Energy Policy 38 (2010) 1759–1763

Contents lists available at ScienceDirect

Energy Policy

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

Long-term contract auctions and market power in regulated power industries

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ARTICLE INFO

Article history:
Received 28 August 2009
Accepted 16 November 2009
Available online 22 December 2009

JEL Classification:
L94
L51

Keywords:
Electricity
Market power
Long-term auctions

ABSTRACT

A number of countries with oligopolistic power industries have used marginal cost pricing to set the price of energy for small customers. This course of action, however, does not necessarily ensure an efficient outcome when competition is imperfect. The purpose of this paper is to study how the auction of long-term contracts could reduce market power. We do so in a two-firm, two-technology, linear-cost, static model where demand is summarized by a price inelastic load curve. In this context we show that the larger the proportion of total demand auctioned in advance, the lower are both the contract and the average spot price of energy.

1. Introduction

In the past 30 years many countries have liberalized their wholesale electricity markets. In some of them deregulation has been complete, while in others prices remain regulated for small clients. The latter situation is frequent among countries that privatized their power systems but where full competition seemed impractical at the outset. This is the case of most Latin American countries including Brazil, Argentina, Chile, Dominican Republic, Peru, Panama, Nicaragua, and, from January 2010, El Salvador. Generally speaking, these countries resorted to marginal cost pricing to set prices for small clients.[2] While large clients bilaterally negotiated long-term contracts with generators, small customers purchased energy—through distribution companies—at the regulated price.[3]

Marginal cost pricing, however, does not necessarily produce an efficient outcome in power industries where competition is insufficient. Von der Fehr and Harbord (1997) and Arellano and Serra (2007), among others, find that oligopolistic producers can still exercise market power by reducing the proportion of baseload technology plants in their generation portfolios below the welfare-maximizing level. Predictably, in Latin American countries dissatisfaction with price regulation triggered a new reform wave. Its central feature is the obligation imposed on distribution companies to auction long-term contracts for delivery a few years ahead to cover their clients' present and future consumptions (Moreno et al., 2009; Barroso et al., 2007). The crucial change in this reform wave was this idea of auctioning future delivery in order to leave incumbent generators and newcomers enough time to build new plants.

In 2004 Brazil established a centralized mechanism run by the regulator to auction long-term contracts to supply regulated customers. Contracts could be for delivery one year ahead and last between 5 and 15 years ("existing energy contracts"), or for delivery 3–5 years ahead and last from 15 to 30 years ("new entry contracts").[4] Similarly, since 2005, Chilean distribution companies must bid out their projected demand at least three years in advance. The first auction took place in 2006 for delivery starting in 2010. Peru, in 2006, adopted the Chilean decentralized approach, but after a few unsuccessful auctions, in 2008 turned to the Brazilian scheme. In December 2006, Colombia replaced the existing capacity payment with call options called "firm energy obligations", which are auctioned in a centralized process.

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[2] More precisely distribution companies contracted energy with generators on behalf of regulated consumers and passed the price through plus a mark-up for their services (distribution value added) and transmission costs. Regulators, however, set a cap on this pass-though based on the marginal cost of energy that usually was binding.

[3] The probable cause for excluding small customers from the contract market is the widespread belief that they are no match for generators' market power and that transaction costs are high.

[4] These contracts may be of two types: "main auction contracts" are awarded five years before energy is required, while "complementary auction contracts" are awarded three years in advance.

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doi:10.1016/j.enpol.2009.11.050

These recent policy changes pose a number of relevant questions. Does auctioning of forward contracts allowing building time reduce market power? How do the contract and the short-term energy markets interact? What is the expected effect on regulated and non-regulated consumers of the latest reform wave in Latin American countries? Our purpose is to provide a formal answer to these questions. We do so in a two-firm, two-technology (baseload and peaking), linear-cost, static power generation model.[5] The baseload technology has lower unit operating costs but higher unit investment costs. Additionally, for simplicity we assume that plants are always available to produce at full capacity, i.e., we leave aside intermittent technologies such as wind farms and small hydro.

Demand, in turn, is summarized by a load curve that is assumed to be price inelastic. We model a load curve to take into consideration the non-storability of energy and the high variability of demand, but assume price inelasticity to keep the problem simple. An exogenously fixed proportion of the load curve is contracted in advance in a competitive auction. The firm that bids the lowest energy price is awarded the entire forward contract, creating a prisoner's dilemma for generators. If both firms submit the same price bid, they either share the contract or draw lots to decide who supplies the entire contract. Without loss of generality, we assume that they draw lots. We further assume that contracts are enforceable.

Thus the game has 3 stages: once the forward contract is awarded (Stage 1), generators make their investment decisions concerning the capacity and composition of their generating portfolios (Stage 2). We assume that each firm chooses its generating portfolio taking its rival's capacity as given. Finally, an independent operator manages the system dispatching plants in strict merit order without regard to existing supply contracts (Stage 3). Dispatch is mandatory and the spot price corresponds to the system's marginal cost, i.e., the variable cost of the plant unit with the highest operational cost being dispatched. Consumers who do not contract energy in advance, purchase energy at the spot price which is also used by generators to trade energy. Thus the spot price is the clearing price in the short-term energy market. Firms and clients are assumed to have perfect foresight. The equilibrium of the game is derived by backwards induction.

We have made some idiosyncratic assumptions that reflect market conditions prevalent in Latin American countries. First, dispatch is cost based and not based on short-term auctions as in most developed countries. Second, the proportion of the whole demand auctioned ahead of the spot market is set exogenously. Third, we assume that generators make their investment decisions after contracts are awarded.

Our purpose is to analyze the impact recent reforms in Latin America that made auctioning of supply contracts mandatory for distribution companies will have in the electricity market of those countries. Hence the amount of forward contracting is exogenous given that it corresponds to the demand of small consumers supplied by distributions companies. The contract market has always been open to large clients, and some of them auction their supply needs. Omitting auctions by large customers would underestimate benefits from recent reforms but not alter the sign of results, as our analysis will show.

We also assume that forward contracts are auctioned in one chunk, as in Brazil and, since recently, Peru, where the regulators aggregate demands of all distribution companies. Results, however, would not change if forward contracts were sold in several individual auctions providing that these were awarded simultaneously. Uncoordinated auctions by different distribution companies would probably reduce the benefits of forward contracting, but this case is not dealt with in this paper.

The third assumption—investment decisions taken after the contract is awarded—is crucial. In our model, market power is exercised through investment decisions given that spot prices are regulated. Thus, if the auction were carried out after investment decisions had been taken, there would be no effect on prices. We believe that this assumption echoes new regulations recently introduced by Latin American countries. Indeed, the idea behind recent policy reforms is to allow for potential newcomers to participate in the auction, increasing competition in this way.

Brazil requires long-term contracts for new capacity to enter into operation in five years time, while Chilean regulations oblige distribution companies to contract energy supply at least three years ahead of the date delivery starts. Colombia auctions the call options at least three years before the energy will be required.[6] Rapid expansion of electricity demand in those countries requires installed generation capacity to increase by about 20% every three years. Hence, bidders' offers will consider existing capacity as well as new capacity they could build once the contract is awarded. Thus, our assumption implies that existing generators would have enough time to make the required adjustment in their generating portfolios and newcomers to install.

In this context we show that the auction of forward long-term contracts lowers the average spot price. The intuition is simple: the generator that wins the bid for the forward contract has an incentive to reduce his energy costs. For that reason he invests more in baseload capacity compared to the case with no contract, reducing the average marginal cost of energy and, therefore, the average spot price of energy. Moreover, the larger the proportion of the total demand contracted, the greater is the reduction in the average spot price. In turn, the reduction in the average spot price of energy leads generators to bid lower prices in the auction for the forward contract. In sum, the larger the proportion of load auctioned, the lower are both the contract energy price and the average spot price of energy. We also show that the contract price is below the average spot price of energy.

These results suggest that auctions should be promoted in these markets. In addition, since in the context of marginal cost pricing, market power is exercised by distorting the choice of the generating technology, our results remark the importance of carrying the auctions out with enough time to allow for new capacity to be built.

Our results are analogous to those reported in a pioneering paper by Allaz and Vila (1993) for a different set of conditions which include an elastic point focal demand, an unregulated spot market, and an atomistic energy demand. Liski and Montero (2006), however, find that voluntary forward contracting need not lead to more competitive outcomes when agents interact repeatedly. Collusive agreements in repeated games may be supported by punishment strategies that are triggered when one of the players deviates from the agreement. In this context, they show that the endogenously determined amount of forward contracting is always such that the contracting has a pro-collusive effect. Finally, Green and Le Coq (2006), who assume price competition in the spot market and fixed proportion of forward

[5] We omit transmission and distribution activities as these are regulated natural monopolies.

[6] There is also evidence that large clients auction their energy supply with enough lead time to allow bidders to build new capacity. Indeed, two Chilean mining companies (Codelco and BHP Billiton) have recently auctioned their new energy supply contracts four and six years, respectively, in advance of the starting delivery date.

contracting, show that the longer the contracts last, the more difficult it is to sustain collusion because the greater the reduction of the punishment triggered by defection.

The paper is organized as follows. The next section summarizes marginal cost pricing without contracts. The equilibrium with forward contract is derived in section 3. The final section concludes.

2. Marginal cost pricing without contracts

We assume a two-technology, linear-cost generating industry. Total baseload installed capacity will be denoted by k. Without loss of generality we set the operating cost at zero for the baseload technology and the capacity cost at zero for the peaking technology. Thus, in what follows c denotes the unit operating cost for the peaking technology and f the unit capacity cost for the baseload technology. Demand is assumed to be inelastic and is summarized in a continuously differentiable load curve $q(\ )$ defined in $[0, T]$. Thus, $q(\tau)$ designates consumption at the τth highest consumption hour and T the number of hours in the period under consideration. Additionally, we assume that plants are always available to produce at full capacity and can adjust their production level instantaneously and without costs.

Given our assumption of an inelastic demand, maximizing welfare is equivalent to minimizing the total cost of the power system. Let $t(\ )$ denote the inverse of function $q(\ )$ defined in $[0, q^m]$, where q^m denotes the maximum demand ($q(0)$). Then, this problem may be formalized as follows[7]:

$$\begin{aligned} &\mathrm{Min}_k\ fk+c\int_0^{t(k)}(q(\tau)\text{-}k)d\tau \\ &\quad \text{s.t.}: q^m \geq k \geq 0 \end{aligned} \tag{1}$$

The formulation of the cost minimization problem already assumes an optimal use of installed capacity as peaking plants are dispatched only when baseload plants operate at full capacity. In fact, between hours $t(k)$ and T, demand is met by baseload plants only, since installed capacity renders it feasible and it is costless. Between hours 0 and $t(k)$, peaking plants generate the demand unmet by baseload plants. Thus, $t(k)$ represents the number of hours in which peaking technology plants operate setting the marginal cost.

The generation portfolio that minimizes the total cost of the system, is such that peaking technology plants operate τ^* hours, where $\tau^*=\mathrm{Min}(f/c, T)$. Thus, the optimal baseload capacity is given by $k^*=q(\tau^*)$. When $f/c > T$, only peaking plants are installed given that the baseload technology is inefficient. In what follows we assume that $f/c < T$.

Given this set of assumptions, marginal cost pricing consists of an instantaneous energy charge equal to the per unit operating cost of the plant with highest operating cost being dispatched at any moment, i.e., c between hours 0 and $t(k)$, and 0 the remaining hours.[8] Merit order dispatch along with marginal cost pricing leads a decentralized fully competitive system to the optimal equilibrium.

2.1. Cournot duopoly

Now assume that there are only two generation companies that behave as Cournot competitors. Peaking plants always have zero profits given that they receive an energy price equal to their unit operating cost.[9] We assume that either regulation or self-regulation obliges firms to have enough capacity to supply peak-demand.[10] Thus, the generators' optimization variable is the share of baseload plants in their portfolios. Each generation company chooses its baseload installed capacity considering its rival's baseload installed capacity as given. Hence, assuming mandatory merit order dispatch, the profit maximization problem of firm i is

$$\mathrm{Max}_{k_i}\, ck_i t(k)\text{-}fk_i \tag{2}$$

where k_i denotes the choice of baseload installed capacity by firm i, and, as before, k denotes the system's baseload total installed capacity. Assuming an interior solution, each generation company's first-order condition is

$$t(k)+t'(k)k_i=\tau^* \tag{3}$$

The second order condition for each firm's profit maximization problem is $2t'(k)+kt''(k)<0$. In what follows, we assume that this condition holds.[11] Thus, the system's equilibrium baseload capacity for the Cournot duopoly k^c is solution to

$$t(k)+\frac{1}{2}t'(k)k=\tau^* \tag{4}$$

Recalling that $t(k^*)=\tau^*$, the above condition implies that $k^c<k^*$ and $\tau^c>\tau^*$ where $\tau^c=t(k^c)$. Cournot competition results in peaking plants setting the price of energy for a longer period of time and, therefore, in a higher average spot price, compared to the welfare-maximizing solution.

3. Equilibrium with auctions of long-term forward contracts

To study the effect of the contract market in the spot market we assume that a share $\alpha\in[0,1]$ of the load curve is auctioned in advance. The generator who offers the lower energy price supplies the entire contract.[12] Once the contract is awarded, producers make their investment decisions, i.e., they choose the installed capacity of each type of technology. Finally, an independent operator dispatches plants in strict merit order independently of each firm's position in the contract market. Marginal cost pricing is used to set prices for small customers as well as for transactions between generators. Therefore the game has three stages:

Stage 1: Firms compete in the contract market where a share α of the load curve is sold.

Stage 2: Firms make their investment decisions.

Stage 3: An independent operator dispatches plants by merit order. Spot energy and capacity prices are set according to marginal cost pricing. Firms sell energy in the spot market.

The equilibrium of this game is derived by backwards induction. Although k_i and k depend on α, it will be sometimes omitted to keep notation simple.

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[7] Since the capacity cost of the peaking technology is zero, there is no need to specify it in the model. Moreover, installed capacity equals maximum demand given that the unit capacity cost of the peaking technology is zero and, as it is later shown, the energy price equals its unit operating cost.

[8] Marginal cost pricing would require a capacity charge equal to the per unit capacity cost of the peaking technology if the latter differed from zero, resulting in the standard peak-load pricing scheme (for a survey on peak load pricing see Crew et al., 1995). The capacity charge applies to consumption at the hour of maximum demand.

[9] If the per unit capacity cost of the peaking technology were strictly positive, the capacity charge in footnote 8 would maintain the zero-profit state of peaking plants.

[10] Alternatively we could assume free entry to peaking technology generation.

[11] A sufficient (but not necessary) condition for $2t'(k)+kt''(k)<0$ is the strict concavity of the load curve $q(\ )$.

[12] If capacity cost of the peaking technology were positive, marginal cost pricing would require including a capacity payment both for contract and spot transactions. In Chile the winner of the contract receives the capacity payment for the energy supplied at the hour of maximum demand.

3.1. Stage 3's solution (spot market equilibrium)

Given the composition of the system's generation portfolio (k_1 and k_2), the system's operation cost is minimized when peaking plants are dispatched only between hours 0 and $t(k)$ to generate the demand unmet by baseload plants.

Hence the spot unit price of energy is c for $0 \le \tau \le t(k)$, and 0 for $t(k) \le \tau \le T$.

3.2. Stage 2's solution (investment decision)

We assume Cournot competition, thus, each firm chooses its baseload installed capacity, taking its rival's capacity as given. Let Firm 1 be the one that is awarded the long-term supply contract. Hence, its profit function π_1 has two components: profits in the spot market, π_1^S and profits from the contract deal, π_1^C. The latter may be calculated as if Firm 1 sold energy in the contract market and later purchased it in the spot market. Let p^c denote the contract price, then

$$\pi_1^S = -fk_1 + ck_1 t(k) \tag{5}$$

$$\pi_1^C = p^c\alpha \int_0^T q(\tau)d\tau - c\alpha \int_0^{t(k)} q(\tau)d\tau \tag{6}$$

$$= (p^c - c)\alpha \int_0^{t(k)} q(\tau)d\tau + p^c\alpha \int_{t(k)}^T q(\tau)d\tau \tag{7}$$

$$\pi_1 = -fk_1 + ck_1 t(k) + (p^c - c)\alpha \int_0^{t(k)} q(\tau)d\tau + p^c\alpha \int_0^{t(k)} q(\tau)d\tau \tag{8}$$

Notice that π_1^C increases with the difference between the contract price and the average spot price. In turn, the average spot price increases with the time peaking plants operate.

Since Firm 2 can only sell its production in the spot market, its profit function is given by

$$\pi_2 = -fk_2 + ck_2 t(k) \tag{9}$$

Assuming an interior solution, Firm 1's FOC is given by

$$-f + c[t(k) + k_1 t'(k)] - c\alpha k t'(k) = 0 \tag{10}$$

and Firm 2's FOC is

$$-f + c[t(k) + k_2 t'(k)] = 0 \tag{11}$$

These FOCs may be written as

$$t(k) + [k_1 - \alpha k]t'(k) = \tau^* \tag{12}$$

$$t(k) + k_2 t'(k) = \tau^* \tag{13}$$

Notice that the only difference between equations (12) and (13) is the term $-\alpha k t'(k)$, which is the gain that Firm 1 gets from the contract with a marginal increase in the system's baseload capacity.[13] This term is positive because, given k_2, the more Firm 1 invests in baseload capacity, the larger is the system's baseload installed capacity and, consequently, the lower is the average energy price in the spot market. This in turn entails a lower cost for the energy Firm 1 sells in the contract auction at price p^c.

Recalling that $k = k_1 + k_2$,

$$\frac{k_1}{k} = \frac{1+\alpha}{2}; \frac{k_2}{k} = \frac{1-\alpha}{2} \tag{14}$$

Notice that with no contracts (α=0), then $k_1 = k_2$. On the other hand, when the entire load curve is auctioned (α=1), then only Firm 1 invests in baseload technology. If $0 < \alpha < 1$, then $k_1 > k_2$. Firm 1 has more incentives to invest in baseload technology as it results in lower cost for the energy sold in the auction. The larger is α, the greater is this effect.

From (12), (13) and (14), we can derive k:

$$t(k) + \frac{1-\alpha}{2} k t'(k) = \tau^* \tag{15}$$

Observe that when α=1, $t(k) = \tau^*$ and $k = k^*$, resulting in the competitive solution, a well known result for non-regulated markets. On the other hand, when α=0, $t(k) = \tau^c$, where τ^c is the Cournot solution with no contracts. Moreover,

$$\frac{dk}{d\alpha} = \frac{kt'(k)}{(3-\alpha)t'(k) + (1-\alpha)kt''(k)} \tag{16}$$

The condition $2t'(k) + kt''(k) < 0$ ensures that the baseload capacity increases with α and that $\tau^c \ge t(k) \ge \tau^*$. Replacing k_i in (5) and (9), we get that

$$\pi_1^S = \frac{1+\alpha}{2} ck\left[t(k) - \tau^*\right] \tag{17}$$

$$\pi_2 = \frac{1-\alpha}{2} ck\left[\text{t(k)} - \tau^*\right] \tag{18}$$

Furthermore

$$\frac{\partial \pi_2}{\partial \alpha} = -\frac{ck(\alpha)}{2}\left[t(k(\alpha)) - \tau^*\right] + \frac{1-\alpha}{2} c\left[k'(\alpha)\left[t(k(\alpha)) - \tau^*\right] + k(\alpha)t'(k(\alpha))\right]\frac{\partial k}{\partial \alpha} \tag{19}$$

Using the FOC leads to

$$\frac{\partial \pi_2}{\partial \alpha} = -\frac{ck(\alpha)}{2}\left[t(k(\alpha)) - \tau^*\right] + \frac{1-\alpha}{2} ck(\alpha)t'(k(\alpha))\frac{\partial k}{\partial \alpha} < 0 \tag{20}$$

Hence, profits of the firm without the forward contract diminish with the proportion of the total demand that is awarded in the contract auction. In fact, Firm 2's profits fall because (i) forward contracting moves the total baseload capacity away from its Cournot equilibrium with no contracts and (ii) the firm's share in the total baseload installed capacity is less.

3.3. Stage 1's solution (contract market equilibrium)

Firms compete to supply the long-term contract, thus π_1 should be equal to π_2 as profits are equalized and therefore

$$\pi_1^C = \pi_2 - \pi_1^S = -\alpha ck[t(k) - \tau^*] < 0 \tag{21}$$

Firm 1 is willing to bear losses in its forward contract in exchange for higher profits in the spot market, which explains why $\pi_1^C < 0$. From (7) and (21)

$$p^c = \frac{c\int_0^{t(k)} q(\tau)d\tau}{Q} - \frac{ck[t(k) - \tau^*]}{Q} \tag{22}$$

where Q denotes total demand ($Q = \int_0^T q(\tau)d\tau$). The first expression on the right-hand side of Eq. (22) corresponds to the average spot price of energy, and will be called p^r. Differentiating p^r with respect to α leads to

$$\frac{\partial p^r}{\partial \alpha} = \frac{ct'(k(\alpha))k(\alpha)}{Q}\frac{\partial k}{\partial \alpha} < 0 \tag{23}$$

Hence, the average spot price decreases with α. This is a direct corollary from our finding that the baseload capacity is an increasing function of α. Moreover, from (22) also follows that the contract price is less than the average spot price. Let ψ denote the price reduction that benefits energy contracts, i.e., $\psi = p^r - p^c$. Thus $\psi = ck[t(k) - \tau^*]/Q$ and

$$\frac{\partial \psi}{\partial \alpha} = \frac{c[t(k(\alpha)) - \tau^*] + k(\alpha)t'(k(\alpha))]}{Q}\frac{\partial k}{\partial \alpha} = \frac{ck_1(\alpha)t'(k(\alpha))}{Q}\frac{\partial k}{\partial \alpha} < 0 \tag{24}$$

Thus, the reduction benefiting the energy contract price decreases with α. However, the contract price falls with α as the

[13] Note that Firm 2's FOC (Eq. 13) is the same as (3).

decrease in p^r outweighs the reduction in ψ. In fact,

$$\frac{\partial p^c}{\partial \alpha} = \frac{ck_2(\alpha)t'(k(\alpha))}{Q}\frac{\partial k}{\partial \alpha} < 0 \qquad (25)$$

4. Final comments

This work develops a simple model to study the implications of auctioning long-term contracts of energy when dispatch is cost-based, investment decisions are taken after the contract is awarded, and spot prices are set according to marginal cost pricing. The main result of this paper is that the larger the proportion of total demand covered by forward contracts, the lower are both the spot price and the contract price. Thus, the expansion of the contract market benefits those consumers that contract energy in advance as well as those consumers that purchase it in the spot market, but the latter at a lesser rate. In this regard, it is clear that the latest reform wave in Latin America is a sensible one.

Thus, in general, policy makers should promote auctions of forward contracts. In principle, it would be optimal to open forward contracting to all consumers. However, generators would shun small clients' auctions as they have no market power. Hence, besides the demand via auctions by large clients, an atomistic demand for forward contracts from small clients would arise. With an endogenously determined amount of forward contracting by small clients and contracts disentangled from physical delivery, a possibility that a priori cannot be discarded is that generators buy forwards in order to sustain collusion.

Hence, requiring retailers to auction the energy supply of their clients is a better solution. If distribution and retail supply were vertically integrated, then distributors would be required to pass through the contract price to their clients plus a regulated mark-up for their services (distribution value added) and transmission costs. If both activities were separated, competition among retailers should ensure the pass-through of contract energy prices to final consumers plus a mark-up for transmission, distribution and retail services.

Design features play an important role in market's outcome. Simultaneous auctioning by all consumers is required to achieve maximum market power mitigation. If forward supply contracts are not awarded simultaneously, collusive equilibria are more likely to appear and therefore we can expect a lesser market power mitigation effect from forward contract auctioning. The Peruvian experience, moving from a decentralized to a centralized auction process, bears witness to this point. Thus, regulation should require retail-suppliers to coordinate their auctions as in Brazil. Furthermore, it should ask for long-standing contracts, in conformity with Green and Le Coq's findings. A final recommendation would be to auction with enough anticipation to allow for new investors to bid, thereby increasing competition.

We have made some crucial assumptions that we intend to surmount in future works. First, we expect to model a price elastic demand but maintaining the critical assumption of a time varying demand that must be satisfied instantaneously. Second, we aim to formalize the entry barriers that give reason for modeling an oligopolistic market. Third, we intend to model repeated interaction in both markets, as it could facilitate collusion. But, as Liski and Montero (2006) point out, if firms are required by some regulatory authority to contract a substantial amount of forward sales, the pro-competitive effect of forward contracting can prevail over the pro-collusion effect. Fourth, we plan to expand the model to consider that a given percentage of generating capacity is installed before the long-term contract is awarded.

Acknowledgements

The authors acknowledge financial support from Fondecyt (Project # 1080395). Comments by two anonymous referees are gratefully acknowledged. We also thank our student Claudio Tabilo who worked during the earlier stages of this research. Earlier versions of this paper were presented at the 2009 International Industrial Organization Conference and the 2009 IAEE European Conference.

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