Long-Term Supply Contracts and Collusion in the Electricity Market*

Chloé Le Coq†
SSE/EFI Working Paper Series in Economics and Finance
No 552

First draft: May 2003
This draft: February 2004

Abstract

It has been argued that having a contract market before the spot market enhances competition (Allaz and Vila, 1993). Taking into account the repeated nature of electricity markets, we check the robustness of the argument that the access to contract markets reduces the market power of generators. In particular, we investigate the sensitivity of this result with respect to the finite horizon assumption. This paper proposes a model of the electricity market where firms sign long-term supply contracts with their retailers. Subsequently, the firms repeatedly interact on the spot market. It is shown that contract markets help sustain collusion on the spot market.

Key words: Contract market, Electricity, Spot Market, Forward, Tacit collusion.

JEL code: C72, D43,G13, L13, L94

*I am very grateful to Tore Ellingsen, Lars Bergman, Dan Kovenock, and Maria Saez-Marti for helpful comments. All errors are mine. I would like to thank also the National Swedish Energy Administration for financial support.

†Department of Economics, Stockholm School of Economics, Box 6501, SE-113 83 Stockholm. E-mail: Chloe.LeCoq@hhs.se.

1 Introduction

For many commodities, there are essentially two ways of selling the good; either firms sell it through long-term contracts, or they sell it on the spot (day-ahead) market. Some formal arguments support the view that firms may have less incentive to exercise market power, if they have large contract positions (Allaz and Vila, 1993, among others). Intuitively, a firm may obtain a leadership position by selling contracts before going on the spot market. Motivated by this opportunity, all players participate in the contract market and as a consequence compete more aggressively overall. Access to contract markets prior to the spot market may thus decrease the market price.

In the process of redesigning domestic electricity markets, many countries have in fact decided to facilitate the access to contract markets. In March 2001, the New Electricity Trading Arrangements (NETA), which allow bilateral contracts between producers and retail companies, were introduced in England and Wales (Ofgem, 1999). Following the energy crisis in the State of California during the summer of 2000, the Market Surveillance Committee (MSC) recommended an unrestricted ability for utility distribution companies to contract. According to the MSC, such a measure would limit the ability of generators to exercise market power (MSC, 2000, p.15). Regulators thus seem to believe that the market power of generators would be reduced by an enhanced opportunity for firms to contract and several authors have confirmed this result for the wholesale electricity market (von der Fehr and Harbord, 1992; Powell, 1993; Newbery, 1998; Green, 1999; Wolak, 2000).

A central feature of the analysis of Allaz and Vila is based on a framework with a finite horizon. As a result, the access to a contract market gives rise to a situation reminiscent of the prisoners' dilemma; each producer has an incentive to offer a contract, but when all producers do so, everyone is worse off. The repeated nature of many markets (in particular for electricity markets) raises the question of whether this result is applicable to that market (Borestein and Bushnell, 1999 or Harvey and Hogan, 2000).[1]

[1] Electricity prices have decreased in England since 2001, that is, after the introduction of NETA. The empirical study of Bower (2002) suggests, however, that the price reduction

The purpose of this paper is to check the robustness of the argument that access to contract markets reduces the market power of generators. In particular, it investigates the sensitivity of this result with respect to the assumption of a finite horizon. We consider a model where two firms initially offer a long-term supply contract before repeatedly interacting on the spot market by choosing prices. Both firms offer retailers the opportunity to sign a contract, which stipulates a quantity of electricity to be bought in every future period at a ceiling spot price. That is, in every period, the retailers commit to buy the contracted quantity at the prevailing spot market price, unless this price is higher than a threshold level specified in the contract; if so, the retailers buy the contracted quantity at a price equal to the threshold level.[2]

In this setup, firms enforce price collusion even though they have signed contracts stipulating that they will supply large amounts of electricity in the future. In fact, the contract market enables collusion on the spot market when firms would compete in the absence of such a market. The reason is twofold. First, the incentives to deviate are smaller than in classical repeated price games. Indeed, a firm undercutting the monopoly price will earn less than the monopoly profits during the deviation phase, since the rival firm still sells the quantity stipulated in its long-term contract. Second, firms' ability to punish deviators is not reduced relative to classical repeated price games. This is due to the ceiling spot price which implies that the contracted quantities will be sold at the spot market price, if sufficiently low. By pricing at marginal cost on the spot market, a firm thus ensures that its rival earns profits equal to zero in the punishment phase.

The above result is related to the work by Schnitzer (1994) who considers a finitely repeated price game with best-price clauses. She shows that sellers can sustain monopoly profits with a meet or release (MOR) clause, that is a clause according to which the seller promises a rebate to its customers if the

was due to changes in market structure rather than increased contracting opportunities.

[2] Such a contract is commonly used in many electricity markets between generators and retailers or between generators and big industrial consumers, mainly as an insurance against events such as high spot prices. It is called "Rate Cap Contract" in the Alberta market, "Vesting contract" in the Australian NSW market or "Physical One-way Contract-for-difference" in the UK market.

purchase price is undercut by competing sellers in the future. The mechanism driving this result is different from the mechanism in the present paper due to the assumption that consumers are strategic. If one seller deviates by undercutting the monopoly price, it triggers a price war in the following period. Anticipating the price war, all consumers buy from the seller offering the MOR clause, since this clause guarantees them a rebate in the future due to the price war. In turn, the initial deviation becomes unprofitable. The analysis in the present paper differs from that by Schnitzer in several respects. First, we consider a game with an infinite horizon and analyze equilibria sustained by irreversible punishments (trigger strategies). Second, we analyze contracts that constituting a combination of the MOR clause and a most favored customer clause.[3] Third, consumers are non-strategic.

A few other papers have analyzed the interaction between contract and spot markets in a dynamic setup. A common feature of these studies is that the contract market is infinitely repeated, while the spot market takes place in one period only. Anderson and Brianza (1991) show that firms are able to sustain collusion if they take long positions and corner the market of their opponents. In effect, each firm nominally commits itself to purchase the whole of its rival's output in each contract period. This result is also valid in a model of a price-setting duopoly with differentiated products (Mahenc and Salanié, 2002). In contrast, we consider a setup where the contract is offered once while the spot market is infinitely repeated. This model can be viewed as a version of a repeated game with capacity constraints (Benoit and Krishna, 1987, Davidson and Deneckere, 1990 or Fabra, 2003). Unlike the case with capacity constraints, the contracted quantity must, however, be fulfilled in each spot period.

The paper is organized as follows. Section 2 presents the model. Section 3 solves for equilibria in the repeated price game, taking contracted quantities as given, and Section 4 analyzes the contracting stage. The paper ends with some concluding remarks.

[3]The most favored customer clause stipulates that buyers are offered a rebate if a seller undercuts its own price in the future. Schnitzer (1994) shows that such a clause is insufficient to enable firms to collude on the monopoly price.

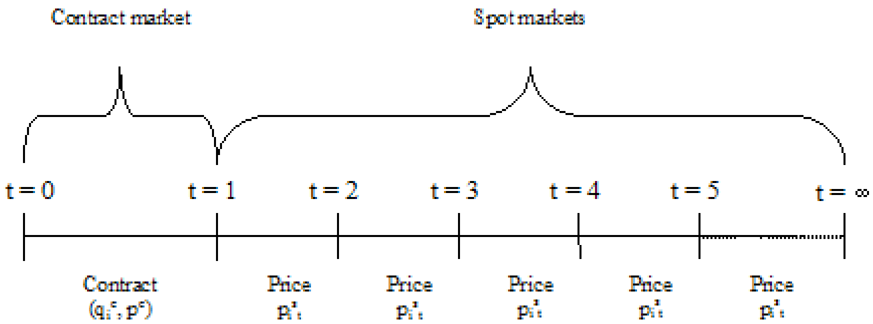

Figure 1: The timing of the game

2 The model

Consider two firms (generators), 1 and 2, who produce an homogeneous good (electricity) with identical constant marginal costs c and no capacity constraints. They sell the good to retailers on two successive wholesale markets, namely a contract market (taking place in period $t = 0$) and an infinitely repeated spot market (taking place in all periods $t = 1, 2, 3, ...$). We consider n regional retailers, which, at the national level, have relatively small market shares. For this reason, retailers are assumed to be price takers, i.e. to be non-strategic players. In each period $t \geq 1$, the demand of each retailer is given by $D(p)$, which is a decreasing and continuous function of the price p. Aggregate profits in each regional market are given by $\pi(p) \equiv (p - c) D(p)$ and are assumed to be single peaked with an unique maximum at $p^M \equiv \arg\max_p \pi(p)$. To eliminate the variable n from the analysis, the total demand facing the firms is summarized by the demand $D(p)$ of a single representative retailer.

The timing of the game is illustrated in Figure 1. The spot market takes place in all periods $t \geq 1$. In this market, the firms repeatedly compete for sales of short duration. More precisely, each firm i $(i = 1, 2)$ posts a price p_{it}^s in each period $t \geq 1$. As a result, the spot price prevailing in period t is determined as $p_t^s \equiv \min\{p_{1t}^s, p_{2t}^s\}$. (Henceforth, the superscript s stands for spot market.)

In period $t = 0$, the contract market opens and the generators simultaneously propose a binding and observable long term supply contract to the retailers. A supply contract between firm i ($i = 1, 2$) and a retailer specifies a pair (q_i^c, p_i^c), whereby the retailer commits to buy and firm i commits to supply the fixed quantity q_i^c in every subsequent period $t \geq 1$. The price p_i^c constitutes a ceiling spot price whereby the retailer, in each period t, pays the spot price p_t^s for the quantity q_i^c; if $p_t^s > p_i^c$, the generator, however, compensates the retailer for the difference $p_t^s - p_i^c$. (Henceforth, the superscript c stands for contract market.)

The analysis will focus on collusive equilibria such that the firms offer the same ceiling spot price, that is equilibria such that $p_1^c = p_2^c = p^c$. We assume that a retailer is willing to sign two contracts (q_1^c, p^c) and (q_2^c, p^c) as long as $q_1^c + q_2^c \leq D(p^c)$.[4] In fact, we will focus on equilibrium contracts such that $q_1^c + q_2^c = D(p^c)$.

Stage-games: A stage-game consists of a single spot market period where each firm i is already committed to the contract (q_i^c, p^c). Its outcome is illustrated in Figure 2, assuming that $p_t^s \leq p^c$. $D(p_t^s)$ is the total quantity sold given the spot price p_t^s. In addition of the contracted quantities $q_1^c + q_2^c = Q^c$, the firms thus supply $Q_t^s = D(p_t^s) - Q^c$ in period t, that is the residual demand evaluated at p_t^s. For this residual demand, firms compete in prices and retailers buy from the cheaper supplier.

In each stage game a firm earns profits, which are decomposed in two parts, namely the profits derived from the contracted quantity q_i^c and the additional profits derived from the residual demand. These profits depend on the contract positions $((q_1^c, p^c), (q_2^c, p^c))$ and on the pair of prices (p_{1t}^s, p_{2t}^s) chosen by the firms in period t. Below, we provide expressions for these profits assuming that $\max\{p_{1t}^s, p_{2t}^s\} \leq p^c$. Our focus will be on equilibria in the repeated spot market, which satisfy this inequality. Subsequently, we will check that the firms do not have an incentive to deviate from the proposed equilibrium by choosing a price in period t which exceeds p^c.

Consider the profits earned by firm i in a single stage game, that is the sum of the profits derived from the contracted quantity and the residual demand. If $p_{it}^s = p_{jt}^s \leq p^c$ (where $i, j = 1, 2$ and $j \neq i$), firm i shares the

[4]Both generators and retailers are assumed to be risk neutral and hence, there are no risk sharing benefits in signing long-term contracts.

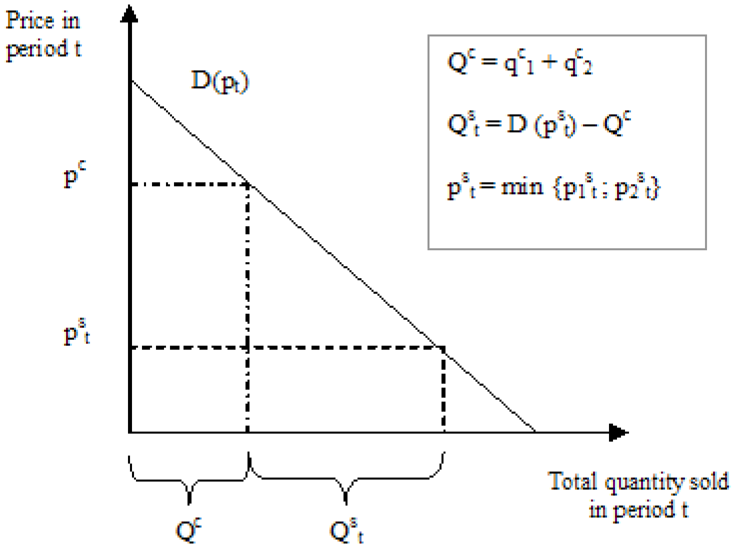

Figure 2: An outcome in a spot-market period

residual demand on the spot market with firm j. Firm i's stage game profits are then given by

$$\begin{aligned}\pi_{it} &= (p^s_{it} - c)\, q^c_i + \tfrac{1}{2}(p^s_{it} - c)\left(D(p^s_{it}) - q^c_i - q^c_j\right) \\ &= \tfrac{1}{2}\left[\pi(p^s_{it}) + (p^s_{it} - c)\left(q^c_i - q^c_j\right)\right]\end{aligned} \qquad \text{if } p^s_{it} = p^s_{jt} \le p^c. \quad (1)$$

If instead $p^s_{it} < p^s_{jt} \le p^c$, firm i supplies all the residual demand in addition of its contracted quantity. Its stage game profits are then given by

$$\begin{aligned}\pi_{it} &= (p^s_{it} - c)\, q^c_i + (p^s_{it} - c)\left(D(p^s_{it}) - q^c_i - q^c_j\right) \\ &= \pi(p^s_{it}) - (p^s_{it} - c)\, q^c_j\end{aligned} \qquad \text{if } p^s_{it} < p^s_{jt} \le p^c. \quad (2)$$

Finally, if $p^s_{jt} < p^s_{it} \le p^c$, firm i only sells its contracted quantity q^c_i. Its stage game profits are then given by

$$\begin{aligned}\pi_{it} &= \left(p^s_{jt} - c\right) q^c_i \\ &= \pi\left(p^s_{jt}\right) - \left(p^s_{jt} - c\right)\left(D\left(p^s_{jt}\right) - q^c_i\right)\end{aligned} \qquad \text{if } p^s_{jt} < p^s_{it} \le p^c. \quad (3)$$

Unlike the traditional repeated Bertrand game, the firm posting the highest price thus earns strictly positive profits as long as $q^c_i > 0$ and $p^s_{jt} > c$. Note also that in equations (1)-(3), the contracted quantity q^c_i is sold for the spot price $p_t^s = \min\{p_{1t}^s, p_{2t}^s\}$ rather than for the ceiling spot price p^c. This is due to the definition of the ceiling spot price and to the fact that in equations (1)-(3), it is assumed that $\max\{p_{1t}^s, p_{2t}^s\} \leq p^c$.

Trigger strategies: We restrict our attention to stationary collusive agreements supported by trigger strategies, that is, firms remain at the collusive price unless someone cheats.[5] If at any point time anyone is detected cheating, players revert to the static Nash equilibrium and remain there forever (Friedman, 1971). This greatly simplifies the analysis as well as the exposition and does not restrict the scope of the results.[6] Let π_i^N denote firm i's per period profits on the spot market when the firms post the one period Nash equilibrium price vector $p^N = \left(p_i^N, p_j^N\right)$. Let π_i^A denote firm i's static payoff when the firms stick to the stationary tacit agreement A, that is when the firms post the collusive price vector $p^A = \left(p_i^A, p_j^A\right)$. Let π_i^D denote firms i's static payoff from unilaterally deviating from A by setting the static best response price $p_i^D\left(p_j^A\right)$.

Given the common discount factor δ and using the one-stage deviation principle for infinite-horizon games (Fudenberg and Tirole, 1991, p.110), a collusive agreement A is sustainable as a subgame-perfect equilibrium as long as neither firm has an incentive to defect unilaterally from the collusive agreement. For firm i, this condition is equivalent to

$$\frac{\pi_i^A}{1-\delta} \geq \pi_i^D + \frac{\delta}{1-\delta}\pi_i^N.$$

This inequality can be rewritten in terms of the minimum level of the discount factor, $\underline{\delta}_i$, such that firm i has no incentive to deviate from the agreement A, that is,

$$\delta \geq \underline{\delta}_i \equiv \frac{\pi_i^D - \pi_i^A}{\pi_i^D - \pi_i^N}. \tag{4}$$

The agreement A is sustainable if, and only if, neither firm has an incentive to deviate, that is if, and only if, $\delta \geq \underline{\delta} \equiv \max\{\underline{\delta}_1, \underline{\delta}_2\}$.

[5] I assume that renegociation and side payment are not possible.

[6] Exactly as in a repeated Bertrand competition, unrelenting trigger strategies are "optimal punishments" in our setting, since the players are at their security levels. Expressed differently, no complex punishment mechanism can enlarge the set of supportable equlibria (Abreu, 1986).

3 Equilibrium in the repeated spot markets

Throughout this section, we take the contract positions $((q_1^c, p^c), (q_2^c, p^c))$ as given and analyze collusive equilibria in the repeated spot market. As a preliminary, we introduce a benchmark, namely the case when no contract market is available or, equivalently, when contracted quantities are equal to 0. This case corresponds to the classical repeated (Bertrand) price game. The purpose is to define the minimum discount factor $\underline{\delta}^B$ at which the firms can sustain collusion in the absence of a contract market. (Henceforth, the superscript B stands for the Bertrand case.)

Benchmark (Repeated spot market without a contract market): Assume that the firms are able to sustain a collusive price $p^A \in (c, p^M]$. In equilibrium, aggregate profits in a stage game are then given by $\pi(p^A)$. If firm i sticks to the agreement, it shares the market with firm j and thus earns $\pi_i^{AB} = \pi(p^A)/2$. If firm i deviates unilaterally by undercutting p^A, it earns at most $\pi_i^{DB} = \pi(p^A)$ during the deviation period. In all future periods, the unilateral deviation triggers a retaliation by firm j. As a result, firm i earns the static Nash equilibrium profits in all future periods, that is $\pi_i^{NB} = \pi(c)/2 = 0$. By equation (4), $\underline{\delta}_1^B = \underline{\delta}_2^B = 1/2$ and consequently collusion is sustainable if $\delta \geq 1/2$.

Remark 1 *In the absence of a contract market,* $\underline{\delta}^B = 1/2$ *is the lowest discount factor that sustains collusion on the spot market (Friedman, 1971).*

We now turn to the more interesting case when the firms attempt to sustain collusion given the contract positions $((q_1^c, p^c), (q_2^c, p^c))$ where $q_1^c + q_2^c = D(p^c)$ and $p^c > c$. The purpose is to find an expression for $\underline{\delta}^C$, that is the lowest discount factor enabling the firms to sustain collusion, and to compare $\underline{\delta}^C$ with $\underline{\delta}^B$.

Assume that the firms are able to sustain the collusive price $p^A \in (c, \min\{p^c, p^M\}]$. By equation (4), we need to define firm i's profits by sticking to the agreement (π_i^{AC}), by deviating unilaterally (π_i^{DC}) and its profits in the punishment phase (π_i^{NC}). (Henceforth, the superscript C indicates the value of a variable when the contract positions $((q_1^c, p^c), (q_2^c, p^c))$ are given.

First, consider firm i's payoffs by sticking to the collusive price p^A. By equation (1), we have that

$$\pi_i^{AC} = \frac{1}{2}\left[\pi\left(p^A\right) + \left(p^A - c\right)\left(q_i^c - q_j^c\right)\right] \tag{5}$$

Second, consider firm i's payoffs in the punishment phase. Note that pricing at marginal cost constitutes a Nash equilibrium of the stage game for any pair of contracts $\{(q_1^c, p^c), (q_2^c, p^c)\}$ such that $q_1^c + q_2^c = D(p^c)$ and $p^c > c$.[7] Consequently, playing the pair of prices $(p_{1t}^s, p_{2t}^s) = (c, c)$ in all periods of the subgame starting in the beginning of the punishment phase constitutes an equilibrium. By equation (1), we thus have that

$$\pi_i^{NC} = 0. \tag{6}$$

Third, consider firm i's payoffs by deviating unilaterally from the collusive price p^A. Let $p_i^D \equiv \arg\max_p \pi_{it|p_{it}^s = p,\, p_{jt}^s = p^A}$ denote the optimal price associated with a unilateral deviation. Clearly $p_i^D < p^A$.[8] By equation (2), it follows immediately that

$$\pi_i^{DC} = \pi\left(p_i^D\right) - \left(p_i^D - c\right) q_j^c. \tag{7}$$

Next, we derive an expression for $\underline{\delta}_i^C$. Insert into equation (4) the expressions for π_i^{AC}, π_i^{NC} and π_i^{DC} in equations (5)-(7) and rearrange:

$$\underline{\delta}_i^C = 1 - \frac{1}{2}\frac{\pi\left(p^A\right) + \left(p^A - c\right)\left(q_i^c - q_j^c\right)}{\pi\left(p_i^D\right) - \left(p_i^D - c\right) q_j^c}. \tag{8}$$

We are now ready to establish the main result of this section.

[7] To see this, assume that $p_{jt}^s = c$. If firm i posts a price $p_{it}^s \geq c$, it makes 0 profits. If it posts a price $p_{it}^s < c$, it makes negative profits. Consequently, the price $p_{it}^s = c$ constitutes a best reply to $p_{jt}^s = c$.

[8] To see this, assume that $p_{jt}^s = p^A$ and note that deviating to a price $p > p^A$ does not increase the profits of the deviating firm. Indeed, by sticking to the price p^A, firm i's static profits are equal to $\pi_i^{AC} = \left(p^A - c\right) q_i^c + \frac{1}{2}\left(p^A - c\right)\left(D\left(p^A\right) - q_i^c - q_j^c\right)$ (by equation (1)). If firm i deviates unilaterally to the price $p \in \left(p^A, p^c\right]$, firm i's static profits are equal to $\left(p^A - c\right) q_i^c$ (by equation (3)). Note that $D\left(p^A\right) - q_i^c - q_j^c \geq D\left(p^c\right) - q_i^c - q_j^c = 0$, since $p^A < p^c$. Consequently $\left(p^A - c\right) q_i^c \leq \pi_i^{AC}$. If firm i deviates unilaterally to the price $p > p^c$, firm i only sells its contracted quantity q_i^c at the spot price $p_t^s = p_{jt}^s = p^A$. Consequently firm i's profits are once more given by $\left(p^A - c\right) q_i^c$ and we already know that $\left(p^A - c\right) q_i^c \leq \pi_i^{AC}$.

Proposition 1 *Assume that* $q_1^c = q_2^c > 0$*. Then firms are able to sustain collusion on the spot market even when* $\delta < \underline{\delta}^B$*.*

Proof: The proof establishes that $\underline{\delta}^C < \underline{\delta}^B$. Note that $p_1^D = p_2^D$, since $q_1^c = q_2^c$. By equation (8), it follows immediately that $\underline{\delta}_1^C = \underline{\delta}_2^C = \underline{\delta}^C$. Consequently $\underline{\delta}^C < \underline{\delta}^B = 1/2$ if, and only if,

$$\pi\left(p^A\right) / \left[\pi\left(p_i^D\right) - \left(p_i^D - c\right) q_j^c\right] > 1.$$

First, note that $-\left(p_i^D - c\right) q_j^c < 0$, since $q_j^c > 0$ and $p_i^D - c > 0$. Second, note that $\pi\left(p^A\right) > \pi\left(p_i^D\right)$, since $\pi(p)$ is single peaked and $p_i^D \leq p^A \leq p^M$. Consequently the above inequality is fulfilled. ■

A contract market with a ceiling spot price helps to sustain collusion for three reasons. First, when a firm deviates, it only "steals" market shares on the spot market. Indeed, the opponent still sells it contracted quantity. Therefore, the deviation profits are smaller when firms have committed to sell positive quantities through the contract market (that is $\pi_i^{DC} < \pi_i^{DB}$). Second, the fact that the contract specifies a ceiling spot price implies that the firms' ability of punishing deviators is not reduced (that is $\pi_i^{NC} = \pi_i^{NB}$). Third, by focusing on equilibria where $q_1^c = q_2^c$, it follows that the profits from sticking to the collusive agreement are not affected by long term contracts (that is $\pi_i^{AC} = \pi_i^{AB}$). Consequently, long term contracts with a ceiling spot price help to sustain collusion, since their only effect is to reduce the incentives to deviate from the collusive agreement.

The above analysis has also the following interesting implications.

Remark 2 *The larger the quantities specified in the long term contracts, the easier it is to sustain collusion on a given price* p^A*.*

Recall that the deviation profit is decreasing with the contracted quantities of the opponent. As an immediate consequence if the contracted quantities of both firms increase, both firms have less incentive to deviate.

Remark 3 *The more asymmetric the contracted quantities are, the more difficult it is to sustain collusion.*

To see this consider an initial situation where $q_1^c = q_2^c$. Increase q_1^c and decrease q_2^c by dq. Such a change, reduces firm 2's incentive to deviate (that is $\underline{\delta}_2^C$ decreases). The change, however, increases firm 1's incentive to deviate (that is $\underline{\delta}_1^C$ increases). Since $\underline{\delta}^C = \max\left\{\underline{\delta}_1^C, \underline{\delta}_2^C\right\}$, it follows that the proposed change makes collusion more difficult.

4 Equilibrium in the contract market

In this section, we analyze the firms' initial choices of contracts (in period $t = 0$), before the repeated spot market game starts (in period $t = 1$). We assume that the firms offer contracts of the form analyzed in the previous section, that is contracts, which define a quantity q_i^c and a ceiling spot price p_i^c. The end of this section provides an informal discussion about this assumption.

Assume that the firms wish to cooperate by choosing the same contract (q^c, p^c) such that $2q^c = D(p^c)$ and $p^c > c$. The next Proposition shows that such a cooperation is possible to implement by means of trigger strategies.

Proposition 2 *Assume that the firms are able to sustain the collusive price $p^A \in \left(c, p^M\right]$ in the repeated spot market if both firms firms have signed the contract $(D(p^c)/2, p^c)$. Then there exists a subgame-perfect equilibrium in which both firms offer the contract $(D(p^c)/2, p^c)$ in period $t = 0$ and collude on the price $p^A \in \left(c, p^M\right]$ in all periods $t \geq 1$.*

Proof: Consider the following strategy for firm $i = (1, 2)$. Choose the contract $(D(p^c)/2, p^c)$ in period $t = 0$. If firm $j \neq i$ chooses any contract $(q_i^c, p_i^c) \neq (D(p^c)/2, p^c)$ in period $t = 0$, then punish firm j in all future periods by pricing at marginal cost. If instead firm j chooses the contract $(D(p^c)/2, p^c)$ in period $t = 0$, then cooperate in period $t = 1$ by choosing the collusive price p^A. In all periods $t \geq 2$, cooperate by choosing the collusive price p^A unless firm j deviated in period $t - 1$. If so, punish firm j in the current as well as in all future periods by pricing at marginal cost.

Assume that firm j follows the same strategy. The proof establishes that firm i has no incentive to deviate from the proposed strategy, given that firm

j follows the same strategy.

If firm j cooperates in period $t = 0$ by choosing the contract $(D(p^c)/2, p^c)$, we know by Proposition 1 that firm i has no incentive to deviate in any period $t \geq 1$, provided that firm j sticks to its strategy in all future periods. If firm j deviates in period $t = 0$, both firms price at marginal costs and thus make 0 profits in all periods $t \geq 1$. This constitutes an equilibrium in the subgame starting after firm j's deviation. The reason is that the price p^c is a ceiling spot price. Therefore, firm i cannot raise its profits by increasing or decreasing its price in any future period. Finally, firm i has no incentive to deviate in period $t = 0$. Indeed, by sticking to the proposed strategy, it makes strictly positive profits. In contrast, by deviating at $t = 0$, it triggers a punishment forever by firm j, implying that firm i will make 0 profits. ■

Like in Allaz and Vila (1993), Proposition 2 shows that when the firms have the choice to sell their output either through long term contracts or on the spot market, both firms may choose the first solution. In a repeated game setting, this choice does not imply, however, that the spot market becomes more competitive. Moreover, the consequence of such a strategy may be that only a small proportion of total output is sold on the spot market. This is a commonly observed feature of electricity markets; according to Shuttleworth and McKenzie (2002), only 10% of the total output of electricity is bought on the spot market.

To derive the result it was important to assume that firms choose contracts with a ceiling spot price, rather than a contract with a fixed price. One way of motivating this assumption would be to assume that the consumers are strategic. Intuitively, such consumers would refuse to sign such a contract. The reason is that strategic consumers realize that a deviation by a firm triggers a price war in the following periods. Signing a contract with a fixed price prohibits the strategic consumer from benefiting from the price war.

5 Conclusion

It has been argued that having a contract market before the spot market enhances competition on the latter market (Allaz and Vila, 1993). This paper proposes a model of the electricity market where firms sign long-term supply contracts with their retailers. Subsequently, the firms repeatedly interact on the spot market. We show that contract markets help sustain collusion on the spot market.

We do not argue that sustaining collusion is the only motive behind firms' contracting decisions. One important motive might be to hedge risk. Unlike the collusion motive, the hedging motive has beneficial effects. However, we believe that the pro-collusive motive is one important reason behind the large amount of contracted quantity. Of course it would be desirable to check this belief empirically. An interesting research project would be to analyze the outcomes of the new market designs in the UK and the State of California where access to contract markets are encouraged by regulators.

6 References

Allaz B., and J.-L.Vila (1993): "Cournot Competition, Forwards Markets and Efficiency", Journal of Economic Theory 59, 1-16.

Anderson R.W. ,and T. Brianza (1991): "Cartel Behaviour and Futures Trading", CEPR, Working paper No. 14.

Benoit J.P., and V. Krishna (1987): "Dynamic Duopoly: Prices and Quantities", Review of Economic Studies 54, 23-35.

Bower J. (2002): "Why Did Electricity Prices Fall in England and Wales?- Market Mechanism or Market Structure?", Oxford Institute for Energy Studies, September.

Borenstein S., and Bushnell J.B. (1999): "An Empirical Analysis of the Potential for Market Power in a Deregulated California Electricity Market", The Journal of Industrial Economics 47 (3), 285-323.

Davidson C., and R. Deneckere (1990): "Excess Capacity and Collusion", International Economic Review 31, 404-415.

von der Fehr N.-H. , and D. Harbord (1992): "Long-term Contracts and Imperfectly Competitive Spot Markets: A Study of the U.K. Electricity Industry", Memorandum 14, University of Oslo.

Friedman J. (1971): "A Noncooperative Equilibrium for Supergames", Review of Economic Studies 28, 1-12.

Fabra N. (2003): "Tacit collusion in repeated auctions: uniform versus discriminatory", The Journal of Industrial Economics LI (3), 271-293.

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

Harvey S.M., and W.W. Hogan (2000). "Californian Electricity Prices and Forward Market Hedging", Mimeo, John F. Kennedy School of Government, Harvard University.

Mahenc P., and Salanié F. (2002): "Tacit Collusion through Trading", Mimeo, LEERNA, Toulouse.

MSC September Report (2000): "An Analysis of the June 2000 Price Spikes in the California ISO's Energy and Ancillary Services Markets", Market Surveillance Committee Report, California Independent System Operator.

Newbery D.M. (1998): "Competition, Contracts, and Entry in the Electricity Spot Market", RAND Journal of Economics 29(4), 726-749.

Ofgem (1999): *The New Electricity Trading Arrangements*, vol.1 and 2, July, www.ofgem.gov.uk/elarch/anetadocs.htm

Powell A. (1993): "Trading Forward in an Imperfect Market: the Case of Electricity in Britain", Economic Journal 103, 444-53.

Schnitzer M. (1994): "Dynamic Duopoly with Best-Price Clauses", RAND Journal of Economics 25 (1), 186-196.

Wolak F A. (2000): "An Empirical Analysis of the Impact of Hedge Contracts on Bidding Behavior in a Competitive Electricity Market", International Economic Journal 14(2), 1-39.