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STRATEGIC INTERACTION BETWEEN FUTURES AND SPOT MARKETS*

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Abstract

There is a literature (e.g., Allaz and Vila, 1992 and Hughes and Kao, 1997) showing that in an oligopolistic context, the presence of a futures market induces firms to use it in order to increase its market share. The consequence of this behavior is that the total quantity supplied by the industry increases, thus making the oligopolistic outcome closer to the competitive equilibrium. In the present work, we propose a model to study the interaction of spot and futures markets that does not imply this pro-competitive effect. The model is the same as in Allaz and Vila in the sense that firms have infinitely many moments to trade in the futures market before the spot market takes place. We analyze the equilibria in the infinite case directly and show that many equilibria emerge in a kind of folk-theorem result (but ours is not a repeated game). The equilibrium in which firms do not use the forward market is particularly robust as it satisfies the most demanding definition of renegotiation-proofness. Furthermore, if firms are allowed to buy in the futures market, they can sustain the monopolistic outcome in a renegotiation-proof equilibrium (notice that there is only one period in the spot market). We also study the role of information in the model and argue that our results fit better stylized facts of some industries like the power market in the U.K.

Keywords: Futures markets, Cournot competition, collusion.

Journal of Economic Literature Classification Numbers: D43, L13, L41, G13.

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1 Introduction

The introduction of futures markets has been most commonly justified as a way for firms to hedge against fluctuations in the price. Other justifications deal with arbitrage reasons. More recently, the strategic interaction between futures and spot markets has been analyzed. In a first attempt, the interaction is due to the way in which positions in one market affect the costs in the other (Williams, 1989). The second approach is based in a work by Allaz and Vila (1992) (from now on, A&V) where, in an oligopolistic context, these authors show that firms use the futures markets as a way to commit to a quantity, thus forcing Cournot competition in the spot market in the residual demand. The result is that all firms have an incentive to do so, with an increase in the total quantity supplied by the industry. When the number of moments to hold positions in the futures markets before the spot market tend to infinity, the total quantity is the same as in perfect competition. In a later work, Hughes and Kao (1997) (H&K) argue that this result holds only if there is perfect observability. Without observability, the equilibrium is again the Cournot behavior.

The above result suggests that, in the presence of a futures market, oligopolies tend to be more competitive. In particular, the presence of trades in the futures market would be an indication that this is indeed the case. Moreover, if the futures markets is transparent one must expect more activity than if the market is opaque. However, the case of the liberalization of the power market in England and Wales does not reflect this pattern. In this sector, the introduction of a futures markets (Contracts for Differences CfD) didn't seem to have had this pro-competitive effect (see OXERA, 1994) although positions were actually taken in this market. Furthermore, when a more transparent market was introduced (the Electricity Forward Agreements, EFA), firms still preferred the use of the much more opaque CdF's. For instance, in 1998 the coverture of the CdF's was near 90% of the market, while the EFAs accounted for less than 30% (Power UK estimates).

In the present work, we propose a model to study the interaction of spot and forward markets that doesn't imply a pro-competitive effect. The model is the same as in A&V in the sense that firms have infinitely many moments to trade in the futures market before the spot market takes place. We analyze the equilibria in the infinite case directly (as oppose to taking the limit of the finite cases) and show that many equilibria emerge. The equilibrium in which firms do not use the forward market (and the overall result is the Cournot outcome) is particularly robust (it is renegotiation-proof). If firms are allowed not only to sell, but also to buy in the futures market, a possibility not contemplated in A&V, then the monopoly outcome is sustained in a renegotiation-proof equilibrium. Hence, the effect of introducing a futures market not only may not have a pro-competitive effect, but may worsen things off.

Then we analyze the role of observability and show that, even in the one period case, the result of H&K was based on a hidden assumption that is not likely to hold (they do not consider the sensitivity of the price in the futures markets to changes in the quantities offered by the firms). When the assumption is removed, the effects are totally different, and observability makes no difference unless the price in the futures market is insensitive with respect to changes in quantities. If firms are risk averse, they have indeed an incentive to sell in the futures market, but they may restrict themselves to sell only to get the optimal insurance. When we combine these results with the standard analysis of repeated games (when the spot market interaction is repeated infinitely many times) we have that firms may or may not sell in the futures markets, without implying a pro-competitive effect. Finally, the possible collusive behavior of firms may be better implemented in real life in the more opaque market.

In section 2 we present the basic model. In section 3, we analyze the many-periods model. Next, in section 4, we discuss on the role of observability. In section 5 we show the case of uncertainty and show the complications that arise, even with risk neutral firms. Section 6 concludes.

2 The basic model

Consider a duopoly producing an homogeneous good competing *a la* Cournot with zero costs (until section 5 zero costs are a notational simplification of constant marginal costs, w.l.o.g.) and facing a demand given by $p = A - q$. Suppose now that there is a futures market in which both firms may sell part of their production. Denote by s_i and f_i the quantities sold in the spot and futures market respectively ($q_i = s_i + f_i$). If positions in the forward market are observable, given f_1 and f_2, in the spot market firm i solves:

$$\begin{array}{ll} \max & ps_i \\ \text{s.t.} & p = A - f_1 - f_2 - s_1 - s_2 \\ & s_i = q_i - f_i \end{array}$$

Which gives: $q_i = \frac{A+2f_i-f_j}{3}$, $p = \frac{A-f_1-f_2}{3}$.

Anticipating this reaction, firms' position in the futures market is calculated as follows:

$$\begin{array}{ll} \max & pq_i \\ \text{s.t.} & q_i = \frac{A+2f_i-f_j}{3} \\ & p = \frac{A-f_1-f_2}{3} \end{array}$$

The solution to this problem is $f_i = \frac{A-f_j}{4}$. Solving the whole problem, one finds $f_i = p = s_i = \frac{A}{5}$, $q_i = \frac{2}{5}A$, and $\Pi_i = \frac{2}{25}A^2$. The equilibrium is thus showing a pro-competitive effect of futures market as the Cournot equilibrium without forward market is $q_i = p = \frac{A}{3}$, with $\Pi_i = \frac{A^2}{9}$. This is the result in Allaz and Vila (1992).

Without observability, Hughes and Kao (1997) conclude a totally different story. If forward positions are not observable, the reaction functions derived from the first of the previous problems require that non observed variables be conjectural:

$$q_i = \frac{A + f_i - q_j'}{2}$$

Where q_j' is anticipated to follow the same reaction:

$$q_j' = \frac{A + f_j' - q_i'}{2}$$

Solving this second system, taking into account that in equilibrium conjectures have to be correct, one finds:

$$q_i' = \frac{A + 2f_i' - f_j'}{3}$$

Finally, reaction functions become:

$$q_i = \frac{A + \frac{2}{3}f_i + \frac{1}{3}f_i' - f_j'}{3}$$

Then, the problem of deciding the positions in the forward market is:

$$\begin{array}{ll} \max & pq_i \\ \text{s.t.} & q_i = \frac{A+\frac{2}{3}f_i+\frac{1}{3}f_i'-f_j'}{3} \\ & q_j = \frac{A+\frac{2}{3}f_j+\frac{1}{3}f_j'-f_i'}{3} \\ & p = A - q_1 - q_2 \end{array}$$

The solution of this problem gives $f_i = \frac{f_j - f_j'}{2}$. In equilibrium $f_j = f_j'$, leading to the Cournot solution with $f_1 = f_2 = 0$. Hence observability is a necessary condition to obtain the pro-competitive effect in the presence of futures markets.

3 The many periods model. Two very different conclusions

According to A&V, if firms are allowed to hold positions at multiple periods in the forward market, the pro-competitive effect is enhanced. Furthermore, the competitive outcome is the limit of the equilibrium outcomes as the number of periods T goes to infinity. The equilibrium is given by $p = s_i = f_i^t = \frac{A}{3+2T}$, $q_i = A\frac{1+T}{3+2T}$. Notice that the position in the futures market in every period (f_i^t) is the same. As T goes to infinity, prices goes to zero and total future positions converge to A, although in every period the position becomes zero (infinitesimal).

The interest of the above result is limited as we will argue. There are many games in which the limit of equilibria in finite versions of a model does not coincide with the equilibria in the infinite version. Game Theory shows many examples of this phenomenon. Our point to the model is precisely that it constitutes another such an example. To show this, consider, then, that $T = \infty$. In proposition 1 we sustain the Cournot outcome as an equilibrium of the game, but before we need to be more precise about the number and timing of the periods to hold positions in the futures market. For this, we will consider that the game starts at moment $t = 0$, that the spot market takes place at moment $t = 1$, and that positions in the futures market can take place in discrete amounts at any time in the interval $[0, 1)$. Since our result will be based in the sustainability of holding no positions in the futures market, we need to find a way to detect deviations from this behavior (see that in the equilibrium above, in the limit case, positions in every period are zero). There are several possibilities. One is to define and evaluate a function $f_i(t)$ that measures the positions in the futures market by firm i at each point in time (in this case, we want it to be zero in our equilibrium instead of $\frac{A}{2}$ as in the limit case of A&V). However, this approach has many problems as one has to define what it means a strategy like "hold no positions in the future market, except if the rival does, in which case, sell in this market immediately after this observation" (see Myerson, 89 for the difficulties in defining this kind of strategies in continuous time models). To overcome this difficulty, in equilibrium firms revise their strategy at times $t_1 = \frac{1}{N}$, $t_2 = t_1 + \frac{1}{N}(1-t_1)$,..., $t_k = t_{k-1} + \frac{1}{N}(1-t_{k-1})$,... That is, we divide the interval $[0, 1)$ in subintervals such that each one has a length of $\frac{1}{N}$ of the remaining time. Denote by f_i^t the quantity that firm i sells in the futures market at time t. Finally let $F_i^t = \sum_{\tau \le t} f_i^\tau$ be the accumulated futures positions by firm i at time t and define $F^t = F_1^t + F_2^t$ and $F = F^1$ (i.e., total of futures positions at the time of the spot market).

Proposition 1 *Let the duopoly game be described with the interval* $[0, 1)$ *as the time to hold positions in the futures market. Then, the Cournot outcome is sustainable in equilibrium.*

Proof: Consider the following strategy:

(i) Firm i holds no positions in the futures market in $t \in [0, t_1]$, $(F_i^{t_1} = 0)$. The game is said to be in state C (after Cournot) at the beginning of play.

(ii) The game remains in state C at time t as long as $F_i^{t_k} = 0$ for all $t' \leq t_k \leq t$, where t' is the last period in which a change of state occurred. If the game is in state C at time t_l play $f_i^{t_l} = 0$.

(iii) If the game is in state C and firm j plays $f_j^{t_k} > 0$, the game goes to state P_j (after punishment).

(iv) If the game has changed from state C to state P_j at moment t, with $t_k < t \leq t_{k+1}$, then firm i plays $f_i^{t_{k+1}} = \frac{1}{4}(A - F^{t_k})$, where F^{t_k} is the total of positions in the futures market by both firms at that moment.

(v) After the game has changed from state C to state P_j at moment t as in (iv), it changes back to state C if firm i plays $f_i^{t_{k+1}} = \frac{1}{4}(A - F^{t_k})$ and firm j plays $f_j^{t_{k+1}} = 0$. If only firm $k (= i, j)$ plays differently, the state changes to state P_k. If both play differently, the game still goes back to state C.

(vi) In the spot market, firms sell $s_i = \frac{A-F}{3}$, where F is the total of positions in the futures market at time one.

This strategy profile gives each firm the Cournot payoff. To prove the proposition, we have to show that at no point there is a profitable deviation by one firm. Consider, first, the best deviation in the first period for firm j, anticipating firm i's reaction and assuming no further deviations by any of them. To find this deviation, firm j solves:

$$
\begin{aligned}
& \max\ pq_j \\
\text{s.t. } p &= A - q_i - q_j \\
q_j &= f_j^{t_1} + s_j \\
q_i &= f_i^{t_2} + s_i \\
f_i^{t_2} &= \frac{1}{4}(A - f_j^{t_1}) \\
s_k &= \frac{A - f_j^{t_1} - f_i^{t_2}}{3}
\end{aligned}
$$

The solution to this problem gives $f_j^{t_1} = \frac{A}{3}$, $f_i^{t_2} = \frac{A}{6} = s_k = p$, $q_j = \frac{A}{2}$, $q_i = \frac{A}{3}$, $\Pi_j = \frac{A^2}{12}$, $\Pi_i = \frac{A^2}{18}$. Since $\Pi_j = \frac{A^2}{12} < \frac{A^2}{9}$, the Cournot's profits, we conclude that no one-shot deviations are profitable in state C with no future positions having taken place in the past. The same conclusion holds for one-period deviations at any other time τ since at the beginning of each period in which strategies may change the game is identical to the original (the only difference being that A is replaced with $A - F^{\tau}$, to account for possible past futures positions). Again, a deviation by firm j when the game is at state P_j is not profitable because it would work as a deviation in state C, but with firm j expecting the Cournot outcome of the residual demand after substracting the total of positions in the futures market and, thus, the similar maximization problem will prove any deviation unprofitable. Finally, deviations in more that one period will induce a punishment that makes each one of the one-period deviations unprofitable. ∎

This result has the resemblance of Folk Theorems in Game Theory. However, the infinite version of the basic model is not a repeated game, and Folk theorems cannot be invoked to prove proposition 1. In particular, subgames are different if they come after a different history in terms of the accumulated futures positions. Hence, subgames in later periods are, in general, a reduced version of the original game (because of the reduced residual demand), and one has to make sure that payoffs in the remaining game are sufficient to sustain punishments. Nevertheless, we can obtain a Folk Theorem-like result in the sense that any price between perfect competition and Cournot can be obtained as an equilibrium, and with arbitrary distribution of profits between the firms. To see this, consider the price $p \in \left[0, \frac{A}{3}\right]$, and the total quantity $q = A - p$. Consider, then, quantities q_1 and q_2 such that $q_1 + q_2 = q$, and distribute them between the spot and the futures market solving the following system of equations:

$$\begin{aligned} s_1 &= s_2 = \frac{A - f_1 - f_2}{3} \\ s_1 + f_i &= q_i \end{aligned}$$

Then, the strategy that consists of selling f_1 and f_2 in the first interval $[0, t_1]$, and supporting the Cournot outcome of the residual demand in the game starting at t_1 is a subgame perfect equilibrium.

In this work we concentrate on the robustness of the pro-competitive effect of forward markets. To this end we remark the following properties of the equilibrium in proposition 1.

Remark 1. The strategy is very simple although formally it requires some elaboration. Firms hold no positions in the futures market unless the rival does, in which case the later sells in this market as well.

Remark 2. During the punishment period, the deviating firm gets hurt while the rival benefits with respect to the strategy that forgets the deviation and continues as in the original plan.

This last remark provides the intuition why the equilibrium is renegotiation-proof as formally defined next and stated in proposition 2.

Definition 1. A subgame perfect equilibria s is said to be strongly renegotiation proof (SRP) if there is no other subgame perfect equilibrium s' and a subgame g such, for all players $U_i^g(s) > U_i^g(s')$. Where $U_i^g(.)$ is the utility for player i of following a given strategy conditioned to the game being in subgame g.

This concept of SRP is originally defined for repeated games (see Bernheim and Ray, 1989 and Farrell and Maskin, 1989). Here we presented its natural extension to standard extensive form games. Note that the definition of SRP is very strong. One equilibrium may fail the test because there exists another subgame perfect equilibrium which, conditioned on some subgame, gives higher payoffs, but nothing is said about the viability of this other equilibrium. Weaker versions of renegotiation-proofness have been suggested, but we don't need to bother about that since, as proposition 2 shows, the equilibrium described in proposition 1 already satisfies this strongest version of renegotiation proofness.

Proposition 2 *The equilibrium described in proposition 1 is a strongly renegotiation-proof equilibrium.*

Proof: It is enough to check that there is no other subgame perfect strategy profile that gives both firms more profits than the equilibrium.

Case 1. At the beginning of the game: Cournot is the only equilibrium in the spot market and any equilibrium in which future positions are not zero necessarily causes the price and total profits to drop. Hence at least one firm losses.

Case 2. In a subgame when a punishment takes place: Suppose that the game is in a subgame that starts in stage P_j. Total profits are reduced if the total quantity sold in the futures market increases. The only possibility, then, for total profits to increase is that firm i reduces its position in the futures market (in equilibrium firm j has no such positions in this subgame). But if firm i reduces its positions in the futures market, its profits are reduced. To see this, notice that $f_i = \frac{1}{4}(A - F^t)$, solves the following problem:

$$\begin{aligned} &\max \quad pq_i \\ \text{s.t. } q_i &= \frac{A + 2f_i - F^t}{3} \\ p &= \frac{A - f_i - F^t}{3} \end{aligned}$$

This is the problem of calculating the best strategy in the futures market for firm i given the residual demand $A - F^t$, given that firm j holds no more futures positions, and given that both firms compete a la Cournot in the spot market. I.e., the strategy in state P_i requires firm i to use its best position compatible with the equilibrium behavior. Given this, no other equilibrium strategy will give this firm more profits.

Case 3. Subgames after a punishment stage: These subgames are the same as case 1, except for the size of the residual demand, which is irrelevant for the argument. ■

In a more general setting, firms would be able to both sell and buy in the futures market. In this case, firms can do better if each produces half the monopoly quantity. This is shown in the next proposition.

Proposition 3 *If firms are allowed to buy in the futures market. The monopoly price and quantity can be achieved in a strongly renegotiation-proof subgame perfect equilibrium.*

Proof: The proof is the same as propositions 1 and 2, except that we make $f_i^{t_1} = -\frac{A}{4}$. The negative sign meaning a buy. One has only to check that, by doing so, the result is indeed the monopolistic outcome. For this, see that if firms follow the strategy, the solution in the spot market requires (see the basic model): $q_i = \frac{A+2f_i-f_j}{3}$, $p = \frac{A-f_1-f_2}{3}$, which, in this case it means $q_i = \frac{A}{4}$, $p = \frac{A}{2}$, i.e., the monopoly price and quantity. ■

4 The role of observability

In this section we study the role of observability in more detail. According to H&K, the pro-competitive effect in A&V takes place only if positions in the futures market are observed. If they are not, the equilibrium reverts to Cournot. However, their result is based in a hidden assumption. Namely, that the observation of the action made by other firms is the only way in which firms learn about their behavior. In general this is not true. In our (and their) model, firms observe prices. From them, they can deduce the quantities. Next we formalize this argument and show that A&V's result still holds in this case. Then we include an explicit formulation of H&K's hidden assumption in the model and show that, contrary to these authors, when firms have no information (direct or indirect) about the futures market, the equilibrium reverts, not to Cournot, but to perfect competition. We discuss the implications of these two results in comparison to H&K.

4.1 Futures market is sensitive

To better understand the argument, start with the Cournot equilibrium in H&K when there is no observability (we are in the basic model with only one period to sell in the futures market): $f_1 = f_2 = 0$, $s_i = q_i = p = \frac{A}{3}$. If the second firm decides to sell $f_2 > 0$, the price will change (the no-arbitrage condition implies only one price). This is true even if there is no reaction by the first firm to this action, since firm 2 will produce in the spot market according to the reaction function

$$s_2 = \frac{A - f_2 - s_1}{2},$$

as $f_2 > 0$ and $s_1 = \frac{A}{3}$, we have

$$q_2 = f_2 + s_2 = f_2 + \frac{A - f_2 - \frac{A}{3}}{2} = \frac{A}{3} + \frac{1}{2}f_2 > \frac{A}{3}$$

This higher quantity can only be sold at a lower price $p < \frac{A}{3}$. Since the price is observed by firm 1, it can deduce firm 2's action. Hence, firm 2 can count on a reaction by firm 1. To compute the equilibrium, consider the following facts:

(i) An equilibrium price p in the spot market means a total equilibrium quantity of $A - p$.

(ii) Total quantities offered by the two firms (q_1 and q_2) must be divided between the two markets in a way so that (a) spot quantities constitute a Cournot equilibrium in the residual demand after discounting futures' positions and (b) futures' positions are the best decision for each firm when the spot decisions are anticipated.

These are precisely the conditions that lead to the result in A&V. Thus we have proved the following proposition:

Proposition 4 *Suppose that two firms compete as in the basic model described above. Then, the observability of the positions in the futures market makes no difference in the equilibrium.*

Naturally, the same conclusion holds for any number of periods in the futures market. In other words, for finitely many periods (and its limit in the infinite case) in the futures market, the result in A&V is independent of observability and so is our result for infinitely many periods.

4.2 Futures market is not sensitive

Another possibility is that the demand in the futures market does not react to deviations made by the firms. This is an explicit modeling of the hidden assumption in H&K, and implies the possibility of different prices in the two markets as a result of deviations form equilibrium. The model then must not allow any arbitrage between them. However, in equilibrium, both prices have to coincide since the equilibrium must be anticipated by all players in the game.

First we see why Cournot is not an equilibrium in this situation. Consider, then, that firm 1 changes plans to sell $f_1 > 0$. Because of the insensitivity, the price in the futures market remains $p_f = \frac{A}{3}$. If this is the case, firm 1 better sells everything the demand can absorb in this market, $f_1 = A - s_2 = \frac{2A}{3}$. Profits change from $\frac{A^2}{3}$ to $\frac{2A^2}{3}$. In the spot market, the residual demand is given by $p_s = A - f_1 - s_2 = 0$, if firm 2 does not change its strategy ($s_2 = \frac{A}{3}$). The equilibrium is given in the next proposition:

Proposition 5 *Suppose that two firms compete as in the basic model described above. If the price in the futures market is insensitive to variations in the quantity, in equilibrium* $f_1 + f_2 = A$, $p_s = p_f = s_i = 0$.

Proof: We show that if $p > 0$, there is no equilibrium. Suppose that firms produce s_i and f_i, such that the price is $p = A - s_1 - s_2 - f_1 - f_2 > 0$, both firms have an incentive to sell all they can in the futures market at that price. This gives $f' = f_1' + f_2' = A - p > f_1 + f_2$ if for a firm i, s_i is greater that zero. This means that $p > 0$ is not an equilibrium as at least one firm is deviating (there is a firm j with $f_j' \neq f_j$). Hence, the equilibrium requires $f_1 + f_2 = A$, $p_s = p_f = s_i = 0$. ■

A possible objection to this version of the model (apart form the insensitivity assumption) may be the following. Consider again the strategy consisting of not selling in the futures market and selling the Cournot quantity in the spot. Even if there are many agents in the futures market, some of them should detect the deviation consisting of a firm selling a positive amount in this market. Knowing this, they have to anticipate a lower price in the spot market and, consequently, negotiate a lower price in the futures market as well. In other words, the assumption of an insensitive demand in the futures market is contradictory with the rest of the model. There are at least two possible justifications. If there are many agents, the deviating firm may sell only a little to each of them, who observes then a small quantity and anticipates a small change in the price. If this amount is small enough, the analysis may ignore it. Alternatively, the action of selling $f_i = 0$ may be interpreted as an ideal description of a reality that is closer to $f_i = \epsilon$, where ϵ is arbitrarily small. In this case, the deviation of selling small quantities to different agents may not be interpreted as a deviation at all. If there are many periods to take positions in the futures market, the result is exactly the same. Firms will sell everything in their first opportunity, regardless of whether in posterior moments in the futures market agents learn what has happened.

4.3 Partial and random sensitivity

For a strategy profile (f_1, f_2, s_1, s_2) to be an equilibrium candidate, it must be that $p_f = p_s = A - f_1 - f_2 - s_1 - s_2$. Consider a deviation from this strategy $f_1' > f_1$, which induces a price in the spot market $p_s' = A - f_1' - f_2 - s_1 - s_2$. We can model partial sensitivity as $p_f' = p_f - \delta(f_1' - f_1)$, where p_f' is the price in the futures market if the deviation takes place. Notice that if $\delta = 1$, $p_f' = p_s'$ (case 1), and that if $\delta = 0$, $p_f' = p_f$ (case 2). However, in this way, firms still may deduce the quantities in the spot market trough the price, taking into account the correction factor δ. The result is the same as case 1.

In order to make the hypothesis of partial sensitivity meaningful, one may introduce a random factor. This has the effect of making it difficult for players to know whether a given price is due to a position in the futures market or to this random factor. Then let $p_f = p_s + \delta$, where δ is now a random variable with mean $\delta_m \in \left[0, \frac{A}{6}\right]$. The equilibrium is now more interesting in the sense that is midway between the result in A&V and the perfect competition.

Proposition 6 *Let the basic model include the randomness indicated above. Then, the equilibrium (in interior solutions) is given by* $f_i = \frac{A+9\delta_m}{5}$ *and* $s_i = p_s = p_f = \frac{A-6\delta_m}{5}$.

Proof: The equilibrium must satisfy (i) and (ii)(a) in case 1. Condition (ii)(b) must be replaced with $p_f = p_s + \delta$. This means that, in the futures market, firm i must solve

$$\max E\{p_f f_i + p_s s_i\}$$

$$\text{s.t. } p_f = p_s + \delta$$
$$s_i = p_s = \frac{A - f_1 - f_2}{3}$$

which gives the solution $f_i = \frac{A+9\delta_m}{5}$ and $s_i = p_s = p_f = \frac{A-6\delta_m}{5}$. ■

Notice that $\frac{A}{2} \geq \frac{A+9\delta_m}{5} \geq \frac{A}{5}$ and $0 \leq \frac{A-6\delta_m}{5} \leq \frac{A}{5}$. The result in case 1 (right hand side of these expressions) is obtained with $\delta_m = 0$, while the result in case 2 (left hand side) is obtained with $\delta_m = \frac{A}{6}$.

5 Uncertainty

Suppose now that the demand is not known until firms compete in the spot market. If firms continue to be risk neutral, it would be optimal for them not to sell in the futures markets and produce the Cournot in the spot market given the realization of the demand. The change with respect to the model without uncertainty is the complication that arises when one tries to support that strategy as an equilibrium that is not only subgame perfect but strongly renegotiation proof as well. Among other things, one has to check what happens in subgames that start after firms have sold some quantities in the futures markets. Without uncertainty, we were able to argue that the remaining game was a reduced version of the original one, and that one could apply the same arguments as before to rule out more positions in the forward market. However, with uncertainty, this is not the case, since it can be that for some realizations of the demand, the positions already hold in the futures market are more than what the demand can absorb at a positive price. This means that we have a corner solution in the spot market. Furthermore, since the uncertainty becomes bigger relative to the size of the residual demand as we consider subgames with more positions in the forward market, we cannot restrict ourselves to the cases in which the uncertainty is small enough compared to the original demand in order to neglect these cases of corner solutions. In other words, the remaining game is not a reduced version of the original.

To simplify things, consider a simple way of introducing uncertainty, namely, that the term A in the demand is a random variable that takes values a or b ($a > b$) with equal probability. Now we can state and prove the following proposition.

Proposition 7 *Let the duopoly game be described with the interval* $[0, 1)$ *as the time to hold positions in the futures market and with the uncertainty* *as described above. Then, the Cournot outcome in each realization of the demand is sustainable in a strongly renegotiation-proof equilibrium.*

Proof: Consider the strategy in proposition 1, except for the following:

(iv)' If the game has changed from state C to state P_j at moment t, with $t_k < t \leq t_{k+1}$, then firm i plays $f_i^{t_{k+1}}$ calculated to be the best response by firm i to the strategy that involves no more forward positions by firm j.

(v)' After the game has changed from state C to state P_j at moment t as in (iv)', it changes back to state C if firm i plays $f_i^{t_{k+1}}$ and firm j plays $f_j^{t_{k+1}} = 0$. If only firm $k(= i, j)$ plays differently, the state changes to state P_k. If both play differently, the game still goes back to state C.

(vi)' In the spot market, firms sell $s_i = \max\left\{\frac{a-f}{3}, 0\right\}$ or $s_i = \max\left\{\frac{b-f}{3}, 0\right\}$, depending on the realization of the demand, where f is the total of positions in the futures market.

The proof consists of showing that this strategy is, in fact, a strongly renegotiation-proof equilibrium. The complete proof with the details about corner solutions are left to the appendix. ■

If firms are allowed to buy in the futures market, they can do better. If positions in the futures market are $f_1 = f_2 = f$ (in the symmetric case), in the spot market, the solution will be $p_a = s_a = \frac{a-2f}{3}$, $p_b = s_b = \frac{b-2f}{3}$, and then $p_f = \frac{a+b-4f}{6}$. The expression for joint profits in the futures market is $2\left(\frac{1}{2}p_a s_a + \frac{1}{2}p_b s_b\right) - 2p_f f$ with solution $f = -\frac{a+b}{8}$. This implies $p_a = s_a = \frac{5a-b}{12}$, $p_b = s_b = \frac{5b-a}{12}$, $q_a = s_a + f = \frac{7a-b}{24}$, and $q_b = s_b + f = \frac{7b-a}{24}$. Notice that $q_a > \frac{a}{4}$, $q_b < \frac{b}{4}$, half the monopolist outcome in the two possible realizations of the demand. Thus, in the presence of uncertainty, firms cannot support the monopolist outcome, but they can improve upon Cournot. This outcome can be sustained in a strongly renegotiation-proof equilibrium as a corollary of proposition 7, just repeating the same proof.

Corollary 1. Let the duopoly game be described with the interval $[0, 1)$ as the time to hold positions in the futures market and with the uncertainty as described above. Then, the outcome $q_a = s_a + f = \frac{7a-b}{24}$, $q_b = s_b + f = \frac{7b-a}{24}$ is sustainable in a strongly renegotiation-proof equilibrium.

The case of non zero costs makes a difference in this case. Until now one needed only to replace A with $A - c$ to consider the case of positive marginal costs and observe no difference in the results. However, with uncertainty, the possibility of $b - c$ being negative requires that one has to take into consideration the corner solution in which the price is bellow costs, but still positive, but the quantity in the spot market is zero. This complicates a lot the study of corner solutions for proposition 7 and its corollary. Obviously, by continuity, small costs will make no difference in the proofs. Since our goal is to provide a counter-argument to existing literature, we prefer to show clarity rather that generality.

5.1 Risk aversion

If firms are risk averse, they will be willing to reduce their risk by selling part of their production at a known price before the spot market takes place. This means that firms have a clear incentive to use the futures market. In the simple model of only a limited number of periods in the futures markets, this effect enhances the strategic effect studied above. However, in the case of an undetermined or infinite number of moments to sell in the futures market, there is a more complicated interaction. Since our goal is to study the robustness of the pro-competitive effect of these markets, we concentrate in the possibility of maintaining the Cournot outcome even in the case of uncertainty as a robust equilibrium, as we argued in the perfect information case.

Since the uncertainty is resolved in the spot market. Firms would play the Cournot outcome in each realization of the demand after substracting the positions in the futures market. The absence of a pro-competitive effect, understood in the strongest sense, means that futures market positions are zero. However, this may not be the best thing for the firms. Since they are risk averse, they may be willing to sell part of their production in advance at the cost of increasing the total quantity because of Cournot competition in the spot market. They may gain in utility even if they lose in expected profits. In other words, in may be Pareto improving to have some quantities sold in the futures market. Consumers benefit from a lower price and firms benefit from a reduction in risk. This effect, however, is more properly attributed to the risk aversion of firms rather that to the presence of the futures market (see that with risk neutrality, there may be no positions in the futures markets as we saw in the previous sections).

6 Conclusion

An existing literature shows a pro-competitive effect when introducing a futures market in an oligopolistic industry. We have shown that this do not need to be the case. In fact, the presence of the futures market may have the opposite effect. Our model fits better some stylized facts found in the U.K. power market where the use of the futures market is not seeing as having a pro-competitive effect. Furthermore, our model is consistent with the fact that firms prefer the more opaque of the two existing futures market. In A&V firms prefer the more transparent to gain from showing a commitment to sell. We have shown that, if markets are sensitive, this transparency is irrelevant for this strategic behavior. However, there may be other uses for the opaque market. For instance, firms may translate collusive behavior from the spot to the futures market, where it cannot be observed by the regulator. This behavior may be in the form of buying in the futures market (as seen in proposition 2 and corollary 1) or maybe by provoking a high volatility in the spot market to induce smaller firms to use the futures market, where the colluding firms have a dominant position. This last point was mentioned as a possibility in OXERA, 1994, and its formalization is left for future research.

Other lines of investigations include the extension to a bigger number of firms and to a more general demand and cost functions. Our point was more to show a counter-argument to the previous literature than to be as general as possible.

One may think that, if collusion is possible, then firms will collude in the spot market, thus rendering these strategic considerations somehow irrelevant. However, the opportunities and costs of colluding may not be same in both markets (for instance if the futures market is opaque to the regulator).

Finally, our work has immediate implications for economic policy: make the futures market as transparent as possible and do not allow firms to buy in the futures market.

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Appendix

Proof of proposition 7:
Case 1. Interior solutions. $F \leq \frac{3b-a}{2}$

First calculate $f_i^{t_k+1}$. For that, notice that $s_l = p_l = \frac{l-F-f_j^{t_k}-f_i^{t_k+1}}{3}$, $l = a, b$ are the Cournot quantities and prices in the spot market. Given that, firm i solves the following problem in the futures market:

$$\max \frac{1}{2}\left(f_i^{t_k+1}p_f + s_a p_a\right) + \frac{1}{2}\left(f_i^{t_k+1}p_f + s_b p_b\right)$$

$$\begin{aligned} \text{s.t. } s_a &= p_a = \frac{a - F - f_j^{t_k} - f_i^{t_k+1}}{3} \\ s_b &= p_b = \frac{b - F - f_j^{t_k} - f_i^{t_k+1}}{3} \\ p_f &= \frac{1}{2}p_a + \frac{1}{2}p_b \end{aligned}$$

The solution to this problem gives the following values:

$$\begin{aligned} f_i^{t_k+1} &= \frac{a+b-2F-2f_j^{t_k}}{8} = p_f \\ s_a &= p_a = \frac{7a-b-6F-6f_j^{t_k}}{24} \\ s_b &= p_b = \frac{7b-a-6F-6f_j^{t_k}}{24} \end{aligned}$$

Given the reaction of firm i, firm j's best one period deviation is calculated solving:

$$\max \frac{1}{2}\left(f_j^{t_k}p_f + s_a p_a\right) + \frac{1}{2}\left(f_j^{t_k}p_f + s_b p_b\right)$$

subject to the above equalities,
the solution gives the values:

$$\begin{aligned} f_j^{t_k} &= \frac{a+b-2F}{6} = p_f \\ f_i^{t_k+1} &= \frac{a+b-2F}{12} \\ s_a &= p_a = \frac{3a-b-2F}{12} \\ s_b &= p_b = \frac{3b-a-2F}{12} \end{aligned}$$

For $s_b = p_b = \frac{3b-a-2F}{12}$ to be positive, it must be the case that $F \leq \frac{3b-a}{2}$. Profits of firm j are:

$$\begin{aligned}\Pi_j^d &= \Pi_j\left(F, f_j^{t_k} = \frac{a+b-2F}{6}, f_i^{t_{k+1}} = \frac{a+b-2F}{6}\right) = \\ &\frac{a+b-2F}{6}\frac{a+b-2F}{12} + \left(\frac{1}{2}\left(\frac{3a-b-2F}{12}\right)^2 + \frac{1}{2}\left(\frac{3b-a-2F}{12}\right)^2\right)\end{aligned}$$

If firms hold no more positions in the futures market, profits will be (see that $F \leq \frac{3b-a}{2} < b$) :

$$\Pi_j^c = \Pi_j\left(F, f_j^{t_k} = 0, f_i^{t_{k+1}} = 0\right) = \frac{1}{2}\left(\frac{a-F}{3}\right)^2 + \frac{1}{2}\left(\frac{b-F}{3}\right)^2$$

One can check that $\Pi_j^c \geq \Pi_j^d$ as long as $F \leq \frac{a+b}{2} < \frac{3b-a}{2}$.

Case 2: $\frac{3b-a}{2} < F \leq 0$. To alleviate notation, let $f_j^{t_k} = g, f_i^{t_{k+1}} = f$. Firm i (risk neutral) solves the following problem in the futures market:

$$\begin{aligned} &\max \ \frac{1}{2}(fp_f + s_a p_a) + \frac{1}{2}(fp_f + s_b p_b) \\ \text{s.t. } s_a &= p_a = \frac{a-F-g-f}{3} \\ p_b &= s_b = 0 \\ p_f &= \frac{1}{2}p_a \end{aligned}$$

with the solution:

$$f = s_a = p_a = \frac{a-F-g}{4}$$

$$p_f = \frac{a-F-g}{8}$$

Given firm i's reaction. Best deviation for firm j:

$$\max gp_f + \frac{1}{2}s_a p_a$$

subject to the above equalities, i.e., maximize:

$$g\frac{a-F-g}{8} + \frac{1}{2}\left(\frac{a-F-g}{4}\right)^2$$

which gives:

$$g = \frac{a-F}{3}$$

substituting:

$$f = s_a = p_a = \frac{a-F}{6}$$

$$p_f = \frac{a-F}{12}$$

Difference in profits for firm j by deviating (Π (deviation) $-$ Π (no deviation)):

$$\frac{a-F}{3}\frac{a-F}{12} + \frac{1}{2}\left(\frac{a-F}{6}\right)^2 - \frac{1}{2}\left(\frac{a-F}{3}\right)^2 < 0$$

this inequality holds for the values of F is case this case.

Case 3: $a \leq F$:

In this case, $s_a = s_b = 0$ which implies zero prices and no profit from selling more.

Finally, the proof of strongly renegotiation-proofness is analogous to that in proposition 2. ■

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