The Strategic Motive to Sell Forward: Experimental Evidence[1]

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Abstract:

We test the strategic motive to sell forward in experimental Cournot duopoly and quadropoly environments with two forward markets. The strategic motive to sell forward is seldom observed for a duopoly as once experienced subjects seldom use forward markets. Production mostly occurs in the spot market phase and output produced is frequently close to the monopoly level for an experienced duopoly. The presence of forward markets helps subjects in coordinating their actions. Output levels are also less than the Cournot Nash equilibrium prediction for a quadropoly. Interestingly, subjects select output levels of zero in both the market structures to signal collusion in the spot phase. Our experiments reject the strategic motive to use forward markets as is proposed by Allaz and Vila (1993) and instead suggest that forward markets may help (once) experienced sellers to coordinate actions.

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1. Introduction

Does the strategic motive in using forward markets enhance competition? The little experimental (Le-Coq and Orzen (2006) and Brandts et al. (2008)) and empirical literature (Wolak, 2000) agrees with this assertion. Theory, however, is not clear on the issue. Allaz (1992) and Allaz and Vila (1993) suggest pro-competitive outcomes while Ferreira (2003), Mahenc and Salanie[2] (2004) and Liski and Montero (2005) suggest anticompetitive outcomes[3].

The experimental evidence points towards the fact that forward markets are competitive (Le-Coq and Orzen, 2006 and Brandts *et al.*, 2008). Le Coq and Orzen motivate their study based on Allaz and Vila (1993). In their experiments they have a single forward and a spot market phase. They show that, relative to the spot market, the introduction of forward markets does have competition enhancing effects. As predicted by theory subjects avail of the forward markets. Forward markets are not as competitive as theory predicts when there are two firms, but are not significantly different than the theory prediction for four players.

In the second experimental study, Brandts *et al.* motivate their study based on a specific design of forward markets in the electric power industry. They consider both quantity and supply functions as strategic variables. In a model following Allaz and Vila, they find that, indeed, subjects show a pro-competitive effect, and that they sell more if the model has a forward market compared with the situation in which this market is not available. Studying the effects of forward markets when 2, or 3, firms can submit quantities, or supply functions, they find that the introduction of forward markets has competition enhancing effects. Moreover, supply functions have efficiency enhancing effects in the presence of forward markets.

The empirical research on forward markets is scarce. For the Australian power market, Wolak (2000) shows that the effect is pro-competitive when firms use forward markets. One should, however, add a note of caution. Even though the use of forward markets is spreading, in many instances market regulation requires firms to participate in these markets. Most models described above agree that, when used, forward markets

[2] They study forward markets with price competition and differentiated goods.

[3] Other papers have explored aspects of the competition that may affect the strategic behavior of the forward markets. For example, Hughes and Kao (1997) and Ferreira (2006) study the observability of actions, Murphy and Smeers (2005) study capacity choice, Gans, Price and Woods (1998) and Newbery (1998) study entry, while Bushnell *et al.*(2008) study regulatory arrangements to promote forward contracting.

are pro-competitive. However, there is still the question whether firms will avoid competition by not using them when deciding in a non-regulated market.

In this paper we experimentally test the strategic motive to sell forward in experimental oligopolies[4]. We run our experiments with two and four firms with inexperienced and experienced[5] subjects. Both the duopoly and quadropoly participate in two forward markets prior to the spot phase. This implementation directly tests the model of Allaz and Vila (1993) where the number of forward periods is (exogenously) fixed by the experimenter[6]. We show that, with *once experienced* subjects, outcomes are towards the collusive side. Experimental duopolies result in near monopoly outcomes and quadropolies produce output below the Nash-Cournot prediction. Further, experienced subjects use forward markets much less compared to inexperienced subjects. Both duopolies and quadropolies avail less of the forward market as the experiment progresses. Our experiments suggest that forward markets may help subjects coordinate actions, an outcome that is contrary to their presumed competitive effects. Support for theory is only observed when subjects are inexperienced. In this case, average output, for both duopolies and quadropolies, is remarkably close to the theoretical prediction. Le-Coq and Orzen (2006) report similar results. However, in their case forward quantities and prices tend to be less competitive than the theoretical prediction for a duopoly and not significantly different from theory for a forward markets quadropoly.

It seems that forward markets, rather than promoting competition, help subjects coordinate their actions and arrive at collusive outcomes. The increase in competition, due to the prisoner´s dilemma nature of production in the presence of forward markets, is never observed with once experienced subjects. Output produced is on the collusive side.

The role of experience seems important especially in a complicated environment such as forward markets, where the results strongly rely on the strategic motive to sell forward. Experienced subjects use forward markets *much less* than their inexperienced counterparts. Further, by signaling zero output in the forward market stage subjects

[4] Note that Brandts *et al.* test the role of forward markets in a design specifically motivated by the electric industry.

[5] Ours is the first experimental study to look at the effect of experience in standard Cournot experimental oligopolies. In a quantity choosing game Nagel and Vriend (1999) study how experienced players adapt to a step model of adaptive behavior. The price of the commodity is fixed for all periods and firms send costly information signals to attract buyers.

[6] Le-Coq and Orzen (2006) study the exogenous close rule with just one forward market.

make clear their intention to collude. Both, experienced duopolies and quadropolies, select a zero output level in the forward markets in most periods. Duopolies operating in forward markets find it much easier to collude without explicit communication. A choice of lower output in the forward markets stage also implies lower output in the spot stage. Experience develops a better understanding of the market functioning and is a precondition (embedded in the rationality assumption) in most theoretical models. Our results support this and point towards the importance of running forward market experiments with experienced subjects.

The paper is structured as follows. In Section 2 we present the theoretical motivation behind the experiments. In Section 3 we present the experimental design. This is followed by the results in Section 4. Section 5 concludes.

2. Theory

In this part we outline the theoretical models that motivate our experimental design. We focus on Allaz (1992) and Allaz and Vila (1993). In a Cournot duopoly, Allaz (1992) shows that, if firms can sell in a forward market previous to the spot market, the strategic interactions result in a more competitive outcome. In a later paper, Allaz and Vila (1993) show that this pro-competitive effect increases as the forward markets open more often.

2.1 Allaz and Vila (1993)

Suppose there are n firms in an oligopolistic market that compete in quantity and face a linear demand $p = A - q$ with zero costs. If, previous to this spot market, firms can sell forward, standard Cournot analysis shows that, in equilibrium, Firm i will sell $s_i = \frac{A-F}{n+1}$ in this spot market, where F is the total of quantities sold in the forward market. The equilibrium price is $p_s = \frac{A-F}{n+1}$.

If there are 2 periods of forward markets, in period $t = 2$ Firm i will solve the problem

$$\max_{f_i^2} (f_i^2 + s_i) p_s ,$$

where $s_i = \frac{A-F}{n+1}$, and $p_s = \frac{A-F}{n+1}$.

Taking into account that now $F = \sum_{j=1}^{n} f_j^1 + \sum_{j=1}^{n} f_j^2$, with f_j^t as the quantity sold by Firm *j* in the forward market at time *t*.

We assume a no-arbitrage condition in solving this problem. This implies that forward and spot prices are equal. For example, Allaz (1992) shows that the introduction of arbitrageurs, that buy in the forward markets to sell in the spot, implies that there is no arbitrage in equilibrium. Substituting the arbitrageurs with the no-arbitrage condition gives the same results and simplifies the model. The solution of the problem for each firm gives the solution

$$f_i^2 = \frac{n-1}{n^2+1}(A - F^1), \text{ and } s_i = p_s = \frac{1}{n^2+1}(A - F^1),$$

where, $F^1 = \sum_{j=1}^{n} f_j^1$.

Now, in period 1 of the forward market, Firm i solves

$$\max_{f_i^1} (f_i^1 + f_i^2 + s_i) p_s ,$$

where $f_i^2 = \frac{n-1}{n^2+1}(A - F^1)$, and $s_i = p_s = \frac{1}{n^2+1}(A - F^1)$.

The solution of this problem for all firms gives

$$f_i^1 = \frac{(n-1)^2 A}{n^3 - n^2 + n + 1} .$$

The rest of the variables are found substituting this value in their corresponding expressions. When firms face identical, constant marginal costs *c*, $A - c$ replaces A in all of the above expressions, and the price will be given by the expression, $p_s + c = \frac{1}{n^2+1}(A - c - F^1)$.

3. Experimental design

Subjects were recruited from the undergraduate student populations at George Mason and Chapman Universities. They were told that the experiments will last around two hours[7]. Subjects were asked to commit to a series of two experiments and were told that a $20 fees will be paid to those that show-up for both experiments[8]. We report

[7] The number of experiments ran depended on subject show-up.

[8] For the experiments at GMU all subjects were not necessarily part of the same group for the second time.

results for both inexperienced and experienced subjects. In-experienced subjects were first time participants in output choice experiments. Table 1 summarizes experimental details.

Including the instructions the experiments finished in two hours (see Appendix for instructions). At the end of the instructions inexperienced subjects were required to play practice rounds against a computer before actually engaging in the game. For experienced players we added a tutorial where they were walked through several examples inputting specific values for output. The objective was to familiarize them with different output choices they, and others, may make during the experiment. It should be pointed out that the tutorial goes over similar kinds of examples that were used in the instructions for both inexperienced and experienced subjects. The texts of instructions and tutorial can be found in the Appendix. Table 1 summarizes the experimental details and parameters[9].

Table 1		
	Number of Experiments (# Subjects)	
	George Mason	Chapman
Inexperienced		
Duopoly	3 (6)	6 (12)
Quadropoly	4 (16)	-
Experienced		
Duopoly	4 (8)	6 (12)
Quadropoly	4 (16)	-
	Demand/Cost	Forward Markets
In- experienced	Q=105-P/15	2
Experienced	Q=60-P/0	2

To deal with the no-arbitrage condition, the forward market price in each of the forward markets periods is computed as the theoretical price that would prevail in the remaining periods if the theoretical model is solved with the residual demand. For example, in the duopoly case, let the total of sales in the first period of forward markets be 20. The program then computes a forward market price for that period as the equilibrium price (as in Allaz and Vila) with one period of forward markets and demand given by $p = A - 20 - q$.

[9] Note that, we were able to run 4 experienced duopolies as subjects who were participating in other (different) forward market experiments were recruited for the experienced pool.

Subjects could see own and others' output, price, and costs of the rivals for any past period. Rival identity is unknown in all the experiments and subjects were randomly re-matched after each period. Subjects are explained the process of price determination in the instructions, and given specific examples. They are provided with a calculator showing two output choices, "mine" and "others", and subsequent own profits. By resetting own and others' output they can estimate how their profits vary as either one of the two output changes. Furthermore, as an exercise in the instructions they are asked to input specific own and other outputs to view its subsequent effect on own profits. We felt that providing this guidance would facilitate the understanding of best response in the strict sense. Further, notice that the inexperienced and experienced experiments were run 5 weeks apart at George Mason University and 2 days apart at Chapman University.

Le Coq and Orzen (2006) were the first to directly test Allaz and Vila's model in the laboratory. Our experimental design, however, has several features that are different from theirs. First, subjects are randomly matched in each round of our experiments. Subjects in our experiments can be matched against the same partner with a positive probability, however, subjects do not observe rival identity which makes collusion and other group behavior very difficult. Given that random matching oligopoly experiments give more competitive outcomes (Huck et al, 2004) we chose this design to give the theory its best shot. Further, note that although theoretically the finite repetition of the game with only one equilibrium cannot generate cooperation, there is experimental evidence that subjects may still cooperate for some rounds if the game is long enough (Dal Bó, 2005).

Second, we run our experiments for nearly seventy rounds (Le-Coq and Orzen ran theirs for 30 periods). We do this to facilitate subject learning as forward markets are complicated mechanisms.

Third, we use two periods of forward markets. Two periods of forward markets make the market much more competitive than just one period, especially for the quadropoly case. This, together with the random matching, made a very pro-competitive experimental setting.

Fourth, we replicate the experiment with experienced subjects. Experiments on competitive markets show that they are robust to design changes. Experimental behavior in these markets is as theory predicts[10]. Forward markets, however, are more complicated[11]. Due to the scant experimental work on forward markets we run our experiments with experienced subjects as a robustness check. Typically real life agents in these markets are firms, or professional traders. It is reasonable to suppose that such agents possess a good working knowledge of these markets. Thus, it seems natural to check whether the experimental results are robust to experience.

4. Experimental results

4.1 A brief look

It will be useful to look at some summary statistics before we look at detailed results. Table 2 (*f* denotes forward markets) compares the theoretical and average values in the experiments for both the 2 and 4-firm case, for both inexperienced and experienced subjects. For completeness, it also shows the average quantities in LeCoq and Orzen (2006). For simplicity of exposition all quantities are expressed relative to the competitive amount (set to 100%).

Table 2: Summary Statistics (% of competitive)

Firms	Cournot (Monop.)	Allaz and Vila $f=1$	Allaz and Vila $f=2$	LeCoq and Orzen. In-experienced $f=1$	**Our experiments. In-experienced** $f=2$	**Our experiments. Experienced** $f=2$
N=2	66.66 (50)	80	85.71	75.04	**85.56**	**62.53**
N=4	80 (50)	94.1	98.11	100.74	**99.85**	**76.84**

Two results stand out in Table 2. First, the average behaviour of in-experienced subjects is in line with theory. While the average output observed for duopoly is near the prediction of the AV model, a quadropoly gives near competitive outcomes. Second, experienced subjects are less competitive and produce outputs below the Nash equilibrium level. This is especially true for duopolies where average output is not only far below the prediction of the AV model, but also below the 2-firms Cournot quantity. Further, a quadropoly is also less competitive with average output below the 4-firm Cournot level, and substantially below the prediction of the AV model.

[10] The Double-Auction institution is one example.

[11] In complicated environments it is common practice to report results for experienced subjects. For example, see Rassenti *et al.* (1994).

Comparing our summary results with Le-Coq and Orzen one sees that, in their experiments, a duopoly (quadropoly) is less (more) competitive than the Cournot-Nash prediction. Relative to the theory prediction, duopoly output in their experiments is marginally significant[12] while quadropoly output is significantly higher than predicted[13].

Output produced by a quadropoly is above the competitive level of output. This could be due to the fact that they had zero marginal costs. The presence of zero marginal costs, however, does not seem to matter for a duopoly. Relative to their results, ours are in line with theory. Average output produced by both, a duopoly and quadropoly, is remarkably close to the equilibrium prediction. Further, we find strikingly different behavior for experienced subjects. Experienced subjects are less competitive and manage to restrict production below the Cournot-Nash prediction both for duopolies and quadropolies. The output chosen in this case is significantly different from the theoretical prediction at any p-level.

4.2 A closer look at the data

Below we present results for two forward markets. Results for inexperienced subjects will be discussed first followed by results for experienced subjects.

4.2.1 Duopoly

Looking at summary data we know that inexperienced subjects behave according to theory. Analyzing how individuals make use of the forward and spot markets, we see that overall output chosen by inexperienced subjects is remarkably close to the theory prediction. Note, however, that the quantities chosen in forward markets are significantly different from the theoretical prediction. Interestingly, even though experienced subjects make use of forward markets in the earlier periods, later on they learn to avoid using them.

Table 3 compares theoretical predictions (inexperienced subjects) for the forward and spot markets against the observed quantities, and the theoretical quantity (given the production in the previous period). The theoretical prediction lists the sub-game perfect equilibrium quantities in each stage. The theoretical predictions for the residual demand are computed as the sub-game perfect equilibrium quantities in the sub-game.

[12] They report a p-value of 0.065 (p-41).
[13] They report p-value of 0.042 (p-41).

Thus, given the average of 35.68 units in the first forward stage, the rest of the game is that of a one-period forward market (Allaz and Vila) with demand $p = (100 - 35.68)q$. The theoretical prediction for the second period of forward markets in this sub-game is 25.73. Given the residual demand and the average production in the two forward markets, the theoretical prediction in the spot market is the Cournot equilibrium in the duopoly game with demand $p = (100 - 35.68 - 22.3)q$ (see Table 5).

We also compare subject behavior with the theoretical quantities in the residual demand (given observed quantities). We do this, because, we can regard as non-equilibrium behavior a choice that indeed is equilibrium behaviour, if we consider the appropriate subgame.

Table 3- Inexperienced duopoly:
Use of forward and spot markets.

	Forward 1	Forward 2	Spot	Total
Theoretical quantity	28.57	28.57	28.57	85.71
Observed quantity	**35.68**	**22.3**	**27.58**	**85.56**
Theoretical q. in the residual demand (given observed quantity)	**28.57**	**25.73**	**28**	**-**
p-value (obs. = theory) (t-test)	0 (8.05)	0 (11.0)	0.07 (1.47)	0.38 (0.29)
p-value (obs. = theory in resid. demand) (t-test)	0 (8.05)	0 (6.0)	0.268 (0.617)	-

As a benchmark it is useful to see what would happen if firms behaved competitively or as a monopolist. If firms behave as a monopolist in the residual demand of the spot market then the quantity is (½)(100-35.68-22.3) = 21.01. However, if firms behaved competitively in the residual demand of the spot market, then the market quantity is 42.02 (relative to the observed quantity of 27.58). We cannot reject the hypothesis that spot and total quantities are the ones dictated by the theory. The fit is even better if we make the comparison with the theoretical outcomes given the observed quantities.

With experience, subjects tacitly collude by not using forward markets. Given the theoretical values in the forward markets they sell more than the theory prediction in the spot market (but, less than the Nash-Cournot theory prediction given the observed use of forward markets). This is shown in Table 4. All quantities are statistically different from theory prediction (or from other quantities like Cournot, Monopoly or Perfect Competition[14].)

Table 4 - Experienced duopoly Use of forward and spot markets.				
	Forward 1	Forward 2	Spot	Total
Theoretical quantity	28.57	28.57	28.57	85.71
Observed quantity	**0.94**	**4.74**	**56.85**	**62.53**
Theoretical q. in the residual demand (given observed quantity)	**28.57**	**39.62**	**62.88**	**-**

Again, as a benchmark, the Monopoly and competitive quantities in the residual demand in the spot markets are (½)(100-0.94-4.74) = 47.16, and 94.32, respectively. Recall that the Cournot Nash Equilibrium in the absence of forward markets is 66.66. Given that the observed values are very far from the theoretical values we do not bother with the statistical tests.

Figures 1 and 2 below shed some light on choices made by inexperienced and experienced subjects. Quantities shown are the average individual quantities for each round. We observe a decreasing trend in the quantities as periods advance in both figures. To capture this tendency, we present an analysis of the data for the first and last ten rounds in Tables 5 and 6. For inexperienced subjects, the significant change between the first and the last 10 rounds is due to a shift from the forward to the spot market. That is, in later rounds subjects tend to sell less in the forward market and more in the spot, thus resulting in smaller sales.

We can have a clearer view of how subjects restrain output in a particular market if we analyze sales with respect to the equilibrium in the residual demand. In Table 5, what looks like a moderate 8.2% decrease (Observed-1 vs. Observed-2) of sales in Forward-2 (the second period of forward markets), is now seen as a 21.2% decrease. This is due to the fact that, given the quantity in Forward-1, more should have been sold in Forward-2 in the last ten rounds. Conversely, what looks like a strong increase in the spot market (52%) is, in fact, a moderate one (9.1%) if, instead of comparing absolute quantities, we compare the percentage of the equilibrium quantities that these quantities represent. Note that all changes are statistically significant except for the change in the spot market measured as a percentage of the theoretical quantity in the residual demand (RD).

[14] All p-values are zero.

Figure 1: Inexperienced duopoly

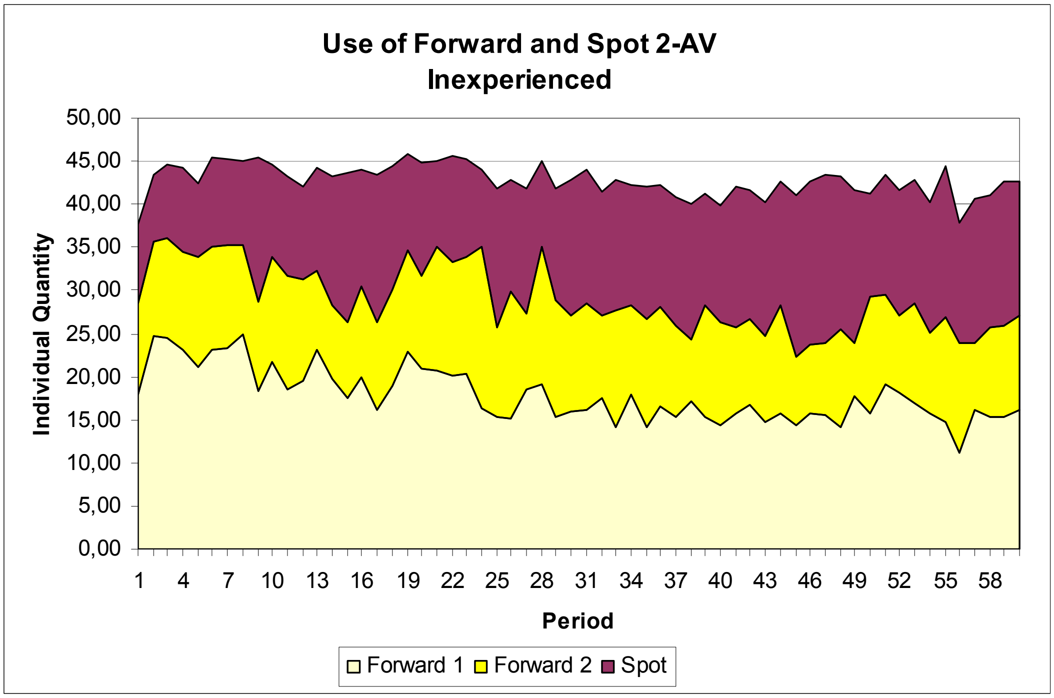


Figure 2: Experienced duopoly

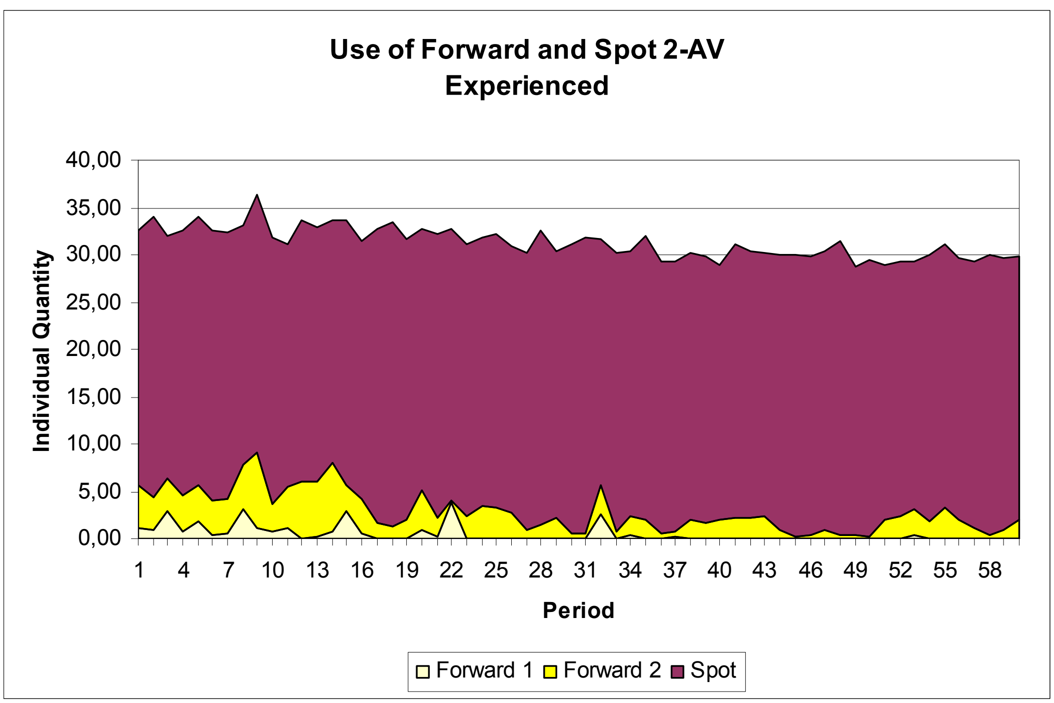


Table 5- Inexperienced duopoly Use of forward and spot-First and Last ten rounds					
		Forward-1	Forward-2	Spot	Total
Theory		28.57	28.57	28.57	85.71
First 10	**Observed-1 (as proportion of theory in RD)**	**44.54 (156)**	**22.86 (113)**	**20.26 (93)**	**87.64 -**
	Theoretical quantity in RD (given observed quantity)	28.57	22.18	21.73	-
Last 10	**Observed-2 (as proportion of theory in RD)**	**31.72 (111)**	**20.98 (89)**	**30.80 (101.82)**	**83.5 -**
	Theoretical quantity (given observed quantity): RD	28.57	27.31	31.53	-
% Change of observation (p-value)		-28.8 (0)	-8.2 (0)	52 (0)	-4.7 (0)
% Change of observation when measured as a proportion of theory in RD (p-value)		-28.8 (0)	-21.2 (0.001)	9.1 (0.09)	-

The story is quite different when one looks at experienced subjects (Table 6). An important result is that one observes is the striking decrease in the use of forward markets. There is no sizeable increase in the quantity sold in the spot market in absolute terms, but there is a decrease with respect to the equilibrium quantity in the residual demand (RD). The reduction is much bigger in the forward market stage. It seems that subjects learn to reduce sales in the forward market before they learn to restrain sales in the spot market.

Table 6- Experienced duopoly Use of forward and spot-First and Last ten rounds					
2 Exog. Exp.		Forward 1	Forward 2	Spot	Total
Theory		28.57	28.57	28.57	85.71
First 10	**Observed-1 (as proportion of theory in RD)**	**2.66 (9.3)**	**8.36 (22)**	**55.24 (97)**	**66.26 -**
	Theoretical quantity (given observed quantity): RD	28.57	38.93	59.32	-
Last 10	**Observed-2 (as proportion of theory in RD)**	**0.08 (0.28)**	**3.72 (9.3)**	**55.62 (86.9)**	**59.42 -**
	Theoretical quantity (given observed quantity): RD	28.57	39.97	64.13	-
% Change of observation (p-value)		-97 (0)	-55.58 (0)	0.69 (0.35)	10.34 (0)
% Change of observation when measured as a proportion of theory in RD (p-value)		-97 (0)	-57.8 (0.001)	-10.4 (0.0008)	-

4.2.2 Quadropoly

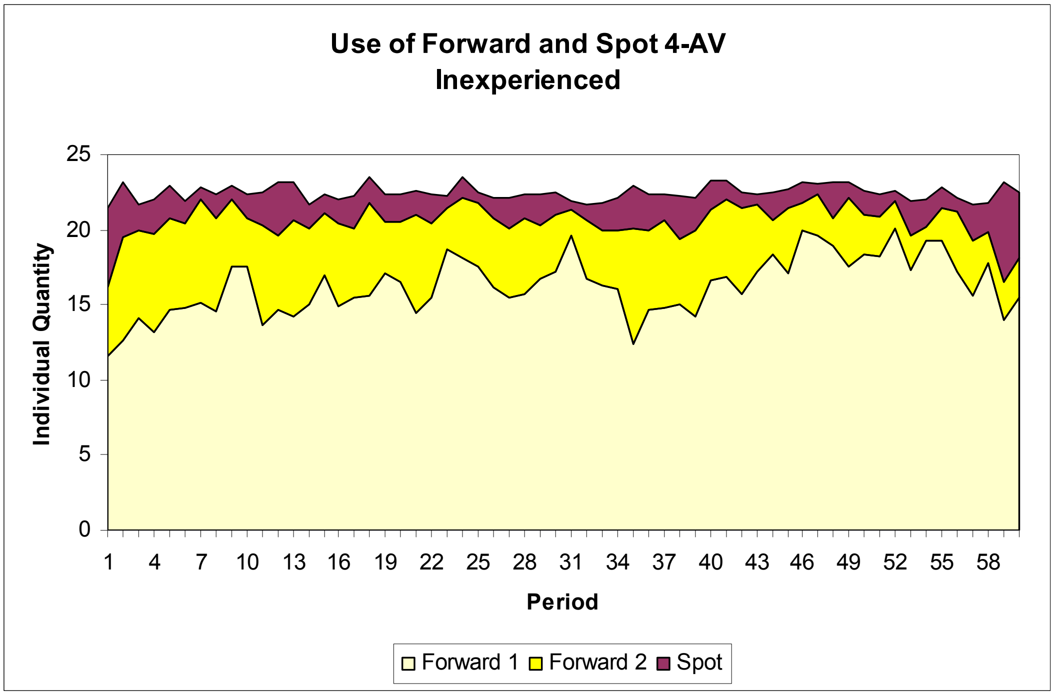
Inexperienced subjects behave remarkably close to the theoretical prediction in both the forward and spot markets under a quadropoly. The exact theoretical prediction is, however, rejected. When one contrasts the outcomes with respect to the theoretical prediction in the residual demand, then the behavior in the second period of forward markets (Forward 2) is as predicted by theory. Both spot and total quantities are not significantly different from competitive behavior. Our results are along the lines of Le-Coq and Orzen where four or more agents behave more competitively than predicted by theory. Table 7 below shows this result.

Table 7- Inexperienced quadropoly Use of forward and spot				
	Forward 1	Forward 2	Spot	Total
Theoretical q	67.92	22.64	7.55	98.11
Observed q	**72.23**	**19.24**	**8.38**	**99.85**
Theoretical q. in the residual demand (given observed quantity)	**67.92**	**19.6**	**6.82**	**-**
Perfect competition in RD	-	-	8.53	100
p-value (Obs.= Theory) (T-test)	0.00029 (3.45)	0 (5.65)	0.015 (2.18)	0 (6.26)
p-value (Obs. = Theory in RD) (t-test)	0.00029 (3.45)	0.27 (0.6)	0 (4.1)	-
p-value (Obs. = perfect competition) (t-test)	-	-	0.34 (0.39)	0.3 (0.53)

Table 8 shows the use of forward and spot market for experienced subjects. As in duopoly, experienced subjects make little use of forward markets. Given the theoretical quantities in the forward markets, spot market production is, again, higher than the theoretical prediction. However, this quantity is less than the theoretical prediction given the actual use of forward markets. The overall total quantity is smaller than total predicted.

Table 8- Experienced quadropoly Use of forward and spot				
	Forward 1	Forward 2	Spot	Total
Theoretical q	67.92	22.64	7.55	98.11
Theoretical q in the RD	67.92	68.22	69.84	-
Observed q	**3.36**	**9.36**	**64.1**	**76.82**

Figure 3: Inexperienced Quadropoly



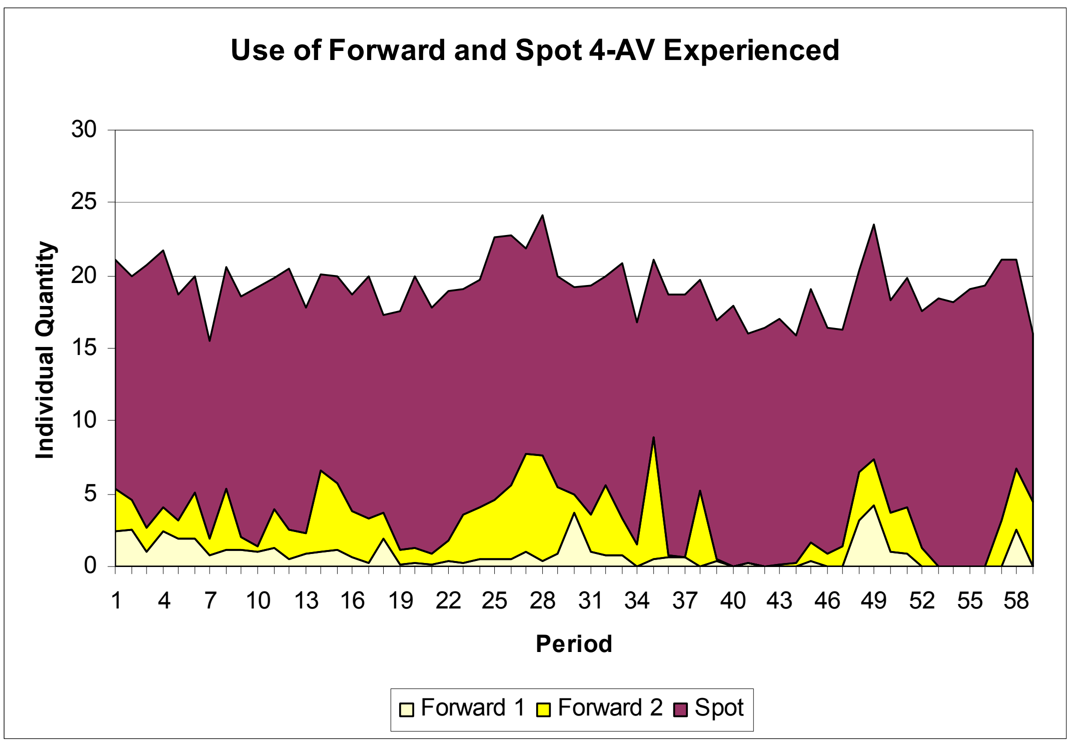
Again, as a benchmark, we calculate the monopoly and competitive output in the residual demand. These are, 43.65 ((½)(100-3.36-9.36)) and 87.3, respectively. Also, recall that the Cournot quantity with one forward markets is 80. We do not show statistical tests as quantities are far from any reference values.

Figures 3 and 4 show us the output choices made by inexperienced and experienced subjects for quadropolies. Quantities shown are the individual averages for each round. For inexperienced subjects, the change in the spot market output is not statistically significant (see Table 9). There is an increase in the use of Forward-1 but a decrease in the use of Forward-2. Spot quantity is slightly above the theoretical prediction in absolute terms and a little lower in relative terms. Regardless, neither of these changes is statistically significant. The changes in the forward and spot markets, however, compensate each other so that there is no effect in the total quantity.

It may look paradoxical that observations are greater on average than the average theoretical prediction and that, at the same time, they are lower as a proportion

Table 9: Inexperienced quadropoly Use of forward and spot-First and Last ten rounds					
		Forward 1	Forward 2	Spot	Total
Theory		67.92	22.64	7.55	98.11
First 10	**Observation (average as proportion RD)**	**64.78 (95.4)**	**25.11 (90.27)**	**9.5 (83.94)**	**99.39 -**
	Theory in RD (average)	67.92	24.86	8.09	-
Last 10	**Observation (average as proportion RD)**	**77.42 (114)**	**11.03 (58.8)**	**10.64 (86.31)**	**99.09 -**
	Theory in RD (average)	67.92	15.94	9.24	-
% Change of observation (p-value)		19.7 (0.001)	-56 (0)	12 (0.25)	-0.3 (0.47)
% Change of observation when measured as a proportion of theory in RD (p-value)		19.7 (0.001)	-34.8 (0)	-2.8 (0.48)	-

Figure 4: Experienced Quadropoly



of the theoretical prediction. The reason is that lower quantities also represent a lower proportion. For example, suppose that we have 3 observations in the spot market of 10, 2 and 18 after forward quantities of 90, 95 and 80, respectively, have been observed. The theoretical prediction in this case is 4/5 of "100 minus the forward quantities", which gives us 8, 4 and 16, respectively. The average of the three spot market observations is 10, greater than the average spot market theoretical prediction, which is 9.33. As a proportion of theoretical values, observations are 125, 50 and 112% of these quantities, giving an average of 95.66%.

Table 10: Experienced quadropoly Use of forward and spot-First and Last ten rounds					
		Forward 1	Forward 2	Spot	Total
Theory		67.92	22.64	7.55	98.11
First 10	**Observation (average as proportion RD)**	**6.46 (9.5)**	**7.75 (12.7)**	**64.21 (101.9)**	**78.42 -**
	Theory in RD (average)	67.92	66.03	68.63	-
Last 10	**Observation (average as proportion RD)**	**1.79 (2.6)**	**7.54 (12.7)**	**66.21 (88.1)**	**75.54 -**
	Theory in RD (average)	67.92	69.32	72.53	-
% Change of observation (p-value)		-72.3 (0.001)	-2.7 (0.47)	3.1 (0.25)	-3.7 (0.24)
% Change of obs. when measured as a proportion of theory in RD (p-value)		-72.3	-0.5 (0.49)	-13.4 (0.029)	-

Another interesting feature that distinguishes in-experienced and experienced subjects is that there is greater volatility in the behavior of experienced subjects. Table 11 shows the variances of total quantities. In all cases the variance of the experienced subjects is significantly higher than the variance of the inexperienced ones.

Table 11:Variance				
	Duo-Exog.	Quad-Endog.	Duo-Endo.	Quad-Endo.
No Experience	66.09	73.96	10.76	71.4
Experience	76.03	87.98	247.43	414.93
p-value for equal variances (F-test)	0.00858 (1.15)	0.00389 (1.18)	0 (22.99)	0 (5.8)

4.3 The use of forward markets:

Experienced subjects choose zero output quite often in the forward market stage both, for a duopoly and quadropoly. This, however, is not observed with in-experienced subjects. The coordination in the forward phase observed for a quadropoly fails in the spot stage where the average output sold is higher than that observed for a duopoly in the second half of the experiments. Though quadropoly output is below the Nash equilibrium, it seems more difficult to maintain collusion under this market structure.

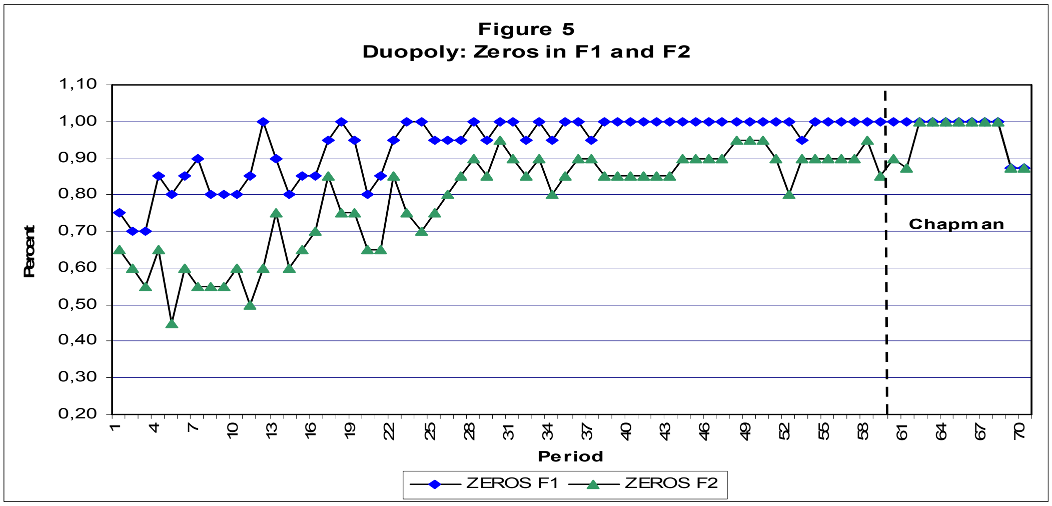
For the duopoly experiments, an average of 94.36% of the experienced subjects choose zero output in F-1 while, 81.11% choose zero output in F-2. The results for quadropoly are along similar lines, 76.06% of the subjects choose zero output in F-1 while, 92.37% choose zero output in F-2. It is interesting to note that choice of zeros declines in F2 for a duopoly while, the contrary is observed for a quadropoly. In both cases, the number of zeros chosen increases in later periods of the experiment. It seems that subjects realize that early deviations can lead to competitive outcomes and select zero in the forward stage to induce collusive outcomes (figures 5 and 6 show the number of zeros by period).

Recall (tables 6 and 10) that, given the output produced in the forward market, the average output in the spot phase for a duopoly is 55.24 and 55.62%[15], respectively. Even though the numbers are similar, it is interesting to note that the difference of this output from the theoretical quantity (given observed) in the residual demand is higher for the last ten periods (8.51%) compared with the first ten periods (4.08%). Though, of a smaller magnitude, this difference also increases for the quadropoly experiments from 4.42% to 6.32% in the first and last periods. This suggests that a duopoly is relatively more successful in maintaining a lower level of output than a quadropoly as the experiment progresses.

Though smaller, there are more deviations from zero in the first half of the experiment than in the second half. Those that occur in the second half are greater, and are followed by an even stronger response from the rivals[16]. A higher level of output, after positive positions, may be viewed as an indicator of punishment after a tacit deviation for collusion in the form of zero forward positions. Tables 12 (below) shows quantities chosen in F2 when one takes a positive positions in F1, and when the position is zero (in F1). Further, it is evident from figures 5 and 6 that, relative to the first half, a positive quantity is chosen less often both in F-1 and F-2 in the second half of the experiments.

[15] Compared with the competitive level of output of 100%.

[16] This may suggest that some subjects may be employing punishing strategies (in the spot stage) towards deviators in the forward stage.



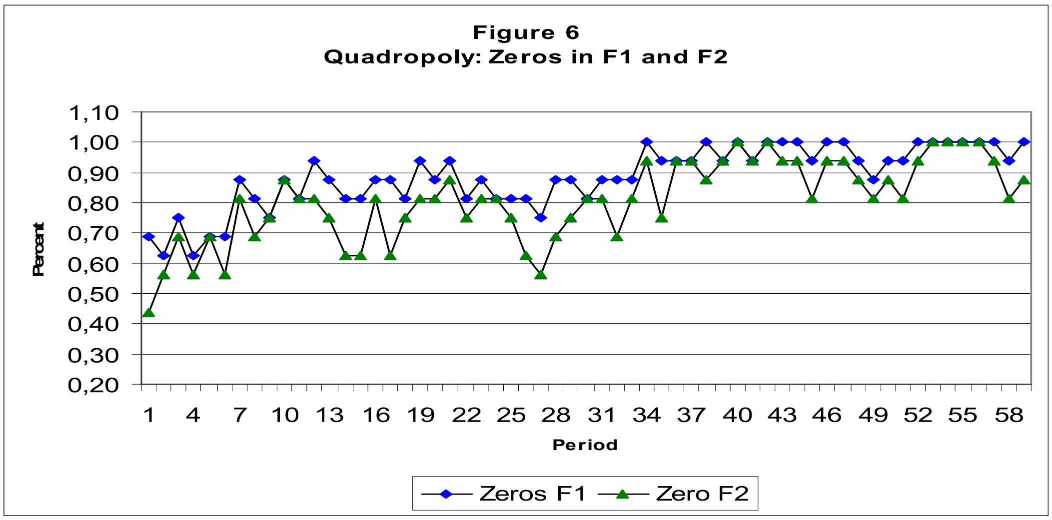


Table 12			
	Duopoly: F1>0		Duopoly: F1=0
	Average q of deviator in F1	Average q of non-deviator in F2	Average in F2
First 30	6.5	8.5	7
Last 35[17]	30	10	7.4
	Quadropoly: F1>0		Quadropoly: F1=0
First 30	4.9	4.2	0.9
Last 29	10.1	13.7	2.5

[17] Only one observation.

We also look at whether zero in the futures stage implies that a collusive output level is chosen in the spot stage (table 13). Below we present some results when a choice of zero in the forward stage may imply that it is more likely that a collusive output level is chosen. To achieve this we look at three cases of output choice in the forward market.

First, is the case when no one deviates in any of the forward markets, i.e. $f_1=f_2=0$. We then look at the case when there is no deviation in f_1, but there may be deviations in f_2, i.e. $f_1=0$ and $f_2>0$. Finally, we look at the case when there are deviations in f_1, i.e. $f_1>0$. Given these choices in the forward market, we look at the corresponding output level in the spot stage. This analysis is done at the individual and the market level[18].

For the individual, we look at output choice in the spot stage according to the three cases above. At the market level the three cases apply to *all* market participants. If choosing zero in the futures stage works as a facilitating collusion device then this would imply that a collusive level of output will be chosen in the spot stage. For the purpose of our analysis, we take a collusive level of output as any level of output below the Nash equilibrium (on the residual demand).

Table 13: Zeros and collusive outcomes

	Duopoly		**Quadropoly**	
	Total	**# (%) < NE**	**total**	**# (%) < NE**
(i) $f_1=f_2=0$				
Market	**441**	**357 (80.96%)**	**130**	**104 (80%)**
Individual	**882**	**225 (74.49%)**	**520**	**333 (64.04%)**
(ii) $f_1=0$, $f_2>0$				
Market	**135**	**59 (43.71%)**	**34**	**24 (70.59%)**
Individual	**270**	**129 (47.79%)**	**136**	**88 (64.71%)**
(iii) $f_1>0$				
Market	**64**	**28 (43.75%)**	**72**	**31 (43.06%)**
Individual	**128**	**50 (39.06%)**	**288**	**132 (45.84%)**

[18] Note that we are treating any output level as a "deviation" in the forward phase. We have excluded output levels that are very small due to our strict interpretation of signalling. Including output levels below the Nash Equilibrium in the forward markets would only strengthen our argument.

From table 13 one can see that the probability that an output level is below the Nash equilibrium is greater when players choose zero output in both the forward market stages. This is true for both, duopolies and quadropolies. At the market level the numbers are similar for both market structures. Notice that as we move from case (i) to (iii) the % of choices below the Nash equilibrium (on the residual demand) drops. It is clear from this analysis that the probability of choosing a collusive level of output is greater when zeros are chosen in both the forward markets.

We can make one more observation regarding output choices in the spot market. It seems that quadropolies are relatively more forgiving in the spot phase than are duopolies. Looking at case when the deviation from zero is in f_2, i.e. $f_1=0$, $f_2>0$, one sees that a higher percentage of subjects choose a collusive output level for quadropolies than for duopolies. This is true both at the individual and the market level. (Deleted: it repeats the same thing.)

4.4 Cournot Oligopoly vs. Forward markets

In another paper (Ferreira *et al.*, 2009) we study experimental Cournot oligopolies[19]. Below we compare some results from this paper with the forward markets experiments. We compare the effect of introducing more firms in the market, *i.e.*, 2 vs. 4, and the addition of forward markets.

Table 12: Cournot vs Forward		
Cournot		
	Inexperienced	Experienced
Duopoly (% of 2-Cournot)	70 (105)	53 (79.5)
Quadropoly (% of 4-Cournot)	84.58 (105.7)	81.58 (102)
Forward Markets (*f*=*2*)		
Duopoly (% of 2-Cournot)	85.56 (99.8)	62.53 (72.9)
Quadropoly (% of 4-Cournot)	99.85 (101.7)	76.84 (78.3)

Table 12 summarizes average sales by duopolies and quadropolies (with no forward markets) relative to the forward market experiments. One sees that average

[19] We report results from a companion paper on Cournot oligopolies (Ferreira, Kujal, Rassenti, 2009, mimeo).

output for in-experienced quadropoly decreases from 84.58 to 81.58. This is a decrease of 3.55%. This decrease, however, is of a much greater magnitude for a duopoly. An experienced duopoly produces output closer to the monopoly level (53) resulting in a decrease of 32.86%.

One sees that experienced quadropolies in forward markets are less competitive than Cournot quadropolies. Note that for the forward market quadropoly, which starts from a higher benchmark (99.85), the output decrease is of a greater magnitude (23.04%) than what is observed for the Cournot case. Further, an (experienced) Cournot duopoly is less competitive than a duopoly with forward markets. Though not as competitive as in Le-Coq and Orzen, our quadropoly results are along their lines and show that the competitive effect of entry is robust to the introduction of experience in experimental Cournot oligopolies. That is, the effect of market entry on competition is of a greater magnitude than the introduction of forward markets.

5. Conclusion

There is some controversy about the effect of the introduction of forward markets on market competitiveness. They are widely used and little understood. Depending upon the model, theory provides results suited to all tastes. The introduction of forward markets can have pro- and anti- competitive effects. The scant experimental literature is also not clear on the issue. Le-Coq and Orzen (2006) provide some support for theory for a duopoly and stronger support for a quadropoly. Brandts et al. (2008), meanwhile, show that the introduction of forward markets can result in competitive outcomes. Their experiments were not reported with experienced subjects and we show that experience can have an important effect on outcomes.

We design our experiments to give theory its best shot. The differences with respect to the design in Le-Coq and Orzen´s are notable. First, we randomly match firms vs. the fixed matching rule adopted in Le-Coq and Orzen. Second, we run our experiments for a longer duration. We hope that subject understanding of the market structure is improved with longer experiments. Thirdly, as a robustness check, we re-run the experiments with subjects experienced in the forward market trading institution.

Compared with LeCoq and Orzen, we find stronger support for the theory with inexperienced subjects. Average output in our experiments is remarkably close to the theoretical prediction. Output produced by inexperienced subjects does capture the prisoners' dilemma nature of the strategic motive. This result, however, does not extend over with once experienced subjects. Experienced subjects are less competitive than inexperienced ones and learn to avoid using forward markets.

Duopolies find it easy to coordinate actions and achieve near monopoly outcomes on several occasions even in the spot market. This behavioral continuity in the spot market, however, does not extend over to quadropolies. Even though the choice of zeros is high for quadropolies, they are unable to sustain this coordination at the same level as a duopoly in the spot market phase. The end game effect seems to be stronger for quadropolies. On the other hand we also find that quadropolies seem more forgiving in the spot market phase.

A high proportion of subjects select zero output levels in the forward periods. It is, however, not clear that this behaviour can be sustained. The use of zeros as a signalling device is maintained both for a duopoly and a quadropoly. It seems that subjects first learn to avoid the use of the forward markets, and, then reduce quantities in the spot market. Regardless, our results with experienced subjects strongly reject the strategic motive to sell forward in futures' markets.

Another important result from our experiments is that we show the robustness of the results on the effect of entry (number of firms) on increasing market competitiveness compared with the introduction of the forward markets (as in Le-Coq and Orzen (2006) and Brandts et al. (2008)). Further, this result is robust to subject experience.

Our results indicate that experienced subjects learn to avoid using forward markets. Several questions, however, remain to be answered. First, if forward markets help subjects in sustaining collusion then it would be interesting to know how few, or how many, forward markets help in sustaining collusive behavior. Another important question relates with the role of arbitrageurs in these markets. We plan to address some of these questions in future research.

References:

Allaz, B. (1992) “Oligopoly, uncertainty and strategic forward transactions”, *International Journal of Industrial Organization* 10, 297-308.

Allaz, B. and Vila, J-L. (1993) “Cournot competition, forward markets and efficiency”, *Journal of Economic Theory* 59, 1-16.

Brandts, J., Pezanis-Christou, P. and Schram, A. (2008) “Competition with forward contracts: A laboratory analysis motivated by electricity market design”, *Economic Journal* 118, 192-214.

Bushnell, J., Mansur, E. and Saravia, C. (2008) “Vertical arrangements, market structure and competition: An analysis of restructured U.S. electricity markets”, *American Economic Review* 98(1), 237–66.

Dal Bó, Pedro (2005), “Cooperation under the shadow of the future: Evidence from infinitely repeated games”, *American Economic Review* 95(5), 1591-1604.

Dilger, A. (2006). “The absent-minded prisoner”, *Spanish Economic Review* 8(4), 301-315.

Ferreira, J.L. (2003). “Strategic interaction between futures and spot markets”, *Journal of Economic Theory,* 108, 141-151.

Ferreira, J.L. (2006). “The role of observability in futures markets”, *Topics in Theoretical Economics*, vol. 6, article 7.

Fudenberg D. and Levine, D. (1983). “Sugame-perfect equilibria of finite and infinite horizon games”, *Journal of Economic Theory* 31, 227-256.

Huck, S., Normann, H.-T., Oechssler, J., (2004). “Two are few and four are many: number effects in experimental oligopolies”, *Journal of Economic Behavior and Organization* 53, 435–446.

Joshua S. Gans, J,S., Price, D. and Woods K. (1998) “Contracts and Electricity Pool Prices”, *Australian Journal of Management* 23(1), 83-96.

Hughes, J. and Kao, J. L. (1997) “Strategic forward contracting and observability”, *International Journal of Industrial Organization* 16, 121-133.

Le Coq, C. and Orzen, H. (2006) “Do forward markets enhance competition?”, *Journal of Economic Behavior and Organization* 61, 415–431.

Liski, M. and Montero, J.P. (2005) “Forward trading and collusion in oligopoly”, *Journal of Economic Theory* 131, 212-230.

Nagel, R. and Vriend, N. (1999), "Inexperienced and Experienced players in an oligopolistic market game with minimal information," *Industrial and Corporate Change*, 8, No. 1, 41-65.

Mahenc, P. and Salanie, F. (2004) "Softening competition through forward trading", *Journal of Economic Theory* 116, 282-293.

Murphy, F. and Smeers, Y. (2005). "Generation capacity expansion in imperfectly Competitive Restructured Electricity Markets", *Operations Research* 53, 646-661

Newbery, D.M. (1998) "Competition, contracts and entry in the electricity spot Market", *RAND Journal of Economics* 29(4), 726-749.

Radner, R. (1980). "Collusive behavior in non-cooperative epsilon euilibria of oligopolies with long but finite lives", *Journal of Economic Theory* 22, 121-157.

Rassenti, S, S. Reynolds and V. L. Smith (1994), "Cotenancy and Competition in an Experimental Auction Market for Natural Gas Pipeline Networks", *Economic Theory* 4, 41-65.

Wolak, F. (2000). "An empirical analysis of the impact of hedge contracts on binding behaviour in competitive electricity markets", *International Economic Journal* 14, 1-39.

APPENDIX 1

Instructions for in-experienced subjects.

INSTRUCTIONS

Introduction: This is a study of decision-making. Funding for this project has been provided by public funding agencies. If you follow these instructions, and make decisions carefully, you might earn a considerable amount of money. You will be paid **IN CASH** at the end of today's session.

Important: At any stage you can raise your hand to ask any question relating to the experiment.

Overview: In today's session each of you is a quantity-setting seller. There are TWO sellers in each market. The experiment is made up of several **weeks.** Each **week** is made up of three **trading days**. You will be randomly and anonymously matched against other opponents.

Trading in each week proceeds as follows:

Each week is made up of **three days**. Note that, the total of the offers made in all the days constitute a **commitment** to sell a good and are final. **In each day you make profits for the quantities sold in that day only**.

First Day:

In the first day you will have 30 seconds to make quantity offers. Note that, once confirmed all **offers to sell** are FINAL and cannot be changed. At the end of the day you will be able to see the quantities offered by the other seller, the price, and your profits **for the day**.

Second Day:

You may choose, or not, to **increase** upon the offer you made in the first day. You will have 30 seconds to make quantity offers. Any change can only be an increase over the total quantity offered in day-1. At the end of the day you will be able to see the quantities offered by the other seller, the price, and your profits **for the day (only for the additional quantity sold in this day)**.

Final Day:

This is the final day of the week. You may choose, or not, to increase the offer you made in the first two days. Any change can only be an increase over the total quantity offered in days -1 and -2. At the end of the day you will be able to see the quantities offered by the other seller, the price, and your profits **for the day (only for the additional quantity sold in this day)**.

You can offer to sell quantity in all, or any, of the days. The **price** received by sellers is the **same for everyone.**

- The market price in Day 1 is determined by the sum total of quantity offered by ALL sellers during that day and a **computer estimate of the quantity that will be sold on Day 2 and the Final Day**.
- The market price in Day 2 is determined by the sum total of quantity offered by ALL sellers during Days 1 and 2 **and a computer estimate of the quantities for the Final Day**.

Example 1 below explains how the price is determined in **the Final day**.

Example 1: Let the market demand be P=10-TQ (P = market price, TQ = total quantity offered by all sellers). Suppose you offered to sell **ZERO units** on **day-1, ONE additional unit** on **day-2, and ONE on Final day**. The sum total of the units offered by you then is 2 (=1+1).

Let us also suppose that the number of units offered by the other seller on **day 1** is 1, 1 on **day 2, and ZERO on the Final Day**. The total quantity (TQ) offered by all sellers across the week then is (3+2=) 5. This implies that the market price for the Final Day is P = 10-TQ = 10-5 = **5**.

Note that the price declines as the total quantity offered (TQ) increases. For all TQ greater than, or equal to, 10 the market price (P=10-TQ=10-10=0) is zero. **Further note that, the market price can never be negative.**

Example 2 below explains the relationship between the total quantity offered (TQ) and the market price in the Final Day (P).

Example 2: Notice that the market price (P=10-TQ) decreases as the total quantity (TQ) sold in the market increases. The table below gives some possible prices for the Final Day for different total quantities (TQ):

Market demand: P=10-TQ	
QUANTITY (TQ)	PRICE (P)
1	P = 10-1 = **9**
2	P = 10-2 = **8**
4	P = 10-4 = **6**
6	P = 10-6 = **4**
7	P = 10-7 = **3**
8	P = 10-8 = **2**
9	P = 10-9 = **1**
10	P = 10-10 = **0**

Procedures for trading are explained in more detail below.

1. Sellers earn profits by selling units. The profit for any unit sold is the selling price minus the cost of the unit. The selling price will be the same for all units, as will be unit costs. Thus a seller's total profit is;

Profits in the Final Day = (Selling Price – Unit Cost) × Number of units sold in the Final Day

2. Buyers. The buyers are automated. The price is determined according to the demand in **Example-1**. Given total quantity (TQ), the market price P=10-TQ. In our example TQ=5, this implies that P = 10-TQ = 10-5 = 5.

Note that the same demand will not be used in the experiment.

In Days 1 and 2, the price is computed by the computer. As explained before the **computer estimates the quantity that will be sold on Day 2 and the Final Day**.

Before you confirm your quantity for the day, you can practice with different quantities for yourself and for the other seller (to have an estimate of the effects on your profits of the total quantity offered that day).

There are several important things to understand.

- The higher (lower) is the total quantity (TQ), the lower (higher) is the price (P) (see **<u>TABLE</u>** in **Example 2** above).
- Your sales are affected by the quantities chosen by the other seller. The higher (lower) is the other seller's quantity lower (higher) is the sales price. The same will be true if you increase your quantity and the other seller does not.

- **A higher quantity today may increase your profits today but may decrease profits later on in the week.**

<u>The trading week:</u>

Each seller can offer to sell some quantity (or none) in each day of the week. While choosing the quantity you should keep in mind that,

(i) you earn profits by selling units at a price above Unit Cost and
(ii) the higher is total quantity, the lower is the sales price (see **table** above).
(iii) you earn zero if you sell nothing.

<u>How to read the screen and submit your offer?</u>

On the right side of the screen, there is a **history table**. A record of all the plays is displayed in the table.

On the left side of the screen, there is a **graphical display** section.

You can try different possible combinations of your offer, the sum of all the other sellers offers and observe your potential profit **on the right side of the display section**.

After you have decided your offer for that day, click the CONFIRM button. NOTE that whenever you click the CONFIRM button, you are confirming **your offer only**. The actual number of units offered by other sellers may be different from yours. Also, NOTE that you **must** click the CONFIRM button in order to submit your offer.

The left side of the graphic display section shows your quantity, the sum of other sellers' quantity and the profit given the price on a particular day.

4) Overview:

a) Today's experiment will consist of a number of **weeks**. A trading week is made up of **three days**. The final trading week will not be disclosed in advance.

b) Each of you can choose to offer a quantity for sale in any trading day. You will be randomly and anonymously matched against other opponents.

c) In today's experiment each one of you will have a Unit Cost of $X in each period. Each participant has identical Unit Costs, and Unit Costs are the same in all trading weeks. You are also informed about the other seller's Unit Costs in a history table on the Right Side of the screen.

d) You will be paid $X U.S. for every Y "experimental dollars" you earn in the market. Thus, for example, every Y experimental dollars equals $U.S. Your total earnings for today's session will be the sum of your earnings in the experiment, plus your appearance fee.

e) Some participants may make their quantity decisions earlier than others. If you make your decision before other sellers, please wait quietly while others finish. The monitor will make sure that there are no unnecessary delays.

f) Please note that, talking with, or looking at, other participants is not allowed. The market will be closed and all participants will be dismissed without further payment if any participant communicates in any way other than the manner described in these instructions.

g) At the end of the experiment you will be called out and your earning will be paid to you in cash.

You will now practice before you start the experiment. Please free feel to continue the practice until you are ready for the experiment. Please click on "Ready to Practice" if you fully understand the instruction.

APPENDIX 2

Instructions for experienced subjects

INSTRUCTIONS

Decisión making:

In this game you will be choosing to sell quantities of a good in different inter-related periods. You may sell in any or all the days in the FIRST PART and a FINAL DAY.

The price in the FINAL DAY is determined by the quantity sold in ALL the periods (quantity offered in all periods in the FIRST PART+FINAL DAY).

How does the market work?

Suppose that ALL sellers (including you) offer to sell a total of 50 in all the periods. Let us suppose that the market demand is P = 100-Q.

1) PRICE IN THE FINAL DAY:

The price in the FINAL DAY is determined by the TOTAL QUANTITY offered by all sellers in all the days.

Then the price in the FINAL DAY is, P=100-50=50.

As mentioned earlier you can offer to sell units anytime in the FIRST PART.

Prices in the different days of the FIRST PART are determined differently than in the FINAL DAY.

How are prices determined in the (different) days of the First Part?

2) FIRST PART.

Day 1:

- First, note that quantity offered by **all sellers** in the first day decreases the demand in the Second and the FINAL DAY.
- Example: If ALL sellers offer 20 on Day 1, then the remaining demand for Day 2/Final Day is; **P = 100-Q-20 = 80-Q.**
- **A smaller demand in future days implies a lower price in the future.**
- How is price determined in the FIRST DAY?
- Recall that the TOTAL QUANTITY sold determines the price **only in the FINAL DAY**.
- Now, a total quantity of 20 is offered on Day 1. To determine the price the computer makes an estimate of the quantity all sellers will sell on **Day 2 and the FINAL Day**.
- The price you obtain on Day 1 of the first part then depends upon what all sellers offer to sell (20, in this case) PLUS the computer's estimate of the quantity sold in ALL future days. Let us suppose that this estimate is 25.

- The price in Day 1 is then: P_1 = 100-(20+**25**) = 55 (where 25 is the estimate of the quantity sold by everyone in all the future days).
- Note, the higher is the quantity sold in the earlier periods, the smaller is the computer estimate of the total quantity sold in the future periods.

Day 2:

- Now suppose that all sellers offer to sell 6 units on Day 2.
- The computer estimates of the total quantity sold on the Final Day will now be smaller (recall that the demand after Day 1 is also smaller; P = 80-Q)
- Let us suppose that the **Computer Estimate** of the total quantity sold on the **Final Day** is **15**.
- Total quantity sold in (Day 1 + Day 2 + **Computer Estimate**) = (20+6+**15**)
- The price on Day 2 will then be, P_2 = 80-(6+**15**) = 80-21 = 59

Final day:

- First note that the demand on the Final Day is P = 100-(Quantity First Day+Quantity Second Day) = 100-(20+15)-Q = 100-35-Q = 65-Q.
- If you offer to sell 5 on the Final Day and OTHER sellers offer to sell 5. Then the price and profit on the Final Day will be:
- P = 65-(Quantity First Day+Quantity Second Day+Quantity Final Day) = 65-(20+15+10) = 65-45 = 20.
- Your profits in the Final Day will then be = (Price-Cost)xQuantity = (20-10)x5 = 50.

About the Computer estimate: A tutorial will show you how the computer makes estimations after the instructions.

Your total profits are the sum of the profits from Day 1, Day 2 and the Final Day.

Recall:

1) The price in the FINAL DAY is determined by the TOTAL QUANTITY offered by all sellers in all the days.
2) The price in the First Part is always determined by the computer estimate of total sales in the future days. This implies that for the same quantity offered in the First Day, or only offering to sell in the Final Day, the price on Day 1 is going to be smaller.
3) The same units give more profits if they are sold in latter days.
4) The same units give fewer profits if some units were already sold in the past days.
5) The higher is the quantity sold in the earlier periods, the smaller is the computer estimate of the total quantity sold in the future periods.

APPENDIX 3

Tutorial for experienced subjects

Tutorial (Print out to be given to the subjects)

2-poly
Lesson 1: The same units give more profits if they are sold in latter days.

Example 1.1: In days 1 and 2 please make an offer of 0 units for yourself and 0 units for others. In the Final Day please enter 18 units for yourself and 22 units for others. You will notice that the price is 20 and that your profits are 380.

How do we obtain the price?

When the units are sold **only** in the last day, the price is determined by the demand P = 60 – Q, where Q is the sum of the quantities sold IN ALL DAYS, and P is the price. In the example, Q = 18+22 = 40 and P = 60-40 = 20. Your profits are 20x18 = 360.

The following table shows the price in the Final Day as a result of total units sold (in all days).

Sum of units sold in ALL DAYS	Price in FINAL DAY
0	60
5	55
10	50
15	45
20	40
25	35
30	30
35	25
40	20
45	15
50	10
55	5
60	0

Example 1.2: In Day 1 please make an offer of 0 units for yourself and 0 units for others. In Day 2 make an offer of 18 units for yourself and enter 22 units for others. Notice that the price is now 6.7 and that your profits are 120.6. Enter zeros for the final day.

How do we obtain the price?

When 40 units are sold in Day 2 (18 by you, 22 by others), the computer estimates a new demand for the Final Day P = 60 – 40 – Q = 20 – Q. Then, the computer makes an estimate of the quantity that will be sold in the Final Day, which in this case is 13.3.

This gives us the price P = 20 – 13.3 = 6.7. The quantities in Day 2 are sold at this price. Your profits in Day 2 are 6.7 x 18 = 120.6.

The following table shows the price for Day 2 based on the units sold on Day 1 and Day 2 AND the computer estimate of total units sold in the Final Day.

Sum of units sold in DAYS 1 and 2	Price for units sold in DAY 2
0	20
5	18.3
10	16.7
15	15
20	13.3
25	11.7
30	10
35	8.3
40	6.7
45	5
50	3.3
55	1.7
60	0

The price at which quantities are sold in the FINAL DAY depends on quantities sold in all days by yourself and the others. Further, these quantities may be different from the computer's estimation.

In this example, sales in Day 1 and the Final Day are zero. Thus, total sales (in ALL DAYS) are 0 + 40 + 0 = 40. Then, the actual price in Final Day is P = 60 – 40 = 20. Your profits in Final Day are 20 x 0 = 0.

Example 1.3: In Day 1 please make an offer of 18 units for yourself and 22 units for others. Notice that the price is 4 and that your profits are 72. Enter zeros for the other days.

Why is this?

When 40 units are sold in Day 1 (18 by you, 22 by others), the computer estimates a new demand of, P = 60 – 40 – Q = 20 – Q, for Day 2 and the Final Day. Given this, the computer makes an estimate of the quantity that will be sold both in Day 2 and the Final Day. In our example this implies a total quantity of 8 in Day 2 and 8 in the Final Day.

Thus, the estimated price in Day 2 and in the Final Day is P = 60 – 40 – 8- 8 = 4. This is the price used to compute profits in Day 1. You profits in Day 1 are 4 x 18 = 72.

As before, the actual prices for Day 2 and Final Day will be different if you or the others choose to sell a different number of units in Day 2 and Final Day. This will not change the price and profits for Day 1.

The following table shows the price for Day 1 based on the units sold on Day 1 AND the computer estimate of total units sold in Day 2 and the Final Day.

Sum of units sold in DAY 1	Price for units sold in DAY 1
0	12
5	11
10	10
15	9
20	8
25	7
30	6
35	5
40	4
45	3
50	2
55	1
60	0

Lesson 2: The same units give fewer profits if some units were already sold in the first few days.

Example 2.1: In Days 1 and 2 enter 0 units for yourself and 0 units for others. In the Final Day enter 20 units for yourself and 20 units for others. Notice that the price is 20 and that your profits are 400.

Example 2.2: In Day 1 enter 0 units for yourself and 0 units for others. In Day 2 enter 5 units for yourself and 5 units for others (see that price is 16.7 and your profits are 83.3 for Day 2.) In the Final Day enter 20 units for yourself and 20 units for others. Notice that the price now is 10 and that your profits in the Final Day are 200. (Compare this with the profit of 400 in the previous example.)

Lesson 3: It may pay to produce in days 1 and 2.

Example 3.1: In Days 1 and 2 enter 0 units for yourself and 0 units for others. In the Final Day enter 24 units for others. Now try entering different units for yourself. You will notice that the number of units that give you the maximum profits in the Final Day is 18. Profits with this quantity are 324.

Example 3.2: In Day 1 enter 0 units for yourself and 0 units for others. In Day 2 enter 10 units for yourself and 0 units for others. (Notice that the price is 16.7 and your profits for Day 2 are 166.7.) In the Final Day enter 24 units for others and 14 units for yourself. Notice that the price now is 14 and that your profits in the Final Day are 168. Your total profits are 166.7 + 168 = 334.7, more than the 324 you got in the previous example.

Note that you made more profits because others chose to sell nothing in Day 2.