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Gas Transportation and Storage Under a Price Cap Regulation

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Abstract

We investigate the effects of a price cap regulation on the consumer's surplus within the framework of two gas ownership structures. In the case of a firm owning both the gas transportation and storage facilities, we find that tightening the price cap constraint is always beneficial to the consumers in terms of consumer's surplus. In the case of a separate ownership, the impact of changes in the cap for the access fee is larger than that of the storage fee, so that a tightening of one price cap and a softening of the other may also lead to consumer's surplus increase.

Key Words: Gas transportation and storage, Price cap.

Résumé

Cet article étudie l'effet d'une réglementation sous forme de plafond sur le surplus du consommateur, dans le contexte de deux types d'organisations pour la vente et distribution du gaz. Dans le premier cas, les installations de transport et de stockage appartiennent à une même firme, et on montre qu'un abaissement du plafond de prix est toujours bénéfique au consommateur. Dans le deuxième cas, ces installations appartiennent à deux firmes différentes, et on montre que l'impact d'un changement des frais de transport est plus important que celui des frais de stockage, de sorte qu'il est possible d'observer une augmentation du surplus du consommateur en modifiant les plafonds dans des directions différentes.

Mots clés : transport et stockage de gaz, plafond de prix.

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1 Introduction

Gas markets liberalization is accompanied in many cases by the requirement to un-bundle gas sales from transportation and storage services. In the U.S, this separation is mandatory under FERC Order 636. Legal unbundling is forced in Europe through the 2003 Gas Directive. In particular, Art.19 (1) of the 2003/557EC Gas Directive requires that access to storage and line pack be offered for efficient use of the networks.

The unbundling of services and the requirement to establish Open Access regime in network industries to promote competition is analyzed extensively in the literature. One stream of the literature deals primarily with the optimal access fees issue (see for example Armstrong et al. 1996 and Armstrong and Vickers, 1998). Another stream deals with the regulation of network industries. Among the regulatory mechanisms that are adopted in many countries is the price cap regulation (PCR). PCR is a preferred mechanism because of its advantages over other regulatory mechanisms such as the rate of return regulation. Indeed, under a PCR, the firm has more incentives to use the least cost technology and to operate with no waste. Under a pure PCR, a cap is imposed on the average prices that the regulated firm may charge for its services. This price cap is adjusted over time to take into account inflation effects, through an inflation measurement instrument such as the CPI, and performances effects, through an offset factor commonly called the X factor (Armstrong et al. 1994). The X factor measures the performance of the regulated company over the whole economy in terms of productivity and in terms of input prices changes (Bernstein and Sappington, 1999). PCR aims at transferring to the customers, by tightening the price cap, some of the "excessive gains" the regulated firm is making .

Price cap change effects on consumer's surplus were analyzed in different studies. Armstrong and Vickers (1991) show that tightening an average revenue constraint (ARC) may deteriorate consumer's welfare in a multi-product case. In the single product framework, consumer's welfare is improved. Law (1995) shows that with independent demands, tightening an ARC can reduce consumer welfare when products marginal costs are different. Kand et al. (2000) investigate conditions under which a price cap reduction impacts consumer's welfare negatively. Using linear demand functions for a two product firm and fixed weights factors in the regulatory constraint, they find that if demands are independent, tightening the price cap constraint is always beneficial to consumers. If demands are interdependent then a reduction in the price cap may deteriorate consumer's surplus.

In this note, we investigate the effects of a price cap reduction and how it relates to the Open Access framework in the gas transportation sector. Like Kand et al. (2000), we use linear demand functions with fixed weights factors. We analyze the consumer's surplus in a stylized gas network for two cases of ownerships, in a two period model. In the first case, a company operates both the pipeline and the storage facilities, and in the second case, the facilities are operated by two separate companies. Charges for access to pipeline and storage facilities are subject to a basket price regulation in the first case. In the second case they are fixed separately by the regulator. The setting however differs from Kand et al. (2000) in that transportation and storage services could be dependent or independent, according to whether the pipeline capacity is binding or not. In addition, there is an inter-temporal dependence of the demand in the second period and the storage in the first one. Contrary to Kand et al. (2000), and in both ownership cases, we find that price cap reductions always have positive effects on consumer's surplus. In the case of separate ownership, a reduction in one price and an increase in the other may also lead to an increase in consumer's welfare.

The remainder of the note is organized as follows. Section 2 describes the model, Section 3 derives the equilibrium in the downstream market. Section 4 analyzes the common ownership case while Section 5 investigates the separate ownership case. Section 6 is a conclusion.

2 The model

We consider a two period model where the two periods form the gas price year. The first period is a low price period while the second is a high price period. We assume that the storage facility is for seasonal storage and not diurnal or peak-shaving storage.

We consider a stylized gas network. The upstream market is a competitive market with no production shortage in any period. In the case of the common ownership structure, the transportation and storage activities are offered by the same pipeline company. In the other case, these activities are offered by two different companies. In both cases, these companies do not operate in the downstream market. This is in line with the tendency to un-bundle retail and transportation activities in many network industries. The downstream market is a competitive market where n identical distribution companies contract for the gas in the upstream market and arrange for transportation and storage services with the pipeline company. Each distribution company is a price taker in the upstream market. The n companies operate within the framework of the standard Cournot game in the downstream market. They are endowed with equal capacity rights; in the case of a congested pipeline, a pro rata mechanism is used to share the available capacity.

Access fees are fixed by the regulator in the case of a separate ownership structure. In the other case, the pipeline and storage company is subject to a price cap regulation. It has some flexibility in fixing the access fees to its pipeline and storage facilities, provided that a weighted average of those prices is less than the price cap imposed by the regulator. We suppose that the weights are fixed; this reflects the case of a stationary demand where the revenue from one activity (pipeline transportation or storage) is a fixed share of the total revenue of the pipeline company. It is also related to a lagged regulatory mechanism. The company is thus subject to:

$$w_1 a + w_2 b \leq P, \tag{1}$$

where:

P : price cap

a : price for the access to the pipeline

b : price for the access to the storage (including withdrawal and injection fees)

w_1, w_2: weight factors such that $w_1 + w_2 = 1$.

Consumer demand for gas is assumed to be deterministic and linear, with a slope normalized to 1, so that inverse demand is given by

$$p_m = L_m - q_m,$$

where p_m is the price in period m, q_m is the total gas delivered to the consumers in period m, and L_m, the intercept in period m, is such that $L_1 < L_2$.

Pipeline capacity will be normalized to 1. We assume that the pipeline capacity constraint is binding in the second period; the conditions on the parameters ensuring this assumption will be given below. Since distribution companies have equal capacity rights, the quantity distributed by each company in the second period is thus equal to $\frac{1}{n}$.Demand in the second period is also assumed to be high enough to justify the need to store gas in the first period. In the first period, capacity is sufficient to satisfy customers demand. However, it may also be binding because of gas purchased and stored for the second period, that is, quantities for storage compete with demand in the first period for pipeline capacity.

Denote:

s_j: Storage of firm j, $j = 1, \ldots, n$, $S = \sum_{j=1}^{n} s_j$, $S^{-j} = S - s_j$

q_j: gas distributed by company j in the first period; $j = 1, \ldots, n$, $Q = \sum_{j=1}^{n} q_j$, $Q^{-j} = q - q_j$

c_m: marginal cost of production in the upstream market in period m, which is also the marginal cost of contracting for gas by a distribution company in the upstream market in period $m, m = 1, 2$

Π_{jm}: profit for distribution company j during period $m, m = 1, 2$, $j = 1, \ldots, n$

$\Pi_j = \Pi_{j1} + \Pi_{j2}$: total profit for distribution company j, $j = 1, \ldots, n$

Π: profit of the pipeline company

u: Unit transportation cost

v: Unit storage cost.

CS_m: Consumer surplus in period m, $CS = CS_1 + CS_2$.

3 Production and storage in the downstream market

In the downstream market, a distribution company chooses the distribution and storage levels maximizing its total profits:

$$\max_{q_j, sj} \Pi_j = q_j(p_1 - c_1 - a) + \frac{1}{n}(p_2 - c_2 - a) + s_j(p_2 - c_1 - a - b) \tag{2}$$

where

$$\begin{aligned} p_1 &= L_1 - Q^{-j} - q_j \\ p_2 &= L_2 - 1 - S^{-j} - s_j \\ q_j + Q^{-j} + s_j + S^{-j} &\leq 1. \end{aligned}$$

It is straightforward to check that individual profit functions are concave, so that, assuming an interior solution and identical firms, the equilibrium productions and storage are obtained by simultaneously solving for the first order conditions which are given by:

$$\begin{aligned} L_1 - \left(2q_j + Q^{-j}\right) - c_1 - a - \lambda_j &= 0 \\ -\frac{1}{n} + L_2 - 1 - 2s_j - S^{-j} - c_1 - a - b - \lambda_j &= 0 \\ \lambda_j(q_j + S_j - \frac{1}{n}) = 0, \lambda_j \geq 0, q_j + s_j - \frac{1}{n} &\geq 0 \end{aligned}$$

where λ_j is the multiplier associated to the capacity constraint in the first period. One can check that a sufficient condition for the second period capacity constraint to be binding is given by $b \geq c_2 - c_1$, which can be interpreted as an inter-temporal no arbitrage condition.

This yields the following two cases for the equilibrium in the downstream market:

1. Capacity constraint not binding in the first period:
   The equilibrium $\left(q_j^{NB}, s_j^{NB}\right)$ is given by (assuming interior solutions):

$$\begin{aligned} q_j^{NB} &= \frac{L_1 - c_1 - a}{n+1}, \\ s_j^{NB} &= \frac{L_2 - c_1 - a - b}{n+1} - \frac{1}{n},\ j = 1, \dots n \end{aligned}$$

   where $L_1 + L_2 - 2c_1 - 2a - b \leq \frac{2+2n}{n}$, which states roughly that the revenue for gas in both periods (through $L_1 + L_2$) is relatively low with respect to the purchase, storage and transportation costs.

2. Capacity constraint binding in the first period:
   The equilibrium $\left(q_j^B, S_j^B\right)$ is given by (assuming interior solutions):

$$\begin{aligned} q^B &= \frac{1}{n} - \frac{L_2 - L_1 - b}{2(n+1)} \\ s_j^B &= \frac{L_2 - L_1 - b}{2(n+1)} \\ \lambda_j^B &= \frac{1}{2}\left(L_2 - b + L_1\right) - c_1 - a - \frac{1+n}{n} \end{aligned}$$

   where $L_1 + L_2 - 2c_1 - 2a - b > \frac{2+2n}{n}$, which states roughly that the revenue for gas in both periods (through $L_1 + L_2$) is high enough with respect to the purchase and transportation costs.

4 Common ownership of transportation and storage facilities

4.1 Access fees

The transportation company maximizes its profits from its two activities subject to the regulator constraint. The optimisation problem is thus:

$$\max_{a,b} \Pi = (a-u)(Q+1+S) + (b-v)S \tag{3}$$

$$\text{s.t.} \tag{4}$$

$$w_1 a + w_2 b \leq P \tag{5}$$

where Q and S are the total quantities sold and stocked, obtained from the solutions in the downstream market. Thus, we get the following two cases:

1. Capacity constraint not binding in the first period:
   The profit of the pipeline company is then:
   $\Pi(a,b) = (a-u)(n\frac{L_1-c_1-a}{n+1} + 1 + n\frac{L_2-c_1-a-b}{n+1} - 1) + (b-v)\left(n\frac{L_2-c_1-a-b}{n+1} - 1\right).$
   It is straightforward to check that this function is concave, so that the solution solves the first order conditions:

$$\frac{n}{n+1}(L_1 + L_2 - 2c_1 + 2u + v - (4a+2b)) - \mu w_1 = 0 \tag{6}$$

$$\frac{n}{n+1}(L_2 - c_1 + u + v - (2a+2b)) - 1 - \mu w_2 = 0 \tag{7}$$

$$\mu P - w_1 a - w_2 b) = 0; P - w_1 a - w_2 b \geq 0, \mu \geq 0 \tag{8}$$

Now, in the absence of a price cap, the optimal prices of the pipeline company are given by:
$a^* = \frac{1}{2}\left(L_1 + u - c_1 + \frac{n+1}{n}\right), b^* = \frac{1}{2}\left(L_2 + v - L_1 - \frac{n+1}{n}\right)$
We assume that

$$w_1\left(L_1 + u - c_1 + \frac{n+1}{n}\right) + w_2\left(L_2 + v - L_1 - \frac{n+1}{n}\right) > 2P,$$

so that the price cap constraint is binding. Finally, using $B \equiv L_1 + L_2 - 2c_1 + 2u + v$ and $D \equiv L_2 - c_1 + u + v$ in (6)-(8), we get the optimal access price for the pipeline company under a price cap:

$$\begin{aligned}
a^{NB} &= \frac{1}{2}\frac{w_2\left(Bw_2 - Dw_1\right) + 2P\left(w_1 - w_2\right)}{w_2^2 + \left(w_1 - w_2\right)^2} \\
b^{NB} &= -\frac{1}{2}\frac{w_1\left(Bw_2 - Dw_1\right) + 2P\left(w_1 - 2w_2\right)}{w_2^2 + \left(w_1 - w_2\right)^2} \\
\mu^{NB} &= \frac{D\left(2w_2 - w_1\right) + B\left(w_1 - w_2\right) - 2P}{w_2^2 + \left(w_1 - w_2\right)^2}
\end{aligned}$$

Conditions ensuring that this solution yields a positive profit are written:

$$\begin{aligned}
&\big(2(L_2 + v) - c_1 - 7u + L_1\big)w_1^2 \\
&\quad + \big(7u - 3(L_2 + v) + c_1 + 4P - 2L_1\big)w_1 \\
&\quad - 2(u + P) + L_1 + L_2 + v > 0 \\
&\big(2L_2 - 8v + L_1 - 3\left(c_1 - u\right)\big)w_1^2 \\
&\quad + \big(-6P - L_2 + 11v - L_1 + 2(c_1 - u)\big)w_1 \\
&\quad - 4(v - P) > 0.
\end{aligned}$$

2. Capacity constraint binding in the first period:
   The profit of the pipeline company is then:

$$\Pi = 2(a - u) + (b - v)\frac{n\left(L_2 - L_1 - b\right)}{2(n+1)},$$

which is again concave. The first order conditions are given by:

$$\begin{aligned}
2 - w_1\mu &= 0 \\
j\frac{n\left(L_2 - L_1 - 2b + v\right)}{2(n+1)} - 2w_2\mu &= 0 \\
\mu\left(w_1 a + w_2 b - P\right) = 0, \mu \geq 0, \left(w_1 a + w_2 b - P\right) &\leq 0.
\end{aligned}$$

In that case, the multiplier is always positive and we get:

$$\begin{aligned}
a^B &= \frac{P}{w_1} - \frac{w_2}{2w_1}(L_2 - L_1 + v) + \frac{2(n+1)}{n}(\frac{w_2}{w_1})^2 \\
b^B &= \frac{L_2 - L_1 + v}{2} - \frac{2(n+1)}{n}\frac{w_2}{w_1} \\
\mu^B &= \frac{2}{w_1}.
\end{aligned}$$

Conditions ensuring that this solution yields a positive profit are written:

$$\begin{aligned}
&\left(L_2 + L_1 - v - 2u + 4\frac{n+1}{n}\right) w_1^2 \\
&\quad + \left(2P - L_2 - L_1 + v - 8\frac{n+1}{n}\right) w_1 \\
&\quad + 4\frac{n+1}{n} > 0 \\
&\left(L_2 - L_1 - v + 4\frac{n+1}{n}\right) w_1 \\
&\quad - 4\frac{n+1}{n} > 0.
\end{aligned}$$

4.2 Consumer's surplus

By reducing the price cap at the end of the regulatory periods, regulators want that some of the profits the companies are making to be shared with customers. Softening the price cap is also a practice used to ensure the viability of the firms. The following discussion aims at verifying whether such decisions are beneficial to customers.

The total consumer's surplus is given by:

$$CS = \frac{Q_1^2}{2} + \frac{(1+S)^2}{2},$$

so that the effect of a change in the price cap P on the total consumer surplus is given by:

$$\frac{\partial CS}{\partial P} = (1+S)\frac{\partial S}{\partial P} + Q\frac{\partial Q}{\partial P}.$$

First note that if capacity is binding in the first period, a reduction in the price cap does not affect consumers surplus. Indeed, if the capacity constraint is binding in both periods, consumers can not increase their utilities by consuming more in the case of a price cap reduction. Moreover, they cannot profit from reductions in storage fees since the latter does not depend on P.

On the other hand, if capacity is not binding in the first period, we have:

$$\begin{aligned}
\frac{\partial S^{NB}}{\partial P} &= -\frac{n}{n+1}(\frac{\partial a^{NB}}{\partial P} + \frac{\partial b^{NB}}{\partial P}) \\
\frac{\partial Q^{NB}}{\partial P} &= -\frac{n}{n+1}\frac{\partial a^{NP}}{\partial P} \\
\frac{\partial a^{NB}}{\partial P} &= \frac{w_1 - w_2}{(w_2 - w_1)^2 + w_2^2} \\
\frac{\partial b^{NB}}{\partial P} &= \frac{2w_2 - w_1}{(w_2 - w_1)^2 + w_2^2}
\end{aligned}$$

1. Notice that the derivatives of a^{NB} and b^{NB} with respect to P show how the pipeline company adjusts to a price cap reduction. This adjustment depends on the weights factors in the price cap constraint. We obtain:

$$\begin{aligned}
\frac{\partial S^{NB}}{\partial P} &= -\frac{n}{n+1}\frac{w_2}{(w_2 - w_1)^2 + w_2^2} \\
\frac{\partial Q^{NB}}{\partial P} &= \frac{n}{n+1}\frac{w_2 - w_1}{(w_2 - w_1)^2 + w_2^2}.
\end{aligned}$$

The above shows that a tightening of the price cap constraint always translates into a reduction in the quantities stored, while the effect on the quantity produced in the first period depends on the weight factors values.

Consumer's surplus is given by

$$\frac{\partial CS}{\partial P} = -\frac{n}{n+1}\left(\frac{w_2(1 - Q + S) + Qw_1}{(w_2 - w_1)^2 + w_2^2}\right) < 0,$$

which shows that a reduction in the price cap is always beneficial to consumers.

4.3 Separate ownership of transportation and storage facilities

4.4 Access fees

In this case, the access fees a and b are directly imposed by the regulator. Notice that, in all cases, the effect of a change in the access fees on the quantities distributed and stored is given by:

$$\begin{aligned}
\frac{\partial S}{\partial a} &= \frac{\partial S}{\partial b} = \frac{\partial Q}{\partial b} = -\frac{n}{1+n} \\
\frac{\partial Q}{\partial a} &= 0.
\end{aligned}$$

We will investigate the impact of changes in these fees on the consumer surplus.

4.5 Consumer's surplus

The impact of a change of access fees on the consumer's surplus is given by:

$$dCS = \frac{\partial CS}{\partial a}da + \frac{\partial CS}{\partial b}db$$

1. Capacity constraint not binding in the first period:
   In this case, we have:

$$\begin{aligned} \frac{\partial CS}{\partial a} &= (1+S)\frac{\partial S}{\partial a} + Q\frac{\partial Q}{\partial a} = -\frac{n}{1+n}(1+S+Q) \\ \frac{\partial CS}{\partial b} &= (1+S)\frac{\partial S}{\partial b} = -\frac{n}{1+n}(1+S) \\ dCS &= -\frac{n}{1+n}\left((1+S+Q)da + (1+S)db\right), \end{aligned}$$

   showing that a reduction in both prices always induces an increase in the consumer's surplus. However, we see that the impact of a change in the pipeline access fee is more important that of a change in the storage fee. Thus, a decrease d in the access fee, accompanied by an increase in the storage fee of less than $\frac{1+S+Q}{1+S}d$, would be beneficial to the consumers.

2. Capacity constraint binding in the first period:
   In this case, we have,

$$\begin{aligned} \frac{\partial CS}{\partial a} &= 0 \\ \frac{\partial CS}{\partial b} &= -\frac{n}{2(1+n)}(1+S-Q). \end{aligned}$$

   Thus, a reduction in the storage fees always induces an increase in the consumer's surplus while a change in the transportation fees have no impact.

5 Conclusion

Price cap regulation is identified as a superior regulatory mechanism because of the incentives it gives to companies to increase productivity and reduce costs. Price cap reductions at the end of the regulatory periods aim at allowing customers to benefit from companies' gains. In a stylized gas network, we investigated the effects of price cap regulation on the consumer's surplus within the framework of two ownership structures. In the case of a pipeline company (under a basket price cap regulation) which is responsible for the transportation and storage activities, we find that the price cap reduction is always beneficial to consumers. In the case of a separate ownership, a reduction in one price cap and an increase of the other may lead to consumer's surplus improvement or deterioration.

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