg follower or a dominant firm facing a competitive fringe, its least preferred option ($\Pi_I^f < \Pi_I^{s_M} < \Pi_I^c < \Pi_I^{s_I}$). Between excessive competition and no competition at all, the choice is obvious since $\Pi_I^f < \Pi_I^m$ is always true. As to the marketer, Figure 4b shows that when the marketer is not merely a price taker and it is independent from the incumbent (this excludes f and m), its profits become larger as one moves from s_I to c and to s_M. When merging with the incumbent is a possibility, the marketer prefers it to a situation where it is an independent follower ($\Pi_M^m > \Pi_M^{s_I}$).

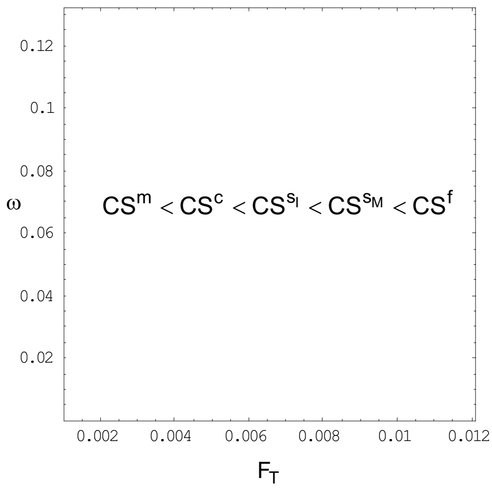


Figure 5a: Ranking of CS

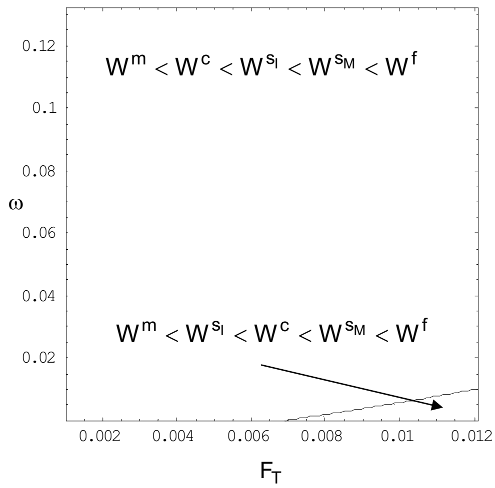


Figure 5b: Ranking of W

Figures 5a and 5b confirm the basic economic principle that more competition should benefit consumers and society as a whole ($CS^m < CS^c < CS^{s_I} < CS^{s_M} < CS^f$ and $W^m < W^c < W^{s_I} < W^{s_M} < W^f$), although we find in our simulations a small region where, because the capacity building technology is characterized by a (very) high fixed cost and a (very) low marginal cost, society is better off under Cournot competition than under Stackelberg leadership of the incumbent. Given that the welfare levels achieved are available, we now examine the preferences of the agents over the different scenarios.[36] Table 2 shows the outcome of pairwise contests based on these welfare levels. Each cell of this table shows the choice of the agent indicated in the column in the contest indicated in the row.[37]

[36]Note that the transporter is indifferent among scenarios as regulation always bind its participation constraint. Moreover, it is obvious that under market structure f the marketer makes zero profits.

[37]A cell showing two choices corresponds to a case where the agent's welfare ordering is not unambiguous.

Table 2: Pairwise contests

Contest	Consumers	Incumbent	Marketer	Society
m vs. s_I	s_I	m, s_I	m	s_I
m vs. s_M	s_M	m, s_M	m, s_M	s_M
m vs. c	c	m, c	m, c	c
m vs. f	f	m	m	f
s_I vs. s_M	s_M	s_I	s_M	s_M
s_I vs. c	s_I	s_I	c	s_I, c
s_I vs. f	f	s_I	s_I	f
s_M vs. c	s_M	c	s_M	s_M
s_M vs. f	f	s_M	s_M	f
c vs. f	f	c	c	f

Three implications of this table are worth mentioning.[38] First, it appears that having the marketer as a follower is generally a "poor" policy. Second, a close examination of the regions of the parameter space indicates that there is no room for a Pareto-improvement, i.e., a move that will make all agents better off. Third, there is a conflict between consumers (and society) and the downstream firms in the choice between no or some competition (m, s_I, c, s_M) and strong competition (f). Indeed, downstream firms will always oppose an extreme strengthening of competition in the downstream market.

6 Conclusion

Traditionally, regulation and competition have been viewed as substitutes for improving the efficiency of some specific markets. Regulation has been typically applied to industries where competition is not sustainable; the so-called "natural monopolies." This was, and still is to some extent, the case of public utilities for decades, most notably the telecommunications, electricity and natural gas industries. Since the eighties, however, following major changes in technology and industry structure, these two mechanisms have come to increasingly complement each other. These industries have moved

[38]The reader should realize that before drawing conclusions from this table, compatibility among the regions of the parameter space over which the choice(s) is (are) made should be checked.

from what essentially was a vertically integrated structure subject to heavy regulation to one in which the natural monopoly portion is separated from segments deemed ready for competition. In gas, transport remains largely under a regulated monopoly while commodity supply has been progressively open to competition.[39] This paper has attempted to assess the relative merits of policies that combine upstream regulation with alternative approaches to downstream competition.

This paper has considered the relationship between the regulated portion of the gas industry (transport) and the segment that has been subject to liberalization (commodity supply).[40] We have modeled the role of pricing of transport capacity in the determination of the equilibrium in the commodity market served by an incumbent and a marketer. We have first characterized the optimal transport capacity pricing rule assuming a "generic" form of downstream competition. This social welfare maximization program has shown that the regulator should balance the impact of the transport charge between the marginal and infra marginal units of capacity built by the transporter (upstream), on the one hand, and the marginal profitability of the marketer and the incumbent (downstream), on the other hand. We have then proceeded to analyze this tradeoff under alternative assumptions about the strategic interaction between firms in the downstream market. In order to compare these second-best policies we have relied on numerical simulations.

While the simulations have confirmed the general wisdom that more competition is preferred to less from the consumers and the social welfare points of view, they have also shown some less expected results about the ordering of key policy variables, such as the capacity of pipelines and its price, across different competitive scenarios. These results have also revealed some redistribution conflicts. In particular, although desirable from a social welfare point of view, a reform that supports high entry in the gas trading segment

[39] The deregulation experience of the UK gas industry provides a good illustration of this interaction between regulation and competition (Waddams Price, 1997).

[40] We should mention the analogy with the electricity industry in which transmission is regulated and generation is open to competition. However, while the approach followed in this paper might be applicable to electricity, the specificities of this sector, in particular, non storability of electricity and network externalities (implied by kirchhoff's laws), should be carefully taken into account.

has been found to make both the incumbent and the existing marketer worse off.[41] The comparative analysis has also shown the important role played by the transporter's technology which, in this paper, has been assumed to be perfectly known by the regulator.

This work raises a whole set of open questions to be investigated in the future. The results obtained so far in our simple industry configuration have shown that transport capacity plays a major role in the shaping of the industry. Indeed, it affects its horizontal structure, its regional developments, and its degree of vertical integration. Adequate regulation is crucial for the networks to follow an "optimal" expansion path and to be financially viable, and for the capacity building activity to be efficient. Concerning the latter, an immediate extension of the model considered here would consist in introducing in the regulator-transporter relationship the assumption that the transporter is privately informed about some aspect of its technology. One would expect this asymmetry of information to have an important impact on the capacity pricing schedules and hence on the functioning of the downstream market.[42] Our model can also be used to analyze the role of temporary initiatives such as gas release measures. Under gas release programs, the incumbent in the downstream gas commodity market is mandated to release a share of its supply, i.e., long-term contracts, to its competitors. In effect, these measures are short-term substitutes to investments in capacity and hence could foster effective competition in the short run.

[41] This is clearly an instance where the strategic affect dominates the substitution effect (see Léautier, 2001).

[42] Gasmi and Oviedo (2005) have explored the impact on transport capacity of asymmetric information on technology of gas commodity supply when the downstream market is a monopoly.

Appendix

Proof of Proposition 1 *Condition (1) in the proposition is just the first-order condition (7) rewritten in such a way that at the left-hand side we obtain the terms that show the impact of p_K on the profitability of the transporter, and at the right-hand side the terms that show the impact on the incumbent and the marketer.* ■

Proof of Lemma 1 *Differentiate the first-order conditions (12) and (13) with respect to p_K to obtain $\frac{dK(\cdot)}{dp_K} = \frac{1}{2p'} - \frac{dq_I}{dp_K}$, $\frac{dq_I(\cdot)}{dp_K} = (\frac{2p'}{C_I'' - 2p'})\frac{dK}{dp_K}$, and $\frac{d^2K(\cdot)}{dp_K^2} = -\frac{d^2q_I}{dp_K^2} = \Omega^m[2\frac{d^2K}{dp_K^2}p' - 2(\frac{dq_I}{dp_K})^2 C_I^{'''}]$, where $\Omega^m \equiv [(2p' - C_I'')]^{-1}$. Then solve the system of equations composed of the first-order derivatives to obtain $\frac{dK^m}{dp_K} = \frac{1}{2p'} - \frac{1}{C_I''} < 0$ and $\frac{dq_I^m}{dp_K} = \frac{1}{C_I''} > 0$ which are rewritten as shown in the first column of (14). Solve the system of equations composed of the second-order derivatives to obtain $\frac{d^2K^m}{dp_K^2} = \frac{C_I^{'''}}{C_I''}(\frac{dq_I^m}{dp_K})^2$ and $\frac{d^2K^m}{dp_K^2} = -\frac{C_I^{'''}}{C_I''}(\frac{dq_I^m}{dp_K})^2$ which are rewritten as shown in the second column of (14).* ■

Proof of Proposition 2 *First, substitute the results (14) from Lemma 1 into condition (10) from Proposition 1, to obtain (15). Next, rewrite the first-order conditions (12) and (13) evaluated at the optimum. This yields (16) and (17).*

When $\phi_T^m > 0$, the capacity pricing rule described by (15) is equivalent to standard average-cost pricing. When $\phi_T^m = 0$, from (15) we obtain that $p_K^m = C_T^{'m}(\cdot) + (p^m - p_K^m - c) + \frac{2(p^m - C_I^{'m})p'}{(2p' - C_I^{''m})}$. From (16) we obtain $(p^m - p_K^m - c) > 0$ which implies $p_K^m < C_T^{'m}(\cdot) + \frac{2(p^m - C_I^{'m})p'}{(2p' - C_I^{''m})}$ and $C_I^{'m} < c + C_T^{'m}$. ■

Proof of Lemma 2 *The slopes and the convexity of the incumbent's and marketer's equilibrium outputs, K^s and q_I^s, under Stackelberg competition are obtained in a similar way to those under the assumption of no downstream competition. Differentiate the first-order condition (18) with respect to p_K to obtain $\frac{dK(\cdot)}{dp_K} = \frac{1}{2}(\frac{1}{p'} - \frac{dq_I}{dp_K})$ and $\frac{d^2K(\cdot)}{dp_K^2} = -\frac{1}{2}\frac{d^2q_I}{dp_K^2}$. Similarly, differentiate (19) to get $\frac{dq_I(\cdot)}{dp_K} = (\frac{2p'}{2C_I'' - 3p'})\frac{dK}{dp_K}$ and $\frac{d^2q_I(\cdot)}{dp_K^2} = -\Omega_1^s[2\frac{d^2K}{dp_K^2}p' - 2(\frac{dq_I}{dp_K})^2 C_I^{'''}]$, where $\Omega_1^{s_I} \equiv [(3p' - 2C_I'')]^{-1}$. Solve the system of equations given by the first-order derivatives to obtain $\frac{dK^{s_I}}{dp_K} = \frac{1}{2p'} + \frac{1}{4(p' - C_I'')} < 0$ and $\frac{dq_I^{s_I}}{dp_K} = -\frac{1}{2(p' - C_I'')} > 0$ which are rewritten as shown in the first column of (20). Next, solve the system of second-order derivatives and obtain $\frac{d^2K^{s_I}}{dp_K^2} = -\frac{\Omega_2^{s_I}}{2}[\frac{dq_I}{dp_K}C_I^{'''}]\frac{dq_I}{dp_K}$ and $\frac{d^2q_I^{s_I}}{dp_K^2} = \Omega_2^{s_I}[\frac{dq_I}{dp_K}C_I^{'''}]\frac{dq_I}{dp_K}$, where $\Omega_2^{s_I} \equiv [(p' - C_I'')]^{-1}$, which are rewritten as shown in the second column of (20).* ■

Proof of Proposition 3 *First, substitute the results (20) from Lemma 2 into condition (10) from Proposition 1, to obtain (21). Next, rewrite the first-order conditions (18) and*

(19) evaluated at the optimum. This gives (22) and (23).

When $\phi_T^{s_I} > 0$, the capacity pricing rule described by (21) is equivalent to standard average-cost pricing. When $\phi_T^{s_I} = 0$, from (21) we obtain that $p_K^{s_I} = C_T^{'s_I}(\cdot) + (p^{s_I} - p_K^{s_I} - c) + \frac{2(p^{s_I} - C_I^{'s_I})p'}{(3p' - 2C_I^{''s_I})}$. From (22) we get $(p^{s_I} - p_K^{s_I} - c) > 0$ which implies $p_K^{s_I} < C_T^{'s_I}(\cdot) + \frac{2(p^{s_I} - C_I^{'s_I})p'}{(3p' - 2C_I^{''s_I})}$ and $C_I^{'s_I} < c + C_T^{'s_I}$. ■

Proof of Lemma 2' *Differentiate the first-order conditions (24) and (25) with respect to p_K, which since $C_I^{'''} = 0$ imply $\frac{dq_I(\cdot)}{dp_K} = (\frac{p'}{C_I'' - 2p'})\frac{dK}{dp_K}$, $\frac{dK(\cdot)}{dp_K} = \frac{2p' - C_I''}{p'(2C_I'' - 3p')}[p'\frac{dq_m}{dp_K} - 1]$, and $\frac{d^2K(\cdot)}{dp_K^2} = \frac{d^2q_I}{dp_K^2} = 0$. Solve the system of first-order derivatives to get $\frac{dK^{s_M}}{dp_K} = \frac{1}{2p'} + \frac{1}{2(p' - C_I'')} < 0$ and $\frac{dq_I^{s_M}}{dp_K} = -\frac{1}{2(p' - C_I'')} > 0$ which are rewritten as shown in the first column of (26).* ■

Proof of Proposition 3' *Substituting the results (26) from Lemma 2' into condition (10) from Proposition 1, we obtain (27). Next, rewrite the first-order conditions (24) and (25) evaluated at the optimum,. This yields (28) and (29). The rest of the proof is omitted as it closely follows the proof of Proposition 3.* ■

Proof of Lemma 3 *Differentiate the first-order condition (30) with respect to p_K to obtain $\frac{dK(\cdot)}{dp_K} = \frac{1}{2}(\frac{1}{p'} - \frac{dq_I}{dp_K})$ and $\frac{d^2K(\cdot)}{dp_K^2} = -\frac{1}{2}\frac{d^2q_I}{dp_K^2}$ (see the proof of Lemma 2). Next, differentiate (31) with respect to p_K to get $\frac{dq_I(\cdot)}{dp_K} = (\frac{p'}{C_I'' - 2p'})\frac{dK}{dp_K}$ and $\frac{d^2q_I(\cdot)}{dp_K^2} = -\Omega_1^c[\frac{d^2K}{dp_K^2}p' - (\frac{dq_I}{dp_K})^2 C_I^{'''}]$, where $\Omega_1^c \equiv [(2p' - C_I'')]^{-1}$. Solve the system of first-order derivatives to get $\frac{dK^c}{dp_K} = \frac{1}{2p'} + \frac{1}{(3p' - 2C_I'')} < 0$ and $\frac{dq_I^c}{dp_K} = -\frac{1}{(3p' - 2C_I'')} > 0$ which are rewritten as shown in the first column of (32). Solve the system of second-order derivatives to obtain $\frac{d^2K^c}{dp_K^2} = -\Omega_2^c[\frac{dq_I}{dp_K}C_I^{'''}]\frac{dq_I}{dp_K}$ and $\frac{d^2q_I^c}{dp_K^2} = 2\Omega_2^c[\frac{dq_I}{dp_K}C_I^{'''}]\frac{dq_I}{dp_K}$, where $\Omega_2^c \equiv [(3p' - 2C_I'')]^{-1}$, which are rewritten as shown in the second column of (32).* ■

Proof of Proposition 4 *Substitute the results (32) from Lemma 3 into condition (10) from Proposition 1, to obtain (33). Next, rewrite the first-order conditions (30) and (31) evaluated at the optimum. This yields (34) and (35).*

When $\phi_T^c > 0$, the capacity pricing rule described by (33) is equivalent to standard average-cost pricing. When $\phi_T^c = 0$, from (33) we obtain that $p_K^c = C_T^{'c}(\cdot) + (p^c - p_K^c - c) + \frac{(p^c - C_I^{'c})p'}{(2p' - C_I^{''c})}$. From condition (34) we get $(p^c - p_K^c - c) > 0$ which implies $p_K^c < C_T^{'c}(\cdot) + \frac{(p^c - C_I^{'c})p'}{(2p' - C_I^{''c})}$ and $C_I^{'c} < c + C_T^{'c}$. ■

Proof of Lemma 4 *Differentiate the first-order condition (36) with respect to* p_K *to get* $\frac{dK(\cdot)}{dp_K} = (\frac{1}{p'} - \frac{dq_I}{dp_K})$ *and* $\frac{d^2K(\cdot)}{dp_K^2} = -\frac{d^2q_I}{dp_K^2}$*. Next, from the proof of Lemma 3 we know the values of* $\frac{dq_I(\cdot)}{dp_K}$ *and* $\frac{d^2q_I(\cdot)}{dp_K^2}$*. Solve the system of first-order derivatives to obtain* $\frac{dK^f}{dp_K} = \frac{1}{p'} + \frac{1}{(p'-C_I'')} < 0$ *and* $\frac{dq_I^f}{dp_K} = -\frac{1}{(p'-C_I'')} > 0$ *which are rewritten as shown in in the first column of (38). Next, solve the system of second-order derivatives to get* $\frac{d^2K^f}{dp_K^2} = -\frac{d^2q_I^f}{dp_K^2} = -\Omega_2^f[\frac{dq_I}{dp_K}C_I^{'''}]\frac{dq_I}{dp_K}$*, where* $\Omega_2^f \equiv [(p' - C_I'')]^{-1}$ *which are rewritten as shown in in the second column of (38).* ■

Proof of Proposition 5 *Substitute the results (38) from Lemma 4 into condition (10) from Proposition 1, to obtain (39). Next, rewrite the first-order conditions (36) and (37) evaluated at the optimum. This yields (40) and (41).*

When $\phi_T^f > 0$*, the capacity pricing rule described by (39) is equivalent to standard average-cost pricing. When* $\phi_T^f = 0$*, from (39) we get* $p_K^f = C_T^{'f}(\cdot) + (p^f - p_K^f - c) + \frac{(p^f - C_I^{'f})p'}{(2p' - C_I^{''f})}$*. From condition (40), we obtain* $(p^f - p_K^f - c) = 0$ *which implies* $p_K^f = C_T^{'f}(\cdot) + \frac{(p^f - C_I^{'f})p'}{(2p' - C_I^{''f})}$ *and* $C_I^{'f} < c + C_T^{'f}$*.* ■

References

Boots, M.G., Rijkers, F.A.M., and B.F. Hobbs, 2004, "Trading in the Downstream European Gas Market: A Successive Oligopoly Approach," *The Energy Journal*, 25(3): 73-102.

Borenstein, S. and J. Bushnell, 1999, "An Empirical Analysis of the Potential for Market Power in California's Electricity Market," *Journal of lndustrial Economics*, 47(3): 285-323.

Borenstein, S., Bushnell, J., and S. Stoft, 2000, "The Competitive Effects of Transmission Capacity in a Deregulated Electricity Industry," *RAND Journal of Economics*, 31(2): 294-325.

Breton, M. and G. Zaccour, 2001, "Equilibria in an Asymmetric Duopoly Facing a Security Constraint," *Energy Economics*, 23: 457-475.

Cardell, C., Hitt, C., and W. Hogan, 1997, "Market Power and Strategic Interaction in Electricity Networks," *Resource and Energy Economics*, 19: 109-137.

Cayrade, P., 2004, "Investments in Gas Pipelines and Liquefied Natural Gas Infrastructure. What it the Impact of the Security of Supply?, Insuring against Discruptions of Energy Supply (INDES) Working Paper No. 3, March 2004, Center for European Policy Studies (CEPS).

Cremer, H., Gasmi, F., and J.J. Laffont, 2003, "Access to Pipelines in Competitive Gas Markets," *Journal of Regulatory Economics*, 24(1): 5-33.

Cremer, H. and J.J. Laffont, 2002, "Competition in Gas Markets," *European Economic Review*, 46: 928-935.

De Vany, A. and W. Walls, 1994, "Open Access and the Emergence of a Competitive Natural Gas Market," *Contemporary Economic Policy*, 12: 77-93.

De Wolf, D. and Y. Smeers, 1997, "A Stochastic Version of a Stackelberg Nash-Cournot equilibrium model," *Management Science*, 43(2): 190197.

Doane, M. and D. Spulber, 1994, "Open Access and the Evolution of the US Spot Market for Natural Gas," *Journal of Law and Economics*, 37(2): 477-515.

Egging, R.G. and S.A. Gabriel, 2006, "Examining Market Power in the European Natural Gas Market," *Energy Policy*, 34(17): 2762-2778.

Gasmi, F., Laffont, J.J., and J.D. Oviedo, 2005, "Controlling Regional Monopolies in The Natural Gas Industry - The Complete Information Case," Mimeo, Toulouse School of Economics (IDEI).

Gasmi, F. and J.D. Oviedo, 2005, "Regulation of Regional Monopolies in Natural Gas Markets," Mimeo, Toulouse School of Economics (IDEI).

Golombek, R, Gjelsvik, E., and K. Rosendahl, 1995, "Effects of Liberalizing the Natural Gas Markets in Western Europe," *The Energy Journal*, 16(1): 85-111.

Golombek, R, Gjelsvik, E., and K. Rosendahl, 1998, "Increased Competition on the Supply Side of the Western European Natural Gas Market," *The Energy Journal*, 19(3): 1-18.

Grais, Z. and K. Zheng, 1996, "Strategic Interdependence in European East-West Trade," *The Energy Journal*, 17(3): 61-84.

Green, R., 1999, "The Electricity Contract Market in England and Wales," *The Journal of lndustrial Economics*, 47(1): 107-124.

Green, R. and D. Newbery, 1992, "Competition in The British Electricity Spot Market," *Journal of Political Economy*, 100: 929-953.

Haurie, A., Zaccour, G., Legrand, J., and Y. Smeers, 1987, "A Stochastie Dynamic Nash-Cournot Model for The European Gas Market," Technical Report G-86-24, GERAD, Ecole des Hautes Etudes Commerciales, Montréal, Québec, Canada.

Léautier, T.O., 2000, "Regulation of an Electric Power Transmission Company," *The Energy Journal*, 21(4): 61-92.

Léautier, T.O., 2001, "Transmission Constraints and Imperfect Markets for Power," *Journal of Regulatory Economics*, 19(1): 27-54.

Mathiesen, L., Roland, K., and K. Thonstad, 1987, "The European Natural Gas Market: Degrees of Monopoly Power," in *Natural Gas Markets and Contracts*. R. Golombeck, M. Hoel, and J. Vislie (eds.). Amsterdam: North Holland.

Nasser, T.O., 1998, "Congestion Pricing and Network Expansion," The World Bank Policy Research Working Paper Series No. 1896.

Oren, S., 1997, "Economic Inefficiency of Passive Transmission Rights in Congested Electricity Systems with Competitive Generation," *The Energy Journal*, 18(1): 63-84.

Rudkevich, A., Duckworth, M., and R. Rosen, 1998, "Modelling Electricity Pricing in a Deregulated Generation Industry: The Potential for Oligopoly Pricing in a PooLCo," *The Energy Journal*, 19(3): 19-48.

Sagen, E.L. and F.R. Aune, 2004, "The Future European Natural Gas Market - Are Lower Prices Attainable?," Statistics Norway Research Department Discussion Paper No. 379.

Smeers, Y. and J.Y. Wei, 1997, "Spatially Oligopolistic Models with Opportunity Cost Pricing for Transmission Capacity Reservations: A Variational Inequality Approach," CORE Discussion Paper 9717.

Smeers, Y. and J.Y. Wei, 1999, "Spatial Oligopolistic Electricity Models with Cournot Generators and Regulated Transmission Prices," *Operations Research*, 47(1): 102-112.

Tirole, J., 1988, *The Theory of lndustrial Organization*, Cambridge: MIT Press.

Tzoannos, J., 1977, "An Empirical Study of Peak-Load Pricing and Investment Policies for the Domestic Market of Gas in Great Britain," *Applied Economics*, 9: 133-153.

Von der Fehr, N. and D. Harbord, 1993, "Spot Market Competition in the UK Electricity Market," *The Economic Journal*, 103(418): 531-546.

Waddams Price, C., 1997, "Competition and Regulation in the UK Gas Industry," *Oxford Review of Economic Policy*, 13(1): 47-63.