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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 either a finite (exogenous close) or an infinite (endogenous close) number of forward markets. In the exogenous close case experienced subjects do not avail themselves of the forward markets and production mostly occurs in the spot market phase. In a forward market duopoly experienced subjects achieve nearly the monopoly output level. For the quadropoly output levels are more competitive and are near the Cournot Nash equilibrium. In both cases output produced is much less than the Allaz-Vila (1993) prediction. The results with inexperienced subjects, however, are in line with theory and as reported in Le-Coq and Orzen (2006). We implement the case of infinitely many forward periods using the endogenous close rule. In this case the results both for a forward market duopoly and quadropoly are much more competitive both with inexperienced and experienced subjects. Unlike the exogenous stopping rule, under the endogenous rule subjects sell forward in the forward markets and find it hard to coordinate their actions.

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1. Introduction

Does the strategic motive in using forward markets enhance competition? General consensus points towards this direction, and the little experimental (Le-Coq and Orzen (2006) and Brandts et al. (2008)) and empirical[2] literature (Wolak, 2000) agrees with this assertion. Theory, however, is not clear on the issue. Alaz (1992) and Alaz and Vila (1993) suggest pro-competitive outcomes while Ferreira (2003), Mahenc and Salanie[3] (2004) and Liski and Montero (2005) suggest anticompetitive outcomes[4].

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. Subjects offer to sell in the forward period realizing profits for the quantity sold in that period. They then play on the residual demand in the subsequent spot period. They show that, relative to the spot market, the introduction of forward markets does have competition enhancing effects. However, 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. They also show that increasing the number of firms from 2 to 4 makes the market more competitive than introducing forward markets.

In the second experimental study, Brandts *et al.* motivate their study based on a specific design of forward markets that occur in the electric power industry. They consider both quantity and supply functions as strategic variables. In a model following Alaz 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.

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[2] Empirical evidence has been scarce and the matter gets further complicated given the fact in some markets firms are *required* to participate in forward markets.

[3] With price competition and differentiated goods.

[4] 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.

The empirical research on forward markets is scarce. For the Australian power market, Wolak (2000) shows that, indeed, when firms use the forward market, the effect is pro-competitive. In general, the use of forward markets is spreading. The problem is that in many instances there is strong regulation that gives firms big incentives to participate in them. Most models described above agree that, when used, forward markets 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. Our paper is closer to Le-Coq and Orzen (2006) in that we directly test the strategic motive to sell in forward markets[5]. We ran our experiments with two and four firms with in-experienced and experienced[6] subjects. The forward markets were run with the exogenous and endogenous close rules. The exogenous-close rule directly tests the model of Allaz and Vila (1993) in which the number of forward periods is (exogenously) fixed by the experimenter[7]. For the purpose of our experiments we had two forward periods prior to the spot market. The endogenous close version was designed keeping in mind the infinitely repeated forward periods prior to the spot market (Allaz and Vila, 1993 and Ferreira, 2003). In the implementation of this version the number of periods in the forward market was not pre-determined. Firms had the opportunity to sell in a sequence of forward markets with the only restriction being that the forward markets were discontinued as soon as they were not used by any firm in the current forward period. When this occured the game went directly to the spot market[8].

We show that, in the exogenous close experiments, with *once experienced* subjects, outcomes are far from the competitive theoretical prediction. Experimental duopolies result in near monopoly outcomes, while quadropolies are closer to the Nash-Cournot prediction. Further, experienced subjects use forward markets much less compared to inexperienced subjects. However, as in Le-Coq and Orzen (2006), with inexperienced subjects adding forward markets has a competition enhancing effect. Further, the pro-competitive outcome is obtained when one increases the number of

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

[6] Ours is the first experimental study to look at the effect of experience in Cournot experimental oligopolies.

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

[8] This setting is inspired by Ferreira (2003), although it does not directly share the same theoretical characteristics.

firms from two to four. The “numbers” result in Le-Coq and Orzen is maintained even with experienced subjects.

The results under the endogenous close rule are much more competitive than under exogenous close both with inexperienced and experienced subjects. Inexperienced subjects produce output nearly at the competitive level while experienced subjects learn to avoid competition in the duopoly case, but not under a quadropoly. The prisoners’ dilemma nature of the strategic motive to sell forward, that results in competitive outcomes, survives under the endogenous-close design. Subjects, especially quadropolies, find it harder to coordinate actions and outcomes are competitive.

We also find that the role of experience is important especially in a complicated environment such as forward markets, where the results strongly rely on the strategic motive to sell forward. Under exogenous close experienced subjects use forward markets *much less* than their inexperienced counterparts. Duopolies operating in forward markets find it much easier to collude without explicit communication. The outcome with four firms is also much less competitive than has been observed for (inexperienced) experimental duopolies (see, Huck *et al.*, 2004). The effect of experience under the endogenous close rule is, however, of a smaller magnitude than what is observed under the exogenous close. Experience develops a better understanding of the market functioning and is a precondition (rationality) in most theoretical models. Our results support this assertion 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 for the exogenous and endogenous models 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), Allaz and Vila (1993) and Ferreira (2003). 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. However, later papers cast some doubts on the robustness of this pro-competitive effect.

Ferreira (2003), on the other hand, shows that if the forward market has infinitely many moments in which trade is allowed, any price between Cournot and perfect competition can be sustained in equilibrium. Further, the Cournot outcome is the only Renegotiation-proof equilibrium. If firms are allowed to buy in the forward market, then the range of equilibrium prices that can be sustained in equilibrium reaches the monopoly price. Below, we outline two versions of forward markets. In the first version (Allaz and Vila, 1993) the number of forward markets is exogenously determined. In the second version the forward markets can open many times, with an endogenously given stopping rule.

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 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 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, $p_s + c = \frac{1}{n^2+1}(A - c - F^1)$.

2.2 Extensions of Allaz and Vila (1993)

Allaz and Vila examine a model with finitely many periods of forward markets and find that, as the total number of periods increases, the total sold quantity also does. Further, as the number of periods of forward markets goes to infinite, the limit of the quantity is the competitive outcome. For the particular case of two firms, the case of *T* periods in which the forward market is open, gives

$$p = s_i = f_i^t = \frac{A}{3+2T}, \text{ and } q = 2\frac{(1+T)A}{3+2T}.$$

It can easily be checked that, as *T* increases, the price *p* goes to zero, and total quantity *q* converges to *A*, the competitive outcome.

However, something similar to a Folk Theorem is obtained if the infinite case is analyzed directly, in which all total quantities (and their corresponding market prices) between competitive and Cournot can be observed in equilibrium. This result is shown in Ferreira (2003). The Cournot result can be supported in equilibrium by the following strategy. Firms sell nothing in the forward markets and play standard Cournot in the spot market. If a firm deviates and sells forward at some point, the other firms also sell in the next period. When one firm sells forward, it makes some extra profits with respect to the equilibrium behavior. However, when the other firms also sell in the next period to punish the deviation, its profits are reduced. The punishment phase is calibrated so the deviator makes a net loss. Ferreira shows that similar strategies can actually support any outcome between the competitive and the Cournot quantities. However, the Cournot outcome is the only one that satisfies some equilibrium refinements like renegotiation-proofness or Pareto perfection.

Notice that after firms sell in the forward market each of the subgames is a reduced version of the original game (with a smaller residual demand, depending on how much was sold in the previous markets). This makes the model different from a repeated game, because, in the repeated game, the demand remains the same in each period. There is, however, a similar result once it is established that there is still room for credible punishments in spite of the smaller demand and of the smaller impact of the punishment.

3. Experimental design

Below we discuss the general experimental design for the exogenous and endogenous close model. After this we discuss experimental details about the design of the endogenous close experiments.

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[9]. 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[10]. We report results for both inexperienced and experienced subjects. Table 1 summarizes experimental details.

Including the instructions the experiments finished in two hours. The instructions setup was the same for the exogenous and endogenous close markets. 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

[9] The number of experiments ran depended on subject show-up.
[10] For the experiments at GMU all subjects were not necessarily part of the same group for the second time.

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 2 summarizes the experimental parameters.

	Table 1: Experiments			
	Exogenous Stop		Endogenous Stop	
	George Mason	Chapman	George Mason	Chapman
Inexperienced				
Duopoly	3	6	4	6
Quadropoly	4	-	5	-
Experienced				
Duopoly	4	6	5	6
Quadropoly	4	-	3	-

Table 2: Experimental parameters			
	Demand	Marginal Cost	Forward Markets
In-experienced	Q=105-P	15	2
Experienced	Q=60-P	0	2

To deal with the no-arbitrage condition, in each of the forward markets periods, the forward market price 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 $p = A - 20 - q$.

Subjects are explained this 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.

Le Coq and Orzen (2006) were the first to test Allaz and Villa's model in the laboratory. Our exogenous close 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, given that they do not observe rival identity this 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 exogenous close experiments for nearly seventy rounds (Le-Coq and Orzen had 30 periods). We do this to facilitate subject learning as forward markets are complicated mechanisms.

Third, we use two periods of forward markets. According to the model in Alaz and Vila, 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 are they are robust to design changes. Experimental behavior in these markets is as theory predicts[11]. Forward markets, however, are more complicated[12]. Due to the scant experimental work on forward markets we run our experiments with experienced subjects as a robustness check. Further, typically real life agents in these markets are going to be big firms, or professional traders, that should have a good working knowledge of the functioning of these markets. Thus, it seems natural to check whether the experimental results are robust to experience.

Endogenous close experiments

One has the obvious problem of time limitation in conducting experiments with infinitely many periods. In standard repeated games the discount factor can be substituted with a probability of ending the game, thus avoiding the problem. Something similar could be done with the repetition of forward markets even if the model requires no discount factor. However there is still a bigger problem. In our

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

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

structure the residual demand decreases as firms sell positive amounts in forward market. This leads to many possible subgames where the residual demand is very small. The analysis in Ferreira (1993) holds for all these subgames (that may never be reached in equilibrium, but are necessary to sustain cooperation). Further, there is the problem of requiring rationality even when the prospects at stake are very small. That is, if for very small residual demands subjects may not care for very small differences in profits. Then for some subgames, the behavior in the residual demand may not work as the theory predicts.

To complicate matters, there is still the problem that, in any practical situation, we cannot work with numbers smaller than any given unit of measure (in our experiment, this unit was the experimental dollar). This means that, after a finite number of periods selling in the forward market, all subgames are the same and trivial (i.e., with zero demand). This means that, in practice, there will be no room for punishments after some (very marginally) profitable deviations. Thus, given the integer problem, the infinite number of periods of forward markets will have only finitely relevant periods. Subsequently, the model will work like Allaz and Vila for many periods of forward markets.

The literature on finitely repeated games shows that, theoretically, small departures from rationality is enough to achieve cooperation (e.g., ε-Nash equilibrium, non-common knowledge of rationality, absent-mindedness[13]). As we mentioned before, the experimental literature shows that, in fact subjects cooperate in finitely repeated games.

There are additional practical problems if we decide to implement a random ending to the periods of forward trade. First, if subjects decided not to use the forward markets, they must rest idle as the computer generates more periods of forward markets. Second, subjects will not feel sure that there will always be a chance to punish deviators who sell in the forward markets.

Due to all these problems we decided to experiment with a somewhat different implementation of the infinite forward market game. The forward markets would continue to open sequentially as long as firms continued to make use of them, but as soon as a forward period occurred when no firm sold any quantity, then there would be no further forward markets and the game would go directly to the spot market.

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[13] See Radner (1980), Fudenberg and Levine (1983) or Dilger (2006).

Theoretically, this game gives us the same equilibria as the model in Ferreira, and does not need an exogenous random ending. In practice, due to the integer problem, the design is closer to Allaz and Vila with finitely many repetitions.

4. Experimental results

4.1 A brief look

Exogenous Close

Before we look at detailed results it will be useful to look at some summary statistics. We first look at the exogenous close model of Allaz and Vila. Table 3 compares the theoretical values and the average of the values in the experiments for both the 2 and 4-firm cases, and for both inexperienced and experienced subjects. For simplicity of exposition all quantities are expressed relative to the competitive amount (set to 100%).

Table 3: Summary Statistics-Exogenous Close

	Compe-titive	Cournot	Monop.	Allaz and Vila (theory pred.)	**In-Experienced**	**Experienced**
2 firms	100	66.66	50	85.71	**85.56**	**62.53**
4 firms	100	80	50	98.11	**99.85**	**76.84**

Two results stand out in Table 3. First, inexperienced subjects tend to behave competitively in accordance 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. 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 and its output is also below the 4-firms Cournot level, and far below the prediction of the AV model.

Our findings for inexperienced subjects agree with Le-Coq and Orzen. However, we find strikingly different behavior for experienced subjects. They not only behave less competitively, but manage to restrict production below the Cournot-Nash prediction both for duopolies and quadropolies.

Endogenous close

Table 4 compares the theoretical and the average values both for inexperienced and experienced subjects. As before, in order to make comparisons easier, we normalize all quantities as percentages of the competitive quantity.

Table 4: Summary Statistics-Endogenous Close					
	Competition and Allaz and Vila	Cournot (Ferreira)	Monopoly	**Inexp. subjects**	**Experienced subjects**
2 firms	100	66.66	50	**98.32**	**79.12**
4 firms	100, (>100)	80	50	**103.23**	**(130)**

As with exogenous close, inexperienced subjects behave competitively. Experienced subjects, however, behave less competitively only for duopolies, although, the outcome is more competitive than the theoretical Cournot-Nash prediction. The higher than competitive quantity in the 4-firm oligopoly can be explained due to zero marginal costs used in that experiment: any quantities that add up to 100 or more, resulting in zero profits, are equivalent. One should, however, note that a competitive quantity produced across all the forward and spot periods does not (always) imply zero profits as profits are realized in each period.

4.2 A closer look at the data

Below we present results for the exogenous and endogenous close models. Results for inexperienced subjects will be discussed first followed by results for experienced subjects.

4.2.1 Duopoly: Exogenous close

Looking at summary data we know that inexperienced subjects behave according to theory, and experienced subjects behave less competitively. Analyzing how individuals make use of the forward and spot markets, we see that inexperienced subjects chose output in consonance with theory (although 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 not to make use of them.

Table 5 compares theoretical predictions for the forward and spot markets, the observed quantities in these markets and the theoretical quantity given the production in the previous period for inexperienced subjects. 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. Thus, given the average of 35.68 units in first forward stage, the rest of the game is that of a one-period forward market (Alaz and Vila) with a demand given by $p = (100 - 35.68)q$. The theoretical prediction in this sub-game is 25.73 units in the second period of forward markets. 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). Note that it is better to compare subject behavior with the theoretical quantities in the residual demand (given observed quantities) rather than with the theoretical quantities as computed from the beginning.

Table 5- Inexperienced duopoly:
Use of forward and spot markets. Exogenous close.

	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 reference it is useful to see what would happen if firms behaved as a monopolist or competitively. If firms behave as a monopolist in the residual demand of the spot market, the market quantity would have been (½)(100-35.68-22.3) = 21.01. However, if firms behaved competitively in the residual demand of the spot market, market quantity would have been 42.02, as compared with the observed 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.

In the case of experienced subjects, subjects tacitly collude by not using the forward markets. In the spot market they sell more than the theory prediction given the theoretical values in the forward markets, but less that the theory prediction (Cournot) given the observed use of forward markets. This is shown in Table 6. All quantities are statistically different from theory prediction (or from other quantities like Cournot, Monopoly or Perfect Competition.)

Table 6 - Experienced duopoly: Exogenous close 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 reference, the Monopoly and competitive quantities in RD in the spot markets are (½)(100-0.94-4.74) = 47.16, and 94.32 respectively. Recall that Cournot behavior without forward markets is 66.66. As the observed values are very far from the theoretical ones we do not bother with the statistical tests.

Figures 1 and 2 below shed 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 rounds advance in both figures. To capture this tendency in Tables 7 and 8 we present an analysis of the data for the first and last ten rounds. 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 7, what looks like a moderate 8.2% decrease (Observed-1 vs Observed-2) of sales in Forward-2 (the second period of forward markets), now is seen as a 21.2% decrease. This is due to the fact that, after observing 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 (a 52%) is, in fact, a moderate one (9.1%) if, instead

Figure 1: Use of forward and spot. Inexperienced duopoly

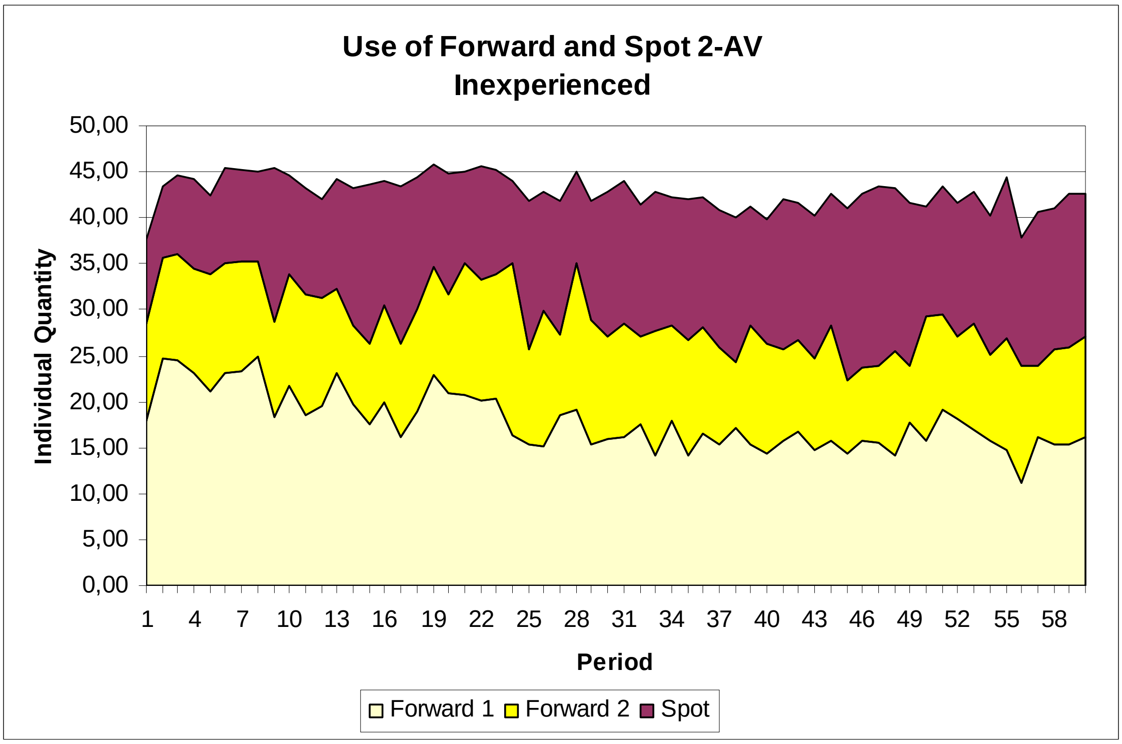
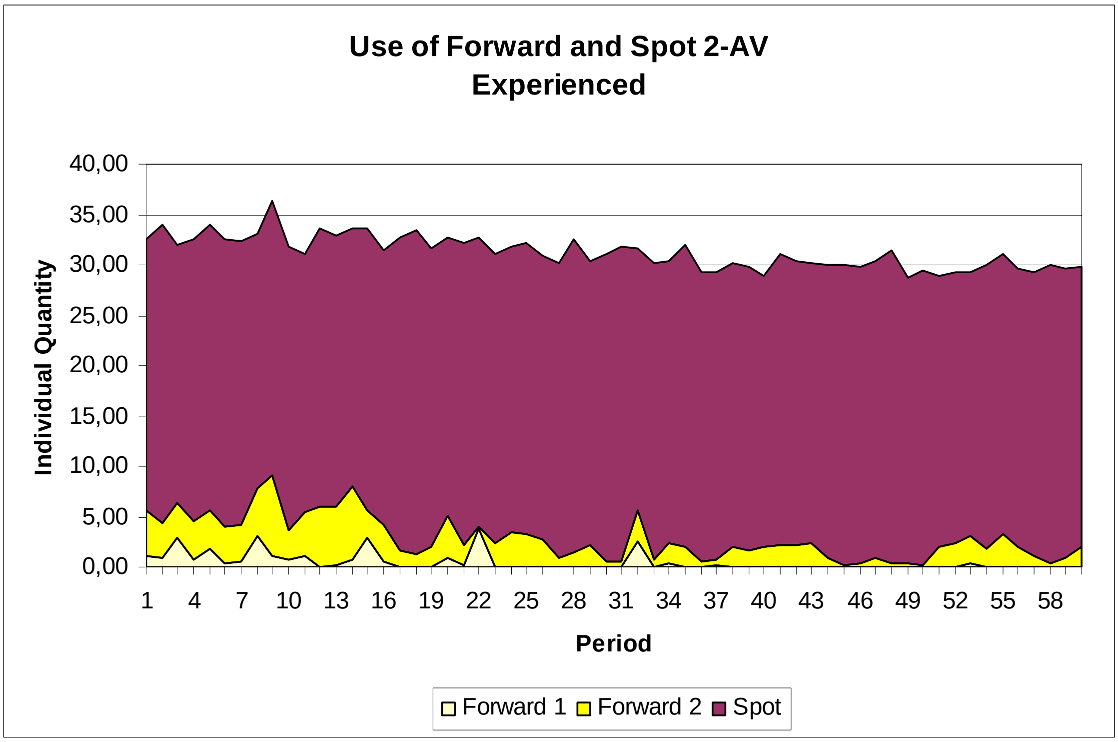


Figure 2: Use of forward and spot. Experienced duopoly



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).

Table 7- Inexperienced duopoly: Exogenous close 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 8). An important result is that one observes a 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 8- Experienced duopoly: Exogenous close 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: Exogenous close

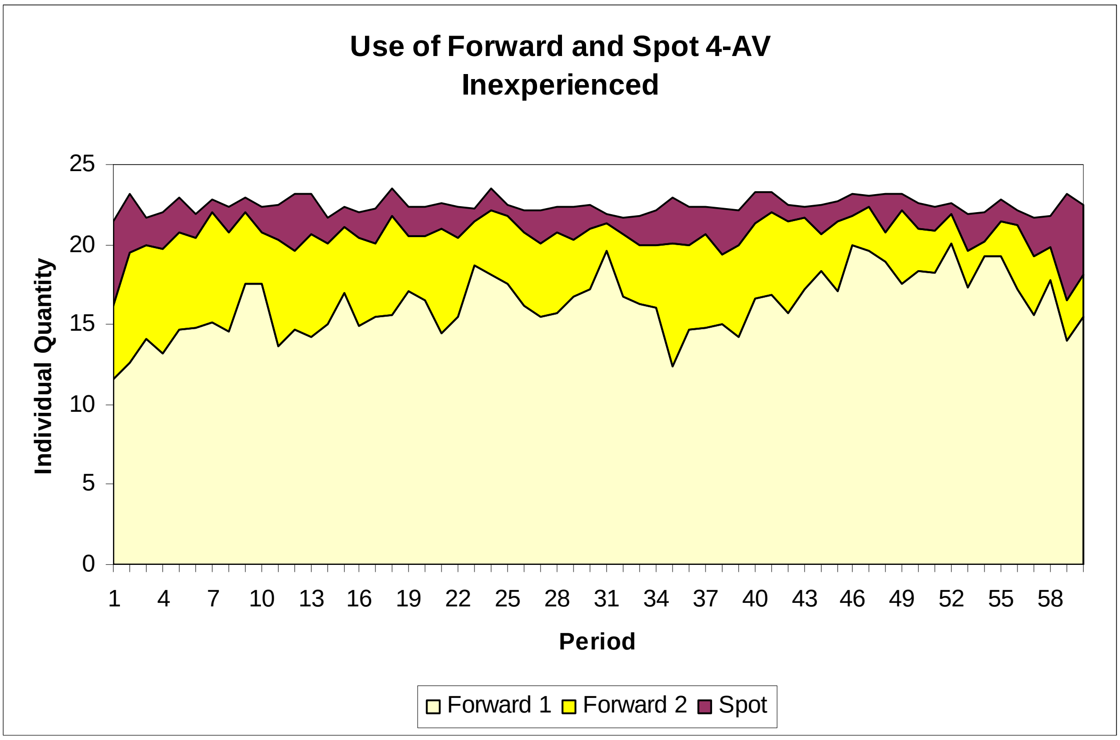
Under a quadropoly, inexperienced subjects behave remarkably close to the theoretical prediction in both the forward and spot markets. The exact theoretical prediction is, however, rejected. When one contrasts the outcomes with respect to the theoretical prediction in the residual demand, then the behavior 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 9 below shows this.

Table 9- Inexperienced quadropoly: Exogenous close 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 10 shows the use of forward and spot market for experienced subjects. As in the duopoly case, experienced subjects make little use of forward markets. The spot market production is, again, higher than the theoretical prediction given the theoretical quantities in the forward markets, but less than the theoretical prediction given the actual use of forward markets. The overall total quantity is smaller than the predicted total.

Table 10- Experienced quadropoly: Exogenous close 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



Again, as a reference, Monopoly in the residual demand is (½)(100-3.36-9.36) = 43.65, and the competitive quantity is 87.3. Also, recall that the Cournot quantity without 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 choices made by inexperienced and experienced subjects for quadropolies. Quantities shown are the average individual quantities for each round.

For inexperienced subjects, the change in the spot market is not statistically significant (see Table 11). 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 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 8, 2 and 18 after forward quantities of 90, 95 and 80, respectively, have been observed. The theory prediction in this case is 4/5 of "100 minus the forward quantities", which gives us 8, 4 and 16, respectively. The observations are 100, 50 and 112% of these quantities. Averages are: 88.33 for observed forward quantities, 9.31 for the average spot theoretical prediction, 10 for the observed spot quantity and 87.5 for the observed spot quantity as a proportion of the theoretical prediction.

For experienced subjects we again observe a significant decrease in the use of the first period (Table 12). The smaller decrease in the use of the second period is not statistically significant. The reduction in the spot quantity is significant when measured as a proportion of the theoretical quantity in the residual demand. We observe that experienced subjects avoid the use of forward markets and produce less than Cournot in the spot market. This is the same pattern observed in the duopoly case, although the total quantities are always higher in the case of the quadropoly.

Table 11: Inexperienced duopoly: Exogenous close 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.

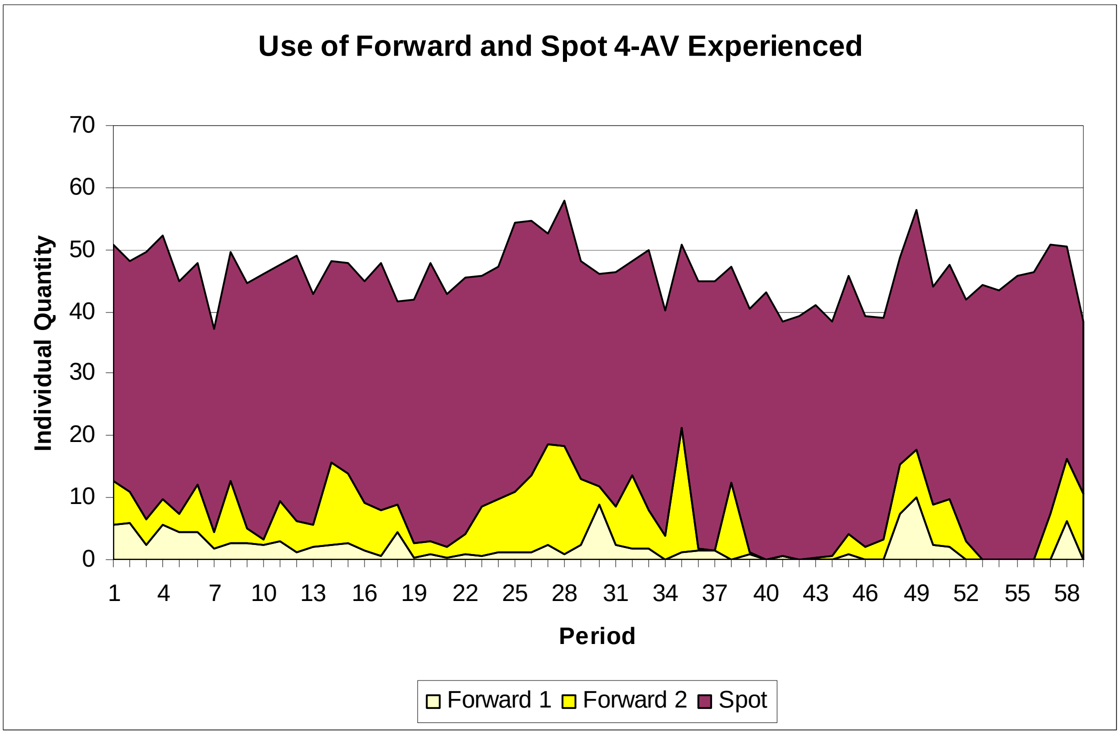


Table 12: Experienced duopoly: Exogenous close Use of forward and spot-First and Last ten rounds					
		Forward 1	Forward 2	Spot	Total
Theory		67.92	22.64	7.55	98.11
First 10	**Observation (average as proportion RD)**	**6.46 (9.5)**	**7.75 (12.7)**	**64.21 (101.9)**	**78.42 -**
	Theory in RD (average)	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)	-

4.2.3 Endogenous close

Recall that in the endogenous close case the market moves over to the spot phase when no seller offers to sell anything in a forward market. To achieve this requires a certain amount of coordination, or tacit behavior, on the part of the subjects. We find that subjects found it hard to achieve this under the endogenous close rule. The endogenous close rule captures the prisoners' dilemma nature of the strategic motive to sell forward as subjects observe rival choices (individual for duopoly and aggregate for quadropoly) in the next forward period. It could be for this reason that subjects had problems coordinating their actions so as to move production to the spot market. One would expect that the coordination would be much easier for a duopoly than for a quadropoly. Looking at data one sees that this is true but, mainly when subjects are experienced. Both for duopoly and quadropoly there are sessions where inexperienced subjects manage to move to the spot market only after 26 periods of forward markets. It is for this reason that a two-hour experiment could only run for less than half as many rounds under endogenous close as under exogenous close. Though, the number of rounds executed by experienced subjects was not much greater, very long drawn out forward markets were not as frequent for them.

Relative to exogenous close, under endogenous close almost all trade takes place in the forward markets with both inexperienced and experienced subjects (Table 13).

Table 13: Endogenous Close-Inexperienced. Output Choice-Forward vs. Spot				
	Observed Forward	**Observed Spot**	Cournot in RD	Monopoly in RD
Duo. in-exp.	**98.7**	**0.1**	0.87	0.65
Duo. exp.	**75.54**	**5.9**	16.31	12.23
Quad. in-exp.	**103.22**	**0.12**	0	0
Quad. exp.	**129.08**	**1.08**	0	0

One can see that there is no substantial difference between inexperienced and experienced subjects for a quadropoly. All market structures behave competitively. In the case of inexperienced subjects, the average quantity produced in the forward stage is 103.22 and is almost the same as the competitive 100. The p-value obtained from the t-test is 0.032. A similar outcome is seen for experienced subjects. In both the cases, no residual demand is left after the use of the forward markets. As a result there is nothing interesting to be seen in the spot market.

Unlike the exogenous stopping rule (and what has been observed in other oligopoly experiments), inexperienced duopolists behave very competitively. The average quantity in this case, however, is statistically different from the competitive outcome. Once more, almost everything is sold in the forward markets. Again, as the residual demand is very small in the spot market it is hard to give any meaning to subject behavior there.

The only case where we observe outcomes that are not competitive is for experienced duopoly (see Table 14). Compared with inexperienced subjects, there is a reduction in the use of forward markets. Also, output choice in the spot market is almost a third of the theoretical Cournot prediction for the residual demand, and almost half the Monopoly quantity. The total quantity produced is between competitive and the standard Cournot. Regardless, outcomes tend towards competitive even for a duopoly.

Behavior for inexperienced subjects does not change much as the rounds unfold. The average quantity chosen in the forward markets is 98.45 and 98.7 for the first and last ten rounds, respectively. The spot quantities are 0.14 and 0.06. Note that none of the differences is significant (with p-values of 0.46 and 0.13, respectively).

In Table 15 we analyze the endogenous close case for experienced duopoly. Showing a similar pattern as for exogenous close, subjects learn to avoid the use of forward markets, although, now they start and end at a much higher level of output. Further, production is greater in the spot market, not only in absolute terms, but also as a proportion of the equilibrium (Cournot) for the residual demand. Both of these changes are statistically significant. The total effect is, however, only slightly decreased (an insignificant change overall).

Table 14: Endogenous Close-Inexperienced. Output Choice-Forward vs. Spot (Duopoly)			
	Forward	Spot	Total
Perfect comp. (AV)	100	0	100
Cournot (Ferrerira)	0	66.67	66.67
Cournot in RD	-	16.3	-
Monopoly in RD	-	12.23	-
Observed q	**75.54**	**5.9**	**81.45**
Observed q as % of Cournot in RD	-	**36.2**	-

Figures 5 and 6, below, show the evolution of subject behavior for the endogenous close rule.

Figure_5

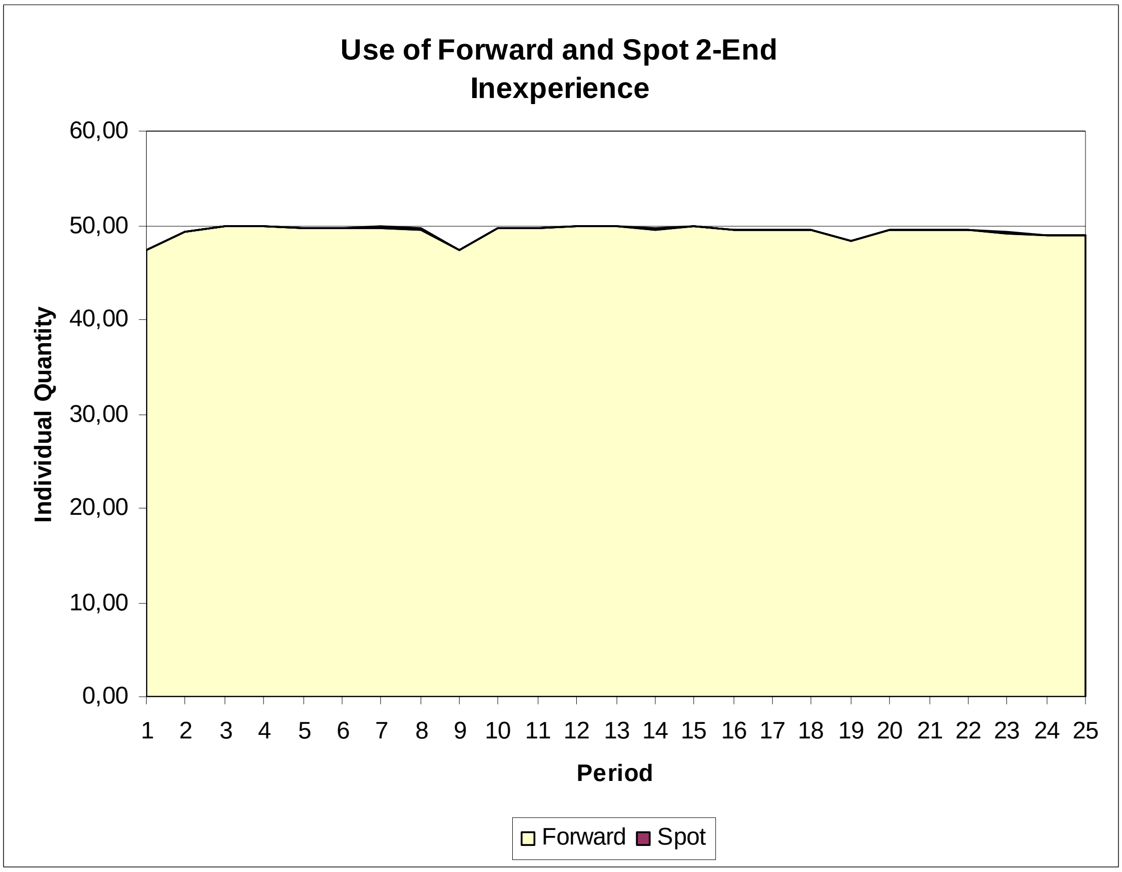
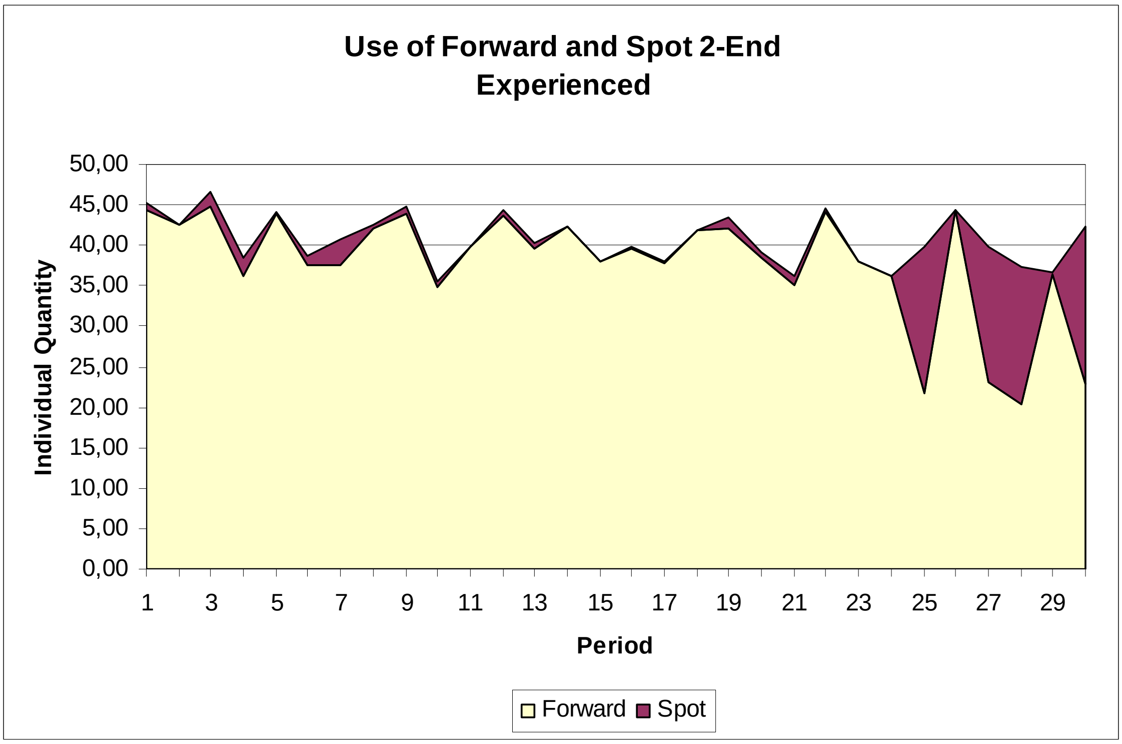


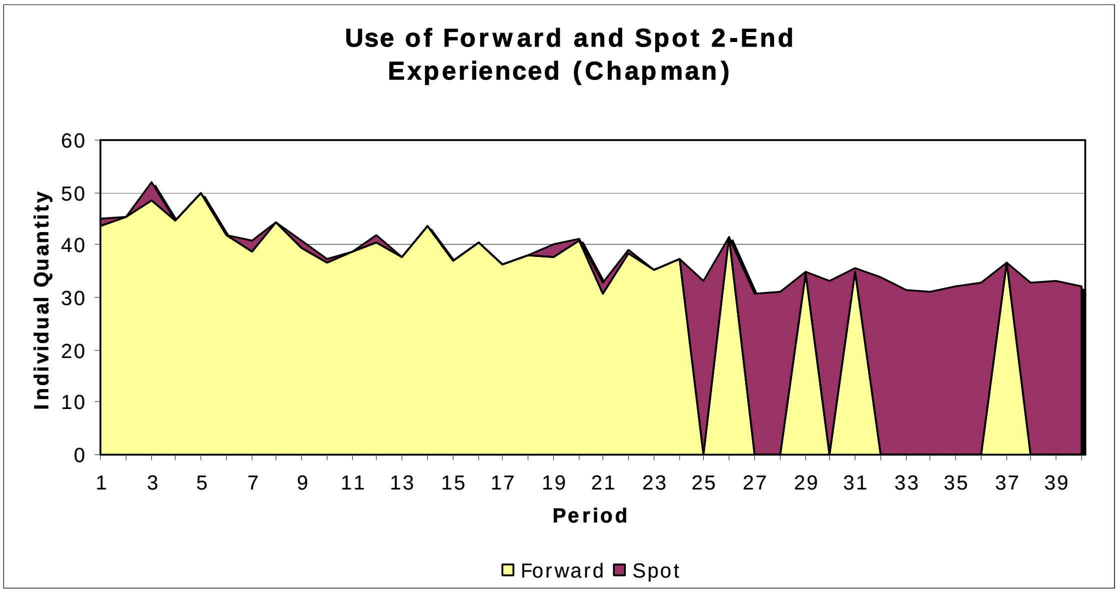
Figure_6



Overall, the pattern has similarities with the exogenous close inexperienced case. There we observe a decrease in the use of forward markets, and an increase in the use of spot markets with the final effect of a decrease in total quantity. It seems that, under endogenous close, it takes more time and learning to avoid the use of forward markets. This hypothesis is reinforced by the fact that, in the final rounds, we observed some markets with zero positions in the forward markets. Further, in the Chapman experiments, we were able to run the experiments for experienced duopoly for more rounds than we did at George Mason. The numbers in Tables 14 and 15 (and Figure 6) correspond to the aggregation of the 30 rounds at George Mason and the first 30 at Chapman. Figure 7 shows the counterpart of Figure 6, but now showing only the data from the 40 last rounds at Chapman. We can observe how the behavior in the last rounds has a clear tendency towards avoiding the use of forward markets. Note that the quadropoly experiments show a pattern similar to Figure 5 (see Appendix).

Table 15: Experienced duopoly: Endogenous close Use of forward and spot-First and Last ten rounds				
		Forward	Spot	Total
Perfect comp. (AV)		100	0	100
Cournot (Ferreira)		0	66.67	66.67
First 10	Cournot in RD	-	12.31	-
	Monopoly in RD	-	9.23	-
	Observed-1 (as % of Cournot in RD)	**81.53 -**	**2.34 (19)**	**83.87 -**
Last 10	Cournot in RD	-	23.67	-
	Monopoly in RD	-	17.75	-
	Observed-2 (as % of Cournot in RD)	**64.5 -**	**14.62 (61.2)**	**79.12 -**
% Change of observed (p-value)		-20.8 (0.0013)	522 (0)	*-5.6 (0.15)*
% Change of observed quantity when measured as a proportion of theory in RD (p-value)		-	223 (0)	-

Figure 7



4.3 Cournot Oligopoly vs. Forward markets

In another paper (Ferreira *et al.*, 2009) we study experimental Cournot oligopolies[14]. Below we compare some results from this paper with the exogenous and endogenous close forward markets experiments. By doing so, we compare the effect of introducing more firms in the market, *i.e.*, 2 vs. 4, and the addition of forward markets. Table 16

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

summarizes average sales by duopolies and quadropolies (with no forward markets) against the exogenous close and the endogenous close forward markets.

Looking at Table 16 one sees that due to experience the average output for a quadropoly decreases from 84.58 to 81.58, a decrease of 3.55%. This decrease is of a much greater magnitude for a duopoly, with an experienced duopoly producing output closer to the monopoly level (53) resulting in a decrease of 32.86%. Comparing these results one sees that experienced quadropolies in forward markets with exogenous close are less competitive than Cournot quadropolies. Note that for an exogenous close 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. Note, however, that a Cournot duopoly with experienced subjects is less competitive than a duopoly in the presence of forward markets.

Table 16: 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 with Exogenous Close		
Duopoly (% of 2-Cournot)	85.56 (99.8)	62.53 (72.9)
Quadropoly (% of 4-Cournot)	99.85 (101.7)	76.84 (78.3)
Forward with Endogenous Close		
Duopoly (% of 2-Cournot)	98.32 (147)	79.12 (118.7)
Quadropoly (% of 4-Cournot)	103.23 (129)	(130) (162.5)

Our quadropoly results are along the lines of Le-Coq and Orzen 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

A lot of legend surrounds 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 (Le-Coq and Orzen (2006) and Brandts et al. (2008)) and empirical (Wolak, 2000) literature points indicates that the introduction of forward markets can result in competitive outcomes.

As in Le-Coq and Orzen we study the strategic motive of the firms to sell in forward markets. Our design has some important differences from them. 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. Finally, we also tested a design with an undefined number of periods of forward markets.

Three main results emerge from our experiments. First, we find that experienced subjects are less competitive than inexperienced ones. Second, an implementation of the infinite opening version of forward markets (endogenous close rule) results in more competitive outcomes. It seems that the prisoners' dilemma nature of the strategic motive is better captured by such a structure. Thirdly, we find that with experienced subjects the effect of entry (number of firms) on increasing market competitiveness is greater than the introduction of the forward markets. Over time subjects learn to avoid using forward markets and produce only in the spot market.

Our most interesting result is for the case of the exogenous close duopoly and quadropoly. We find that both are much less competitive than theory and earlier experimental evidence indicate. Duopolies find it easy to coordinate actions and achieve a near monopoly outcome. Quadropolies are relatively more competitive, however, they are much less competitive than theory predicts. The use of forward markets by experienced subjects is minimal. Looking at data one sees that subjects first learn to avoid the use of the forward markets, and, then to reduce quantities in the spot market.

Another interesting feature that distinguishes in-experienced and experienced subjects is that there is greater volatility in the behavior of experienced subjects. Table

17 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 17: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)

We also report new results for our implementation of a design with potentially infinitely many periods of forward markets (endogenous close rule). Compared with two forward markets (exogenous close) we find that the infinite forward market (endogenous close) scenario is much more competitive. In such an environment subjects find it had to coordinate actions, much more so when the number of players is four. In the endogenous close scenario, subjects have more opportunity to stake a position and to punish deviators that use the forward market. To do so: one is always certain that there will be another forward market period after any position is taken. However, it seems that to have more opportunities to deviate from collusive behavior is more important than to have opportunities to punish deviators.

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APPENDIX 1

Figures A.1 and A.2 show the evolution in the use of forward and spot markets for both unexperienced and experienced quadropolies in the endogenous close case. Table A.1 shows the changes between the first and the last 10 rounds, and shows no significant difference.

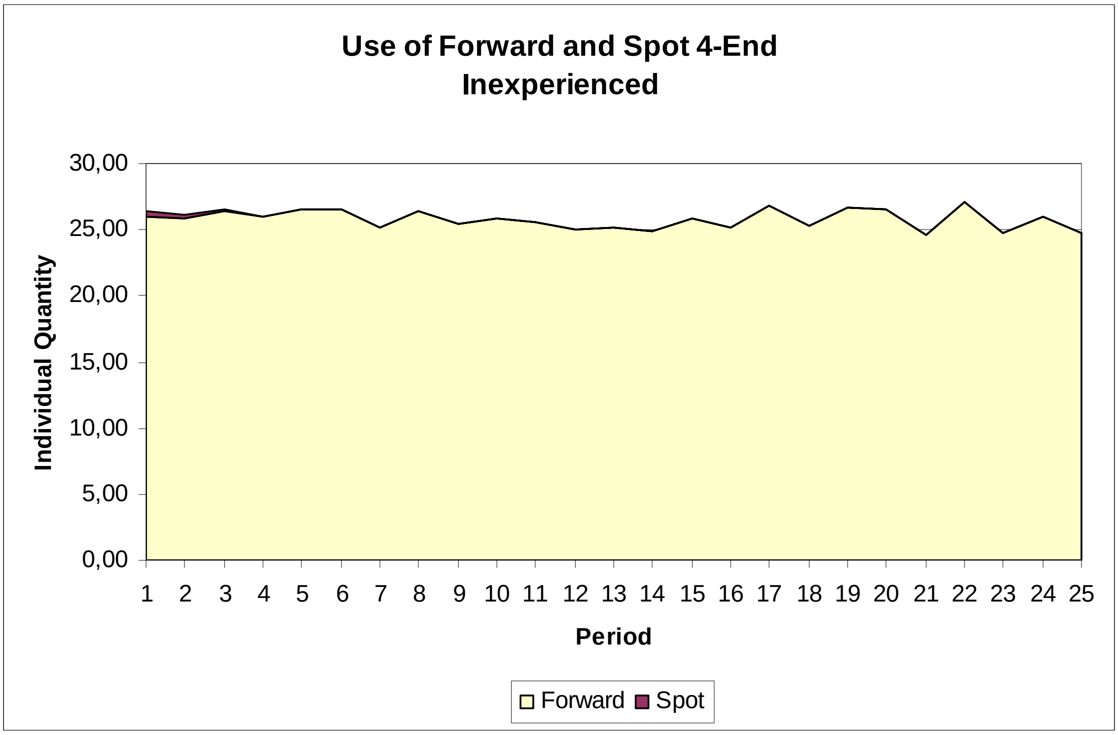

Figure A.1

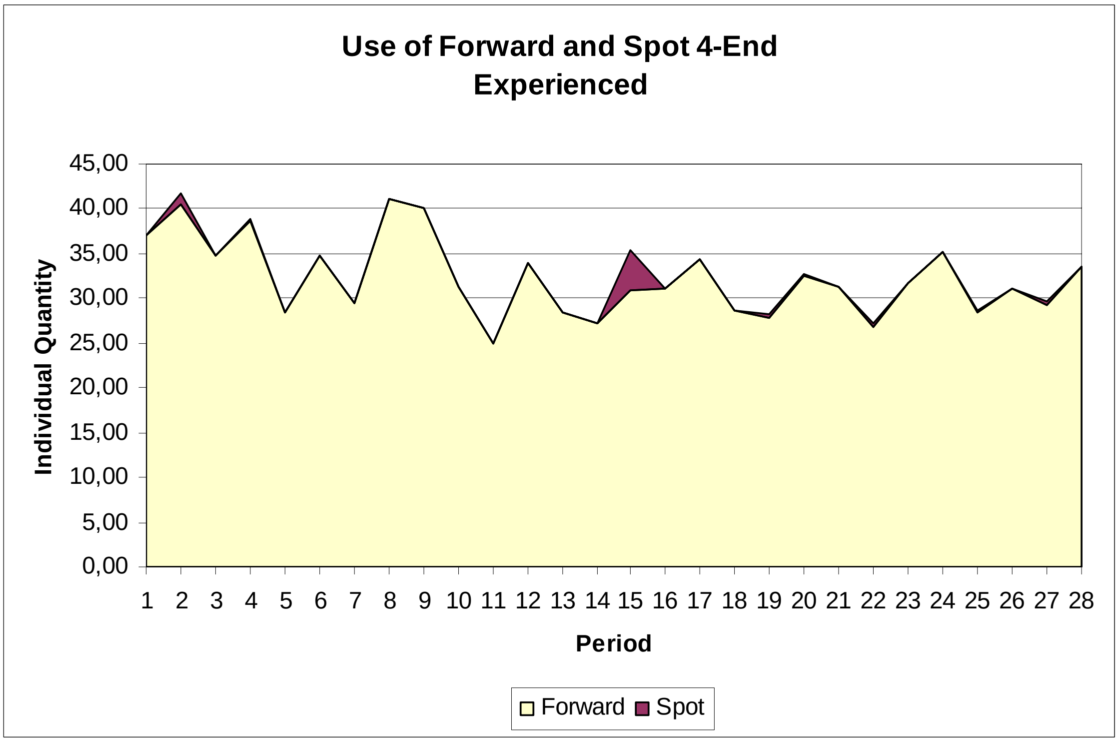

Figure A.2

	4 Endog. No exp.	4 Endog. Exper.
First 10	104.38	143.10
Last 10	103.07	123.67
% Change	-1.25	-13.58
p-value w/ one tail (T-test)	0.35 (0.38)	0.025 (1.96)

Table A.1

APPENDIX 2

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**.

<u>Example 1</u>: 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).
<u>Example 2:</u> 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 3

Instructions for experienced subjects

INSTRUCTIONS

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<u>Decisión making:</u>

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.

<u>Day 1:</u>

- 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.

<u>Day 2:</u>

- 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

<u>Final day:</u>

- 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 4

Tutorial for experienced subjects

Tutorial (Print out to be given to the subjects)

2-poly
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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 **<u>only</u>** 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.