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and Spot Market Competition**

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Index Contracts and Spot Market Competition*

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Abstract

It has long been argued that long-term contracts enhance competition, but the repeated nature of many markets has been neglected. This paper analyzes the impact of long-term contracts on the ability to sustain collusive outcomes. I consider a simple model where firms have signed index contracts and repeatedly interact on the spot market. The contracts specify a quantity and a price indexed to the spot price where the indexation can take different forms. It is shown that these contracts facilitate collusion on the spot market provided that the indexation to the spot price is sufficiently strong.

Key words: Commodity market, Contract market, Energy sector, Spot Market, Tacit collusion.

JEL code: C7, D4, L1.

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1 Introduction

Long-term contracts have a long history in commodity markets but have also become increasingly important elsewhere, particularly in the energy sector. For market design it is of interest whether contract markets have desirable effects on welfare and efficiency. Some formal arguments support the view that firms with large contract positions may have less incentive to exercise market power (e.g. Allaz and Vila, 1993). Intuitively, contract markets give rise to a situation reminiscent of the prisoners' dilemma; each producer has an incentive to offer a contract, but when all producers do so, each one is worse off. In particular, a firm obtains 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.

A central feature of this analysis is based on a framework with a finite horizon. The repeated nature of many markets (such as electricity markets or most commodity markets) raises the question of whether this result is robust.¹ Moreover Allaz and Vila focused on a forward contract, namely a contract that specifies a fixed quantity at a fixed contracted price. In reality, different types of contracts coexist, depending on the industry and the institutional rules. It is not uncommon that the contract price is indexed to the spot market price where the indexation may take various forms. In the copper industry most of the transactions between producers and consumers of refined copper involve one-year contracts that specify a monthly quantity with a price equal to the spot price on the day of delivery (Slade and Tille, 2004). In the electricity sector some producers offer a contract to the end-use customers where the electricity is sold at the daily spot price with a fixed margin added to cover administrative costs. For example, in Sweden, 12% of Vattenfall's customers (the largest producer) have signed such a contract. In

¹For the UK electricity market, Bower (2002) found that the price reduction after the introduction of NETA was due to changes in market structure rather than increased contracting opportunities. Studying spot price levels for the six commodities traded in the London Metal Exchange in the 1990's, Slade and Thille (2004) find no evidence that the existence of forward trading eliminates firms' market power.

Norway, about 16% of the consumers buy their electricity through contracts tied directly to the spot price. Several variants of these contracts coexist in the Norwegian market, including an optional cap on the maximum price payable (Littlechild, 2005). In the UK, 85% of natural gas is sold under long-term contracts and most of the contracts contain a price indexation to the spot market (Neumann and Hirschhausen, 2005).

The purpose of this paper is to investigate the sensitivity of Allaz and Vila's result with respect to the assumption of a finite horizon and the type of contract considered. It is shown that when the spot market is repeated and customers have signed index contracts, these contracts facilitate collusion on the spot market provided that the indexation to the spot price is sufficiently strong.

I consider a model where two firms initially have offered long-term index contracts before repeatedly competing in price on the spot market. The contracts specify a quantity to be bought in every future spot period and a price indexed to the spot price. The indexation can take different forms.² I consider first the simplest version of indexation where the contract price equals the price prevailing in the spot market at the time of the delivery. In this setup, firms may enforce price collusion even though they have signed contracts. In fact, the contract market enables collusion on the spot market when firms would compete in the absence of such a market. The intuition underlying this result is two-fold. First, given that the contracted quantities are not traded in the spot market, contracts reduce the size of the market that a deviator can serve when undercutting the rival's price. Second, given that the contract's price equals the spot price, the contract does not affect profit levels in the optimal punishment phase. Consequently profits in the punishment phase can be driven down to zero just as in the case when there is no contract market. I argue in the paper that contracts with others forms of indexation have the same qualitative effects, provided that the indexation

²If the spot market were to take place once only, the contracts would have no impact on equilibrium output and price. The reason is that the firms play a price game on the spot market and therefore marginal-cost pricing would prevail. By contrast, Allaz and Vila analyzes a game with quantities as strategic variables and as a result find that contracts markets are procompetitive. (See Allaz (1992) or Haskel and Powell (1994) for a discussion about the sensitivity of two stage contract-spot models with respect to the conjectural variations.)

to the spot price is sufficiently strong.

A few papers have analyzed the interaction between contract and spot markets in a dynamic setup. Both, Ferreira (2003) and Liski and Montero (2004), consider a repeated version of Allaz and Vila's model, where the firms offer forward contracts with a fixed quantity and a fixed contract price and show that there exists a multiplicity of equilibria. Ferreira finds that the most robust (renegotiation-proof) equilibrium is the one in which firms do not use the contract market. Liski and Montero find that forward trading allows firms to sustain collusive profits that otherwise would not be possible. Anderson and Brianza (1991) as well as Mahenc and Salanié, (2004) 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. Common features of these studies are that (i) the amount of contract sold calls for one delivery (spot) period and, (ii) the contract price is fixed. In contrast, I consider a setup where the amount of contract sold calls for an infinite delivery (spot) periods and the contract price is indexed to the spot price.³ Polinsky (1987) focuses on two extreme indexation forms. He considers a fixed price contract (there is no indexation, the price is specified in advance) and a spot price contract (there is perfect indexation, the price is the price prevailing in the spot market at the time of the delivery). His purpose is to compare how fixed and spot price contracts allocate risk. He defines conditions determining which contract form would be preferred when the seller and/or the buyer is risk averse. The purpose is thus different from mine, since I analyse how the contract form affect the competition on the spot market. Finally, in repeated games with capacity constraints (Benoit and Krishna, 1987, Davidson and Deneckere, 1990 or Fabra, 2006), capacities play a similar role as contracts to the extent that they both limit the profitability of deviation by reducing the "size" of the market that the deviator can gain. With capacity constraints, deviation profits are reduced by the deviating firm's own capacity constraint; with contracts, the deviation profits are reduced, the larger the contracted

³As Green and Le Coq (2006) point out, the length of the contract matters for firms' ability to sustain collusion; the shorter the contract, the easier it is to collude. My assumption of a call for delivery for an infinite number of periods thus makes collusion more difficult to sustain.

quantities of the rival firm. Another difference is that while capacity constraints also limit the severity of the punishment, a index contract with a price perfectly indexed to the spot price contract does not.

The paper is organized as follows. Section 2 presents the model. Section 3 solves for equilibria in the repeated price game, when firms have signed so-called "spot price contract" where the contract price is the prevailing spot price. Section 4 presents different examples of indexation where the result of the last section holds qualitatively. Section 5 discusses some robustness issues and the paper ends with some concluding remarks.

2 The model

Consider two symmetric firms, 1 and 2, producing an homogeneous good at identical and constant marginal costs b . They sell the good to buyers in two successive wholesale markets, namely a contract market and an infinitely repeated spot market.⁴ 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 $t \geq 1$ and the spot price prevailing in period t is determined as $p_t^s \equiv \min \{p_{1t}^s, p_{2t}^s\}$. The timing of the game is illustrated in Figure 1.

In period $t = 0$, the firms have proposed a long-term index contract to the buyers. A contract between firm i ($i = 1, 2$) and a buyer specifies a pair $[q_i^c, p_i^c(p_t^s)]$, whereby the buyer commits to buy and firm i commits to supply the fixed quantity q_i^c at the contract price $p_i^c(p_t^s)$, which is indexed to the spot price of every subsequent period $t \geq 1$. The indexation can take various forms. The simplest indexation corresponds to a spot price contract, in which case $p_i^c(p_t^s) = p_t^s$. In this case the indexation is perfect. In section 4 I will consider other forms of contracts including cases where the contract price is imperfectly indexed to the spot market price. Note also that the contract is binding and observable. For simplicity I focus on symmetric contracts, that is $[q^c, p^c(p_t^s)]$, where I have dropped the subscript i . The significance of this

⁴Both sellers and buyers are assumed to be risk neutral and hence there are no risk sharing benefits in signing long-term contracts.

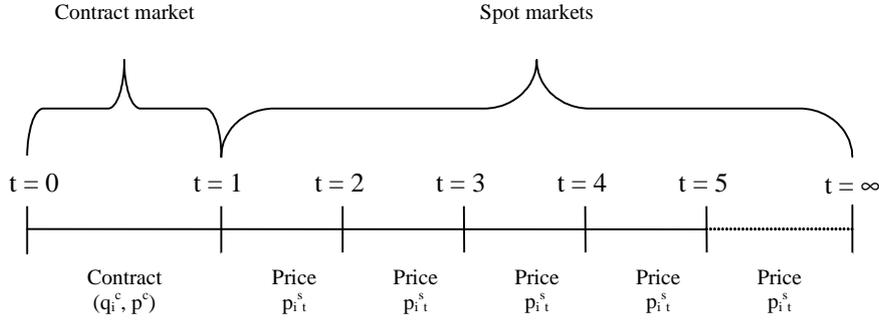


Figure 1: The timing of the game

assumption is discussed in Section 5.

In each period $t \geq 1$, the demand is given by $D(p)$, which is a decreasing and continuous function of the price p . Consumers are assumed to be price-takers. The aggregate profits in each period t are given by $\Pi(p) \equiv (p - b) D(p)$ and are assumed to be single peaked with a unique maximum at $p^M \equiv \arg \max_p \Pi(p)$. The firms use the same discount factor $\delta \in (0, 1)$ and maximize the sum of their discounted profits $\sum_{t \geq 1} \delta^{t-1} \pi_{it}$ where π_{it} denotes firm i 's profit in period t .

Stage-game: A stage-game consists of a single spot market period where each firm i is already committed to the contract $[q^c, p^c(p_t^s)]$. In addition to the total contracted quantities $2q^c$, the firms thus supply $Q_t^s = D(p_t^s) - 2q^c$ in period t , that is the residual demand on the spot market evaluated at p_t^s . The firms compete in prices for this residual spot demand and buyers buy from the cheapest supplier.

In each stage-game, firm i earns profits decomposed into two parts: the profits π_i^c derived from the contract market and the additional profits π_{it}^s derived from the spot market. Note that π_i^c depends on t (since the contract price is indexed to the spot market price) but does not depend on a firm's identity (since contracts are symmetric). Provided that $2q^c \leq D(p_t^s)$ the profits earned by firm i in a single stage game are given by

$$\pi_{it} = \pi_t^c + \pi_{it}^s = (p^c(p_t^s) - b)q^c + (p_t^s - b) D_{it}(p_{it}^s, p_{jt}^s),$$

where

$$D_{it}(p_{it}^s, p_{jt}^s) = \begin{cases} D(p_{it}^s) - 2q^c & \text{if } p_{it}^s < p_{jt}^s \\ \frac{1}{2} [D(p_{it}^s) - 2q^c] & \text{if } p_{it}^s = p_{jt}^s \\ 0 & \text{if } p_{it}^s > p_{jt}^s \end{cases}$$

In contrast to the classic Bertrand game, the firm posting the highest spot price thus earns strictly positive profits when the contracted quantity is positive ($q^c > 0$) and the contract price exceeds the marginal cost ($p^c(p_t^s) > b$). Note also that for the remainder of the paper, I will focus attention on contracts and (collusive) spot prices satisfying the condition $2q^c \leq D(p_t^s)$.⁵

Trigger strategies: I restrict attention to stationary collusive agreements supported by trigger strategies.⁶ That is, firms remain at the collusive price unless someone cheats; if at any point in time a firm is detected cheating, players revert forever to the static Nash equilibrium (Friedman, 1971).

Let π_i^N denote firm i 's static profits on the spot market when the firms post the one period Nash equilibrium price vector (p_i^N, p_j^N) . Let π_i^A denote firm i 's static payoff when the firms stick to the stationary tacit agreement A, that is when both firms post the collusive price p^A . Let π_i^D denote firm i 's static payoff resulting from an unilateral deviation from A by setting the static best response price $p_i^D(p^A)$. Note that it becomes redundant to keep track of the firms' identities when they have identical contract positions. Therefore the subscript i can be dropped.

Equilibrium: By the one-stage deviation principle, a collusive agreement A is sustainable as a subgame-perfect equilibrium if and only if no firm has an incentive to defect unilaterally from the collusive agreement, or equivalently:

$$\frac{\pi^A}{1 - \delta} \geq \pi^D + \frac{\delta}{1 - \delta} \pi^N \iff \delta \geq \underline{\delta} \equiv \frac{\pi^D - \pi^A}{\pi^D - \pi^N} \in (0, 1). \quad (1)$$

⁵The case where firms are net buyers on the spot market (implying that $2q^c > D(p_t^s)$) is not considered here (see Mahenc and Salanié (2004) on this issue).

⁶I assume that renegotiation and side payments are not possible.

Collusion on the agreement A is thus sustainable using unrelenting trigger strategies if and only if the firms' discount factor δ exceeds a critical level $\underline{\delta}$.

Benchmark (Repeated spot market without a long-term contract market): I 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 classic repeated (Bertrand) price game. Assume that the firms are able to sustain a collusive price $p^A \in (b, p^M]$. In equilibrium, aggregate profits in a stage game are then given by $\Pi(p^A)$. If both firms stick to the agreement, they share the market and thus earn $\Pi(p^A)/2$. If a firm deviates unilaterally by undercutting p^A , it earns at most $\Pi(p^A)$ during the deviation period. In all subsequent periods, the unilateral deviation triggers a retaliation by the other firm. As a result, the deviator earns the static Nash equilibrium profits in all subsequent periods, that is $\Pi(b)/2 = 0$. Inserting these profit levels in equation (1) yields the following remark.

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

The aim of this paper is to highlight the effect of long-term contracts on the sustainability of collusion on repeated spot markets. More specifically I characterize the sufficient conditions for the collusive price p^A in the spot market to be sustainable in a subgame perfect equilibrium of the infinitely repeated game described above, taking the contracts $(q^c, p^c(p_i^s))$ as given. To do so, I consider first a simple case where firms offer so-called "spot price" contracts where the contract price is the prevailing spot price. As mentioned earlier, such contracts can be found in the copper industry, the electricity sector, and the gasoline market.

3 A spot price contract

This section focuses on specific index contracts, namely spot price contracts, where the contract price $p^c(p_t^s)$ is equal to the period spot price p_t^s . Taking the contract positions as given, the next proposition shows that spot price contracts may facilitate collusion relative to the benchmark.

Proposition 1 *Consider a tacit agreement where the firms collude on $p^A \in (b, p^M]$, assuming that they have signed spot price contracts where $q^c \in \left(0, \frac{D(p^A)}{2}\right]$. Such an agreement is sustainable for all $\delta \geq \underline{\delta}^C$ where $\underline{\delta}^C < \underline{\delta}^B$.*

Proof: The proof starts by finding expressions for π^A , π^N and π^D . If the firms stick to the agreement, then $\pi^A = \Pi(p^A)/2$, since the firms share the residual demand on the spot market and since the firms have signed spot price contracts so that $p^c(p^A) = p^A$. If a firm deviates unilaterally from the agreement, its optimal price deviation is given $p^D \equiv \arg \max_p \pi_{it|p_{it}^s=p, p_{jt}^s=p^A}$. Note that $p^D < p^A$.⁷ Hence, $\pi^D = \Pi(p^D) - (p^D - b)q^c$, since the contract price equals the spot price p^D so that the deviating firm earns the aggregate profits evaluated at p^D minus the profits that the rival earns on his contracts. Finally, note that $\pi^N = 0$, since playing the pair of prices $(p_{1t}^s, p_{2t}^s) = (b, b)$ in all periods of the subgame starting in the beginning of the punishment phase constitutes an equilibrium.⁸

By equation (1), the critical discount factor $\underline{\delta}^C$ above which collusion can be sustained is thus given by

$$\underline{\delta}^C = 1 - \frac{1}{2} \frac{\Pi(p^A)}{\Pi(p^D) - (p^D - b)q^c}. \quad (2)$$

It remains to prove that $\underline{\delta}^C < \underline{\delta}^B = 1/2$. This inequality is fulfilled since $\Pi(p^A) / [\Pi(p^D) - (p^D - b)q^c] > 1$. Indeed, note first that $(p^D - b)q^c > 0$,

⁷By deviating to a higher price, the deviator would sell nothing on the spot market, and the profits derived from its contract are unaffected by its own price.

⁸To see this, assume that $p_{jt}^s = b$. If firm i posts a price $p_{it}^s \geq b$, it makes 0 profits. If it posts a price $p_{it}^s < b$, it makes negative profits. Consequently, the price $p_{it}^s = b$ constitutes a best reply to $p_{jt}^s = b$. Exactly as in a repeated Bertrand competition, unrelenting trigger strategies are “optimal punishments” here, since the players are at their security levels. As a result, no complex punishment mechanism can enlarge the set of supportable equilibria (Abreu, 1986).

since $q^c > 0$ and $p^D - b > 0$. Second, note that $\Pi(p^A) > \Pi(p^D)$, since $\Pi(p)$ is single peaked and $p^D < p^A \leq p^M$. Finally, note that $[\Pi(p^D) - (p^D - b)q^c] > 0$, since $\Pi(p^D) = (p^D - b)D(p^D)$ and $q^c \leq D(p^A)/2 < D(p^D)$. ■

The existence of such index contracts facilitates collusion on the spot market for three reasons. First, when a firm deviates, it only “steals” market shares on the spot market, since the rival firm still sells its contracted quantity. Hence, the deviation profits are smaller when firms have committed to sell positive quantities through the contract market. Second, the fact that the contract price equals the spot price implies that the firms’ ability to punish deviators is not reduced relative to the benchmark. Third, since I assume symmetric contract cover, it follows that the profits from sticking to the collusive agreement are unaffected by long-term contracts. Consequently, spot price contracts help to sustain collusion, since their only effect is to reduce the incentives to deviate from the collusive agreement.

A few remarks about Proposition 1 are warranted. The deviation profits become smaller when the rival firm has signed larger quantities of contracts. This observation implies that in order to maximize the range of discount factors enabling collusion on a given price p^A , the contracted quantities must be maximized, that is $q^c = D(p^A)/2$. Note also that it is not necessarily possible to collude on the monopoly price whenever collusion is sustainable on a lower price. The reason is that following an increase in p^A and a simultaneous reduction in q^c (so that $q^c = D(p^A)/2$), the profits from deviation may increase at a faster rate than the profits from sticking to the agreement.

The next proposition considers the endogenous choice of contracted quantities before the repeated spot market game starts in period $t = 1$.

Proposition 2 *For any discount factor $\delta \geq \underline{\delta}^C$, assuming that firms only offer spot price contracts, there exists a subgame-perfect equilibrium in which firms offer the contract $(D(p^A)/2, p^A)$ in period $t = 0$ and collude on the price p^A in all periods $t \geq 1$.*

Proof: Consider the following strategy for firm $i = (1, 2)$. Choose the contract $(D(p^A)/2, p^A)$ in period $t = 0$. If firm $j (\neq i)$ chooses any contract

$(p^c, q^c) \neq (D(p^A)/2, p^A)$ in period $t = 0$, then punish firm j in all future periods by pricing at marginal cost. If instead firm j chooses the contract $(D(p^A)/2, p^A)$ 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. It is assumed that there is always $\varepsilon > 0$ quantity on the spot market.

If firm j cooperates in period $t = 0$ by choosing the contract $(D(p^A)/2, p^A)$ 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 (see from Proposition 1). 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 contract price is the 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 since $\delta \geq \underline{\delta}^C$. In contrast, by deviating at $t = 0$, it triggers a punishment forever by firm j , implying that firm i will make 0 profits. ■

The most collusive contract choice, for a given discount factor $\delta \geq \underline{\delta}^C$, is the monopoly quantity $(D(p^M)/2, p^M)$. Like in Allaz and Vila (1993), Proposition 2 shows that when the firms have the choice to sell their output either through spot price contracts or on the spot market, both firms may offer most of their quantity on the contract market. In a repeated game setting, however, this choice does not necessarily imply that the spot market becomes more competitive.

In this section I have assumed that firms can only offer contracts with a contract price perfectly indexed to the spot price. This is a restrictive assumption and in reality firms are able to offer different type of contracts. I discuss some alternative forms of indexation in the next section.

4 Alternative forms of contract

In the previous section, it has been shown that spot price contracts where $p^c(p_t^s) = p_t^s$ facilitate collusion in the spot market. In this section I consider two forms of existing indexations and argue that the result still holds qualitatively.

Perfect indexation with a price cap. Consider a contract with a price cap, which stipulates a quantity to be bought in every future period at the prevailing spot market price, unless this price is higher than a threshold level specified in the contract; if so, the buyers buy the contracted quantity at a price equal to the threshold level.⁹ Basically this is a spot price contract with a maximum contract price p^* . Assuming that $p^* < p^M$ (otherwise it is the same problem as in the previous section), it is easy to show that Proposition 1 holds for any collusive price $p^A \in (b, p^*]$.

Imperfect indexation. Consider now a contract where the contract price is imperfectly indexed to the spot market price. More precisely, consider the contract $(q^c, p^c(p_t^s))$ where $p^c(p_t^s) = \alpha\beta + (1 - \alpha)p_t^s$, $\alpha \in [0, 1]$ and $\beta \in (b, p^M]$. This contract thus weighs two components: a fixed price β and the spot market price p_t^s . Note also that the contract boils down to the previously analyzed spot price contract when $\alpha = 0$. Assume that the firms want to collude on the fixed price component, that is $p^A = \beta$. If the firms stick to the agreement so that $p_t^s = p^A$, then $p^c(p_t^s) = p^A$ and the collusive profits are given by $\pi^A = \Pi(p^A)/2$. Hence, the profits from sticking to the agreement remain unchanged relative to the case of a spot price contract. If a firm undercuts p^A optimally by choosing the price p^D , it earns $\pi^D = \Pi(p^D) - (p^D - b)q^c + \alpha(p^A - p^D)q^c$. As expected this expression for π^D is the same as in the case of a spot price contract if $\alpha = 0$. When $\alpha > 0$, the last positive term is added. As a result the deviation profits are larger relative to the case with a spot price contract.¹⁰ Finally, in the punishment phase the

⁹Such contracts are used mainly as an insurance against events such as high spot prices. It is called a "collar agreement" in the oil market, "Vesting contract" in the Australian electricity market or "Physical One-way Contract- for-difference" in the former UK Pool electricity market.

¹⁰Due to the last positive term, π^D increases even if the deviating firm were to deviate

deviator earns the static Nash equilibrium profits in all subsequent periods. The punishment reduces the profits derived from the spot market to zero, but the deviating firm still earns some profits from its contracted quantity, namely $\alpha (p^A - b) q^c$. Thus the severity of the punishment is reduced relative to the case when $\alpha = 0$.¹¹ Since π^A remains unchanged while both π^D and π^N increases as α increases, it follows immediately that $\underline{\delta}^C$ increases as α increases. Expressed differently, collusion becomes more difficult to sustain as the strength of the indexation to the spot price decreases. Nevertheless contracts will increase the scope of collusion relative to the benchmark case without contracts as long as the contracts give sufficient weight to the spot market price.¹²

5 Robustness

In this section I discuss some robustness issues concerning the effects of asymmetric contracts and consumers' attitudes.

Asymmetric contracted quantities. It is easy to show that Proposition 1 holds qualitatively even if firms have different contract positions. The more asymmetric the contracted quantities are, however, the more difficult it is to sustain collusion. Formally, assume that firms have offered the same type of spot price contract (so that $p^c(p_t^s) = p_t^s$) but with different amounts of contracted quantities ($q_i^c \neq q_j^c$). Consider an initial situation where $q_i^c = q_j^c$ and increase q_i^c and decrease q_j^c by the same amount. In this case, the residual spot demand remains unchanged but firm i sells more contracted quantities than firm j . This implies that firm i 's deviation profits are increased so that firm i has more incentives to deviate (that is $\underline{\delta}_i^C$ increases). The opposite reasoning applies to firm j so that firm j 's incentives to deviate are reduced

to the same (suboptimal) price as in the case with a spot price contract. Consequently, π^D must be even larger if p^D is chosen optimally.

¹¹In this case, however, unrelenting trigger strategies need not constitute optimal punishments, since the players' payoffs are not driven down to their security level in the punishment phase.

¹²Indeed, note that $\underline{\delta}^C$ is a continuous function of α . Since $\underline{\delta}^C < \underline{\delta}^B$ if $\alpha = 0$, it follows that the inequality still holds if α is sufficiently small.

(that is $\underline{\delta}_j^C$ decreases). Since $\underline{\delta}^C = \max\{\underline{\delta}_i^C, \underline{\delta}_j^C\}$, it follows that the proposed change makes collusion more difficult. Note however that the contracts facilitate collusion relative to the benchmark as long as both firms have strictly positive contracted quantities.

Asymmetric indexation to the spot price. It is also easy to show that Proposition 1 holds qualitatively even if firms have signed contracts with different indexation forms for the same contracted quantity q^c . To see this, assume that firm i offers a spot price contract and firm j a contract where the contract price is imperfectly indexed to the spot market price, that is $p_j^c(p_t^s) = \alpha\beta + (1 - \alpha)p_t^s$, $\alpha \in (0, 1)$. In the former section it was argued that the latter contract both increases firm j 's deviation profits and reduces the strength of the punishment against firm j . As a result, firm j 's lowest discount factor enabling collusion would increase relative to the case with a spot price contract. It follows immediately that collusion becomes more difficult to sustain as compared to the case where both firms offer spot price contracts. It is clear, however, that an indexation to the spot price still facilitates collusion relative to the benchmark as long as the contract with the weakest indexation gives sufficient weight to the spot market price.

Buyers' side. I mentioned earlier that collusion becomes more difficult to sustain as the strength of the indexation to the spot price decreases. Hence it is an open question why consumers would sign a contract with a contract price indexed to the spot market. Rather they should only sign contracts with fixed prices. A tentative answer is that consumers may believe that price wars are likely and signing a contract with a fixed price prohibits the consumers from benefiting from such price wars. Of course price wars do not occur in equilibrium in the model presented in this paper and therefore this explanation is not fully satisfactory. An interesting extension could be to incorporate long-term contracts in the framework of Green and Porter (1984) where price wars do occur in equilibrium. Such an extension is however beyond the scope of this paper and is therefore left for future research.

6 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 where firms sign long-term contracts with their buyers. Subsequently, the firms repeatedly interact on the spot market. It is shown that spot price contract markets help sustain collusion on the spot market. Other types of contracts where the price is indexed to the spot market price may also facilitate collusion, depending on the form of indexation. I do not argue that sustaining collusion is the only motive behind firms' contracting decisions. Other motives have been discussed, such as hedging risk (Wolak, 2000 or Bessembinder and Lemmon, 2002), deterring entry (Newbery, 1998) or facing technological constraints (Wolak, 2005). However, the pro-collusive motive may be one important reason behind the large amount of contracted quantities.

7 References

- Abreu D. (1986): "Extremal Equilibria of Oligopolistic Supergames", *Journal of Economic Theory* 39, 191-225.
- Allaz B., and J.-L. Vila (1993): "Cournot Competition, Forwards Markets and Efficiency", *Journal of Economic Theory* 59, 1-16.
- Allaz B. (1992): "Oligopoly, Uncertainty and Strategic Forward Transactions", *International Journal of Industrial Organization* 10, 297-308.
- 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.
- Bessembinder H., and M. L. Lemmon (2002): "Equilibrium Pricing and Optimal Hedging in Electricity Forward Markets", *The Journal of Finance* 57, 1041-1558.
- Bower J. (2002): "Why Did Electricity Prices Fall in England and Wales? Market Mechanism or Market Structure?", *Oxford Institute for Energy Studies*, September.
- Davidson C., and R. Deneckere (1990): "Excess Capacity and Collusion", *International Economic Review* 31, 404-415.
- Fabra N. (2006): "Collusion with Capacity Constraint over the Business Cycle", *International Journal of Industrial Organization* 24 (1), 69-81.
- Ferreira J.L. (2003): "Strategic Interaction between Futures and Spot Markets", *Journal of Economic Theory* 108, 141-151.
- Green E. and R. Porter (1984): "Noncooperative Collusion under Imperfect Price Information", *Econometrica* 52(1), 87-100.
- Green R.J, and C. Le Coq (2006): "The Length of the Contract and Collusion", CSEM working paper 154, University of California, Berkeley.

- Haskel J, and A. Powell (1994): "Contract Markets and Competition", Mimeo, Department of Economics, Queen Mary and Westfield College, London, UK.
- Le Coq C. (2004): "Long-Term Supply Contracts and Collusion in the Electricity Market", Stockholm, SSE/EFI Working Paper Series in Economics and Finance No 552.
- Liski M., and J-P Montero (2004): "Forward Trading and Collusion in Oligopoly", Forthcoming in Journal of Economic Theory.
- Littlechild S. (2005) "Competition and Contracts in the Nordic Residential Electricity Markets", Cambridge Working Papers in Economics No 0550.
- Mahenc P., and F. Salanié (2004): "Softening Competition through Forward Trading", Journal of Economic Theory 116, 282-293.
- Neumann A., and C. von Hirschhausen (2004): "Less Gas to Europe? An Empirical Assessment of Long-term Contracts for European Energy Supply". Zeitschrift für Energiewirtschaft, 28(3), 175-182.
- Newbery D.M. (1998): "Competition, Contracts, and Entry in the Electricity Spot Market", RAND Journal of Economics 29(4), 726-749.
- Polinsky A. M. (1987): "Fixed Price versus Spot Price Contracts: A Study in Risk Allocation", Journal of Law, Economics, and Organization 3(1), 27-46.
- Slade M., and H. Thille (2004): "Commodity Spot prices: An Explanatory Assessment", Forthcoming in *Economica*.
- 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.
- Wolak F.A. (2005): "Quantifying the Supply-Side Benefits from Forward Contracting in Wholesale Electricity Markets", Mimeo, Stanford University.