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Transportation and storage under a dynamic price cap regulation process

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ABSTRACT

We study the welfare effects of Price Cap Regulation (PCR) and the strategic behavior it may induce in gas transportation networks by analyzing a stylized gas network within the framework of a multi-period game model under three scenarios: No regulation, a dynamic setting where the price cap adjustment mechanism is not endogenized by the players, and a dynamic setting where it is endogenized by the players.

1. Introduction

Gas markets liberalization is accompanied in many cases by the requirement to unbundle gas sales from transportation and storage services. In the U.S.A., 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 this literature deals primarily with the optimal access fees issue (see for example Armstrong et al., 1996; Armstrong and Vickers, 1998). Another stream deals with the regulation of network industries as a means to protect consumers from monopolistic behavior. Price cap regulation (PCR) is adopted in many countries and is one of the preferred regulatory mechanisms for network industries (Beesley and Littlechild, 1989; Brennan, 1989; Isaacs, 1991). Under a pure PCR, a cap is imposed on the average prices that the regulated company may charge for its services. This price cap is adjusted over time to take into account inflation effects (Armstrong et al., 1994; Bernstein and Sappington, 1999).

Different PCR schemes are used in practice. Armstrong et al. (1994) report that fixed weights (tariff basket or Laspeyres index approach in practice) and average revenue regulation (lagged average revenue approach in practice) schemes are widely used to regulate utilities in England and in other counties (Jamasb and Pollitt, 2007). The impact of price cap regulation has been studied under various perspectives, namely performance attributes (Domah and Politt, 2001), investment effects (Buehler et al., 2010), and welfare effects.

With respect to the effect of price cap changes on consumer surplus, Armstrong and Vickers (1991) show that tightening an average revenue constraint may deteriorate consumer's welfare in a multiproduct case. In the single product framework, consumer's welfare is improved. Law (1995) shows that with independent demands, tightening an average revenue constraint can reduce consumer's welfare when products marginal costs are different. Cowan (1997) concludes that no regulation can be better than a very tight price cap in average revenue regulation. Concerning the Laspeyres index approach, Cowan (1997) shows that a tight price cap could result in a welfare depreciation with respect to no regulation, whereas, under certain conditions, the Laspeyres index approach based on lagged quantities will always improve welfare. In all the above papers, the authors are assuming independent demand functions. Kang et al. (2000) investigate conditions under which a price cap reduction impacts consumer's welfare negatively. In a static setting, 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, whereas if demands are interdependent then a reduction in the price cap may deteriorate consumer surplus.

While it is widely accepted that PCR is an efficient regulatory mechanisms, it is not necessarily immune from firms' strategic behavior. In the case of Chile, it is reported that there are evidences that stock market prices of the regulated firms react differently to cost announcements in review years than in non review years (Di Tella and Dyck, 2002). In the case of benchmarking use within incentive-based regulation frameworks, regulated firms can also act strategically by gaming the regulator's benchmarking and not achieving the announced performance improvements (Jamasb et al., 2003).

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This paper contributes to the literature on the impact of PCR under the perspective of welfare effects. We specifically consider the case of a stylized gas transportation and storage network with seasonal demand variation. In that case, contrary to most of the literature about welfare effects, demands for transportation and storage services are not independent. Interdependent demand has been studied in Kang et al. (2000); however, our setting differs significantly from theirs, as interdependency of demand here is not exogenous, but rather arises from the network industry structure, and from seasonality and network capacity constraints. Moreover, with seasonal demand variation, when pipeline capacity becomes binding, then storage and quantities become substitutes on an inter-temporal basis. Accordingly, the degree of demand interdependency may change over time, as a result of the regulation. A second contribution of the paper is the analysis of the impact of PCR in a dynamic setting. We specifically account for the change in the price cap resulting from a lagged revenue weights regulation. To our knowledge, no dynamic model of the impact of PCR on output, prices and welfare effects has been proposed in the literature. Finally, our paper also contributes to the literature on strategic implications of PCR by considering that regulated players may anticipate the changes in the PCR and demands over time and adjust their pricing decisions accordingly.

We show that, as a consequence of a tariff basket PCR, the pipeline company reduces its access to pipeline tariff while increasing the storage access fee. The reduction in pipeline access fees translates into higher transmitted quantities both for final consumption and storage, as long as pipeline capacity is not binding. As a consequence, downstream prices are reduced, which implies an increase in consumer surplus. As long as the pipeline capacity is not binding, we show that tightening the price cap constraint is always beneficial to consumers, as in the static model of Kang et al. (2000). However, the reverse is true when the pipeline capacity is fully used; in that case, storage quantities start decreasing and prices in the high demand season increase, which results in reduced consumer surplus.

Over time, PCR eventually results in binding pipeline capacity and reduced demand for storage. We find that this outcome occurs whether the pipeline firm acts strategically or not. Moreover, we show that when the capacity constraint is binding, the benefits of the mechanism are essentially captured by the downstream distribution companies. Finally, we find that acting strategically to manipulate the weights over time cannot significantly retard this outcome for the pipeline company.

The remainder of the paper is organized as follows. Section 2 describes the model and notation. Section 3 solves the static game between the pipeline and downstream companies for a given year and for given weights and cap. Section 4 illustrates the impact of imposing a price cap over time, assuming both myopic and strategic behavior from the pipeline company. Section 5 is a conclusion.

2. The model

We consider a stylized gas network. The upstream market is a competitive market with no production shortage in any period. 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 an independent pipeline company. The latter is operating a pipeline connecting the gas producers to the consumer market. A storage facility is located at the city gate (consumer market). 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 prorating mechanism is used to share the available capacity. This stylized system represents the physical gas market (Fig. 1).

We consider a dynamic system where the gas year is divided into two periods or seasons. Season 1 is a low-price period while Season 2 is a high-price one. The storage facility is used for seasonal storage and not diurnal or peak-shaving storage. (Peak shaving storage is used for hedging activities on a daily or hourly basis). Seasonal storage facilities are filled during the low-price season and emptied during the high-price season.

In order to simplify notation, both the pipeline capacity (in units of volume per year) and the slope of the annual inverse demand function are normalized to 1, so that the volume unit is denoted u and the currency unit is denoted $\mathcal{S}$.

The integrated pipeline and storage company is subject to a price cap regulation. Thus, the company 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. The pipeline company is thus subject to

$$w_{1t}g_t + w_{2t}f_t \le \theta, \tag{1}$$

where:

- θ price cap,
- g_t price for the access to the pipeline during year t ($\mathcal{S}/u$),
- f_t price for the access to the storage (including withdrawal and injection fees) during year t ($\mathcal{S}/u$),
- w_{1t}, w_{2t} weight factors at year t ($u/\mathcal{S}$).

The tariff basket PCR is widely used in the gas industry. In tariff basket PCR, w_{1t} and w_{2t} are defined as follows:

$$w_{1t} = \frac{T_{t-1}}{(g_{t-1}T_{t-1} + f_{t-1}S_{t-1})} \tag{2}$$

$$w_{2t} = \frac{S_{t-1}}{(g_{t-1}T_{t-1} + f_{t-1}S_{t-1})} \tag{3}$$

where:

- T_{t-1} total gas transported during year $t-1$ (u),
- S_{t-1} total gas stored during year $t-1$ (u).

Consumer demand for gas in the downstream market is assumed to be constant over time, deterministic and linear, with a slope normalized to 1, so that the inverse demand function is given by

$$P_{tm} = L_m - D_{tm},$$

where P_{tm} is the price ($\mathcal{S}/u$) in season m of year t, D_{tm} is the total gas (u) delivered to the consumers in season m of year t, and L_m, the intercept in season m of the gas year ($\mathcal{S}/u$), is such that $1<L_1<L_2$.

We assume that the pipeline capacity constraint is binding in the second (high-price) season, justifying the need for storage in the first season. Since distribution companies have equal capacity rights, the quantity (in u) distributed by each company in the second season is thus equal to $\frac{1}{n}$. As long as storage capacity is available, if the pipeline is used at full capacity in the second season, then distribution companies have incentives in storing gas in the first season in order to sell it in the second season at higher prices. In the first season, pipeline capacity may or may not be binding, depending on the quantity of gas purchased and stored for the second season, that is, quantities for storage compete with demand in the first season for pipeline capacity.

Denote:

- Q_{tm} gas contracted and distributed (u) by the downstream companies in season m of year t; $m=1,2$,
- S_t storage (u) in year t, that is, gas contracted by distribution firms in season 1 and distributed in season 2 of year t,