The No-Arbitrage Hypothesis with Two or More Forward Markets (and Active Buyers)

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Comments
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The no-arbitrage hypothesis with two or more forward markets (and active buyers)\textsuperscript{1}

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Abstract:
We test the no-arbitrage condition and an inertia hypothesis for fixed exogenous and an indefinite endogenous (intended to mimic infinitely repeated forward trading) close forward market. The no-arbitrage condition in forward markets, an important prediction in Allaz and Vila (1993), only holds when both buyers and sellers behave as the theory predicts. Introducing active buyers enables us to test this prediction. We further test the inertia hypothesis by providing sellers with prior spot market experience, a condition that occurs in real-world markets. We find that the no-arbitrage hypothesis does not hold with prices in the forward market being higher than in the spot. Importantly, even though near competitive levels of output are observed, sellers obtain a third of the total surplus. We find no evidence of the inertia hypothesis, that would enable sellers to limit quantities to Cournot output levels, either. Finally, we confirm earlier experimental results on competition enhancing effects of forward markets.

JEL codes: L13, C92, G13.
Keywords: Oligopoly, forward markets, no-arbitrage hypothesis, futures pricing.

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1. Introduction

In a forward market, occurring before the spot market, firms can commit to some sales at contracted prices. If the demand is uncertain and firms show some degree of risk aversion, risk hedging is a powerful motivation for entering the forward market. In this setting, Allaz and Vila (1993) laid out an additional strategic motive for the use of forward markets even in the case of certainty and perfect foresight of the demand in a Cournot oligopoly. In their model producers participate in forward transactions (as strategic variables) to improve their situation in the spot market. This is similar to the prisoners’ dilemma, where, when all producers enter in the forward market, the result is one of a higher quantity and market efficiency, and of lower profits compared to the Cournot equilibrium. The authors also show that, as the number of forward markets openings becomes large, oligopolists will produce near the competitive level.

One of the key features of this model is the assumption of an automated demand. Consider a typical Cournot market. The demand side is modeled with an aggregated demand function for competitive buyers. There is no strategic behavior on the part of the buyers and, for every quantity offered by the sellers, the corresponding price is the one at which the demand absorbs the quantity. Now consider the model with one forward market previous to the spot market. In this case, when firms choose quantities in the forward, they know that there will be a spot market later, where they will compete for the residual demand. This has two consequences: (i) buyers need to anticipate this in their plans for the first opening –this is the novelty of their results–, and (ii) the price must be the same in all openings of the market to avoid arbitrage.

In a previous paper, Allaz (1992) shows that the no-arbitrage condition in (ii) is obtained as a feature of the equilibrium if the model allows for strategic behavior on the part of the buyers. Thus, both models give identical results. However, as the model with automated buyers is simpler, one finds it in theoretical and experimental research (Le Coq and Orzen (2006), Brandts J, Pezanis-Christou P, Schram A (2008), Koten and Ortmann (2013), Ferreira, Kujal and Rassenti (2016), Cox, Karam and Pelster (forthcoming)).

The no-arbitrage condition is an essential element of the Allaz and Vila (1993) model that is yet to be tested. This can, however, only be done if the experimental design is with real buyers, allowing for experimental subjects to take decisions both on the supply and the demand side of the market. This is precisely what we do in this paper. Introducing real buyers allows for trades at different prices in different openings.
of the forward markets and in the spot market (in the forward market phase). More specifically, in our design firms and buyers choose not only quantities, but also prices, and the market clears accordingly in every forward market. The rule by which the market clears is known to the experimental subjects and is explained in detail in the next section. It is based on the actions taken only in that forward market and does not depend on the equilibrium of the remaining game. Thus, the no-arbitrage condition only holds if subjects behave as the theory predicts.

The second distinguishing aspect of our design enables us to test whether there is an inertia effect if there is an initial Cournot duopoly (spot-only) phase. While forward markets coexist with spot markets, it is not clear whether prior experience in a spot market has an inertia effect on the forward market stage. This is an important point as the existence of inertia can alter future actions. Given this, we add the forward markets after the sellers have participated in a series of (only) spot market duopolies. Again, theoretically, this should not change anything, but this implementation arms the non-inertia hypothesis that we test. In sum, our design enables us to check for the two important hypotheses, the “no-arbitrage” and the “inertia” hypotheses in addition to checking for the, by now well established, pro-competitive effect of the forward markets in experimental forward markets. Neither has been studied to date.

The structure of our experiments is as follows. To test for the inertia hypothesis, in the first phase, subjects as sellers, play in a sequence of spot-markets for a given number of periods. This is followed by a second forward markets phase where subjects as sellers play in another sequence of periods where forward market are introduced previous to each spot market. Active buyers are a feature of all forward markets. The closure of the forward market is either exogenously or endogenously determined, depending on the experimental treatment. While the exogenous close, with a predetermined number of futures markets previous to the spot market, is used in most experimental setups, the endogenous close is an adaptation which mimics the indefinitely repeated forward market version of Allaz and Vila (1993)².

Our experiments provide some new results on prices in the forward and spot phase, and surplus sharing. The introduction of real buyers in the forward markets enables us to track prices during the sequence of market openings. We find that prices are higher in the earlier forward markets. This has two important consequences: (i) we

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² That was implemented in Ferreira, Kujal and Rassenti (2016).
find that the no-arbitrage condition is not satisfied, and (ii) in the case of the endogenous close, the sellers keep a third of the total surplus. This occurs even when the total quantity sold is very close to the competitive outcome where theoretically they should make zero profits. Interestingly, the above occurs even if subjects seem to be aware (reflected in their forecasts) of the way prices change as the futures markets unfold. Finally, we confirm that forward markets are competition enhancing. Additionally, the size of the pro-competitive effect is consistent with previous literature for both the fixed, and indefinite, numbers of forward markets.

Prior literature:

There is already some experimental literature that has studied the strategic market for forward markets in experiments (LeCoq and Orzen, 2006; Ferreira, Kujal, Rassenti, 2016; Brandts, Pezanis-Christou and Schram, 2008) and empirically (Wolak, 2000). This literature directly tests the strategic motive and finds that forward markets are indeed competition enhancing and that the effect increases with two forward markets (Ferreira, Kujal, Rassenti, 2016) relative to one (LeCoq and Orzen, 2006). Additionally, Ferreira, Kujal and Rassenti (2016) implement the endogenous close version of a forward market and find it to be competition enhancing with little remaining role for the final spot market. Thus, Allaz and Vila’s (1993) assertions of efficiency enhancement and competitive limits of output with a large number of forward markets is confirmed³.

There are other experimental papers that study questions different from ours using forward markets. Cox, Karam and Pelster (forthcoming) experimentally study a dynamic multi-period Cournot duopoly with a simultaneous option to manage financial risk and a real option to delay supply. They find that firms make use of the hedging instrument thus enhancing competition. Meanwhile, Koten (2021) experimentally studies the risk premia in electricity markets.

The empirical research on forward markets, however, is scarce. For the Australian power market, Wolak (2000) shows that the effect of using forward markets is pro-competitive. 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 of the theoretical models described above agree that,

³ Finally, 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.
when used, forward markets are pro-competitive. However, they differ in a very important respect. In some models, the equilibrium behaviour forces firms to enter the forward market, while in others, equilibria exist in which firms avoid these markets. Hence, sensu stricto, Wolak’s conclusion is only about the subgames in which firms do enter into forward market competition and says nothing about the question of whether firms would avoid competition by not using forward markets when allowed to decide in a non-regulated market. Wolak (2003) also identifies the lack of forward contracting in the California electricity market as the primary cause of extremely high spot prices for the period June 2000 to June 2001.

The paper is organized as follows: in Section 2 we present details of the experimental design; Section 3 presents the formal results; and Section 4 concludes.

2. The experiment design\textsuperscript{4,5}

The experiments had IRB approval. Under the title "The Economics of Decision Making" (IRB permit #: 1415H012, Chapman University), the Institutional Review Board (IRB) at Chapman University provided ethical approval and approval of an electronic consent procedure for all experiments done at Economic Science Institute (ESI) that involve no deception, no audio or video taping, and no invasive procedures, or food or drugs. To be included in the ESI subject database, volunteers must provide electronic consent (name, student ID#, and acknowledgment of agreement to the terms of an electronic consent form they must read). Subjects for all generic decision-making experiments covered by IRB permit #: 1415H012 are then randomly selected from the database to participate in particular experiments.

Participants were recruited from the undergraduate student population from Chapman University. The experiments consisted of two treatments, exogenous (EXO) and endogenous (ENDO\textsuperscript{6}) number of forward markets, with each treatment having two parts. The first part is the same in both the EXO and ENDO treatments and consists of Cournot quantity competition which lasts for 25 periods. The second part introduces a series of forward markets before each spot market, where the final forward market is determined exogenously (preset) or endogenously (based on a no volume rule). Each

\textsuperscript{4} We ran some preliminary tests and a pilot experiment that served to polish the instructions and to ensure that the definitive experiments did not present any problem with regard to time constraints or understanding of the game.

\textsuperscript{5} All instructions are presented in the Appendix.

\textsuperscript{6} We discuss details below.
spot market duopoly with forward markets is played for a total of 50 periods for both the EXO and ENDO treatments.

All participants knew exactly the format and the number of periods they would be playing. The subjects were randomly allocated to being buyers or sellers. Each duopoly consisted of two buyers and two sellers. Sellers had a cost $c = 12$ for selling each unit, and buyers had individual demands given by $q_i = 51 - \frac{p}{2}$, which gave a total demand of $q = 102 - p$. All duopoly pairs were fixed. Participants were told that the experiment consisted of two parts. All participants could see a Status-Box that showed Time Remaining in each Day, Week number, and their earnings in dollars. As is customary in Cournot oligopolies, buyers were passive with an important exception. Given that buyers would be participating in the phase with forward markets, during the spot only phase we asked them to make estimates of the next market price. They knew that it would have no impact on their earnings during the first phase. They were shown the information below.

**Your Computer Screen**

The numbers in the My Choice Box at the bottom of your screen provide you with information about the relationship between the quantity you buy, the market price, and your profit.

On this screen during Part I, you may enter your estimate of the next market price. This will have no effect on your earnings whatsoever, but it will help you learn to accurately estimate prices which will be needed during Part II.

- If your estimate is correct, then the numbers you see will show the exact quantity you will buy and the earnings you will make when your computer automatically buys the quantity that maximizes your earnings.
- If the actual market price is higher than your estimate, then both the quantity you buy and your earnings will be lower than what you estimated.
- If the actual market price is lower than your estimate, then both the quantity you buy and your earnings will be higher than what you estimated.

The green shaded area gives the size of your earnings for the estimated price and quantity.

**Page 10 [End part I instructions]**

You have now finished the instructions for the first part of the experiment. Please wait patiently while the remaining participants finish.

It is important that buyers were active in the subsequent second phase during each forward market, stating the volume and price they were willing to pay and creating the current forward demand. The seller’s offered quantities to sell and the program computed earnings according to the buyers’ demand. During the second phase’s 50

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7 See Appendix for details.
periods of forward-plus-spot market, subjects played in either the exogenous or the endogenous close treatment. We first explain how buyers make their choices and then we explain the exogenous, and endogenous, close forward markets.

We tried to implement all instructions in a manner such that buyers and sellers could visualize the implication of their choices. This was important as they were going to participate as buyers in the subsequent forward market phase. For example, buyers were told the following:

**Maximizing Profit**

Remember, during Part I your computer will automatically buy the quantity that gives you the highest earnings. If your demand is like the one in the graph and the market price is 20, then your computer will buy 40 units, because each of those units has a value greater than 20. The shaded area would represent your total earnings of 1600, which is 40 units times an average profit of $\frac{1}{2} \times (100-20)$.

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**Buyer choices-forward market**

As mentioned earlier, the novelty of our design is the introduction of buyers in the forward market implementation. Buyers know the number of buyers and sellers in each market, and that there will be 50 periods (called weeks), with each week having either two forward, and one spot market (exogenous close) or multiple forward and one spot (endogenous close). They are also told that they will need to make decisions on how to distribute their total purchases among the different markets within each week. The intra-week markets are called days. They are also informed that their total purchases...
purchases are ultimately determined by what they purchase actively in the forward markets plus what they automatically (passively) purchase in the last day of the spot market depending on the price in the last day.

“If you decide to buy some units in the earlier days of each week, then these units will be subtracted from the total possible purchases in the last day. Notice that the purchase price may be different each day.”

A buyer has to select a price and quantity pair \((p, q)\) to bid in each of the forward markets. This \((p, q)\) bid, along with the buyer’s current total remaining (unpurchased) demand at price zero, implicitly determine the buyer’s submitted linear demand. Given this demand function, the computer automatically purchases the quantity that maximizes profits for the buyer. For example, if the market price is the same as the bid price, \(p\), the buyer purchases the same quantity, \(q\), that it bid. If the market price is lower (higher) than the bid price, \(p\), then the buyer purchases more (less) than \(q\).

For the buyers, the computer updates its remaining (unpurchased) demand given its successive purchases. For example, suppose that a buyer purchased 15 units at a price of 47 in the first day. The computer screen then displays a graph like the one below for the next day. In the graph, a dotted black line shows the past results, and remaining demand is shown in colour.\(^9\) There are two remaining demand lines: the lighter (upper) one shows the actual values to the buyer for its remaining units while the heavier (lower) line shows the demand to be submitted in the next forward market if the buyer bids the same price, \(p = 47\), for a quantity of all remaining unpurchased units, \(q = (50 - 15) = 35\).

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\(^9\) In the instructions the graph used employs the style of the buyer screen in the actual experiment.
Buyers are provided with the following weeklong example:

**Week Example**

Say you begin with a demand for 50 units, and on day 1 you buy 10 units at a price of 40. Suppose that on day 2 you buy 15 more units at a price of 20.

Your remaining demand for the rest of the week is 25 units (50-10-15), with the highest remaining units valued at 50 and the lowest one valued at 0. Your remaining demand is represented on the graph to the right by the blue part of the original demand.

Also notice in the graph you can see the quantity you purchased and what price you paid for day 1 and day 2. Finally, your profits for day 1 (500) and day 2 (575) are shaded in gray and green respectively.

By presenting clear graphical instructions our goal was to make the understanding of the complicated forward market process as intuitive as possible. In addition to information about the past days a buyer could also make estimates about total profit during the week by trying different combinations of prices and quantities. If a buyer did not submit any bid in a given forward market, then the buyer cannot buy anything unless the price is zero (at which price all remaining demand is purchased).
Following the instructions, buyers are guided through two practice rounds each with a three-day week. They are then informed that they can themselves engage in more practice rounds. They simply click on “ready to go on” when they think that they have had enough practice.

**Exogenous close (EXO)**

We ran a total of 16 duopolies in this treatment, each consisting of two sellers and two-buyers. Each period (week) has two days with forward markets followed by one day with a spot market. A seller offer consists of a quantity and price pair. In the first forward market, sellers choose a quantity to sell and a reservation price, which, together with the origin, define a supply curve. Buyers, meanwhile, choose a quantity and a price that, together with the intercept point of the original demand \( \left( p = 0, q_i = 51 \right) \), define a new linear demand. Given, buyers and sellers bids and offers, an equilibrium price is computed, quantities are traded at the equilibrium price, and subjects collect profits. The traded quantities are subtracted from the buyer demands and the market proceeds to the second forward day, which is conducted similarly using the buyers’ residual demands. After once more subtracting the traded quantities, the spot market is finally conducted. Buyers are passive in the final spot market and sellers play a standard Cournot game in the remaining demand.

Sellers are requested to provide estimates of future price and quantities (both their own and their rival’s). They are provided by a two-day market example so they can visualize how the units demanded by the buyers interact with sellers’ offers.
Two-Day Market Example

Suppose a total of 100 units are demanded by the buyers. If 25 units are sold the first day, then 75 units is what remains of the buyers’ demand. The remaining 75 units demanded are shown by the blue line on the graph.

Now suppose 45 units are sold on the last day. This means a total of 70 of the 100 units have been sold \(25 + 45 = 70\). In this case, the units sold on the last day are sold at a price of 30.

The 25 units sold on the first day could have been sold at any price. The price on the first day is determined by how many units are for sale that day and whether the buyers prefer to buy more now or later.

Finally, sellers are also provided an example that explains the selling process.

To sell units, you must enter both a maximum quantity and the minimum price you will accept per unit. You will receive the market price for any units you sell.

- If the market price is lower than the price you submitted, then you will not sell any of the units you offered.
- If the market price is higher than the price you submitted, then you will sell all the units you offered.
- If the market price is the same as the price you submitted, you will sell some of the quantity you offered.

Endogenous close (ENDO)

The ENDO treatment is same as EXO in the first quantity competition part. The only difference is that during the second part, the forward markets end in day \(T\) if no further quantities are traded in that day’s forward market. When this occurs then the experiment goes to the last day’s \((T + 1)\) spot market. We have data for 11 duopolies in this
treatment\textsuperscript{10}. As in the EXO treatment, sellers are asked to provide estimates of future price and quantities (both their own and their rival’s). This was done to prompt subjects to think more about their best responses to their own predictions.

3. Results
We implemented these experiments in a manner that preserves the duopolistic oligopoly in the supply side while maintaining a competitive demand side. Since the buyers have no say in the final spot period market outcomes, their best option in the forward markets is to reveal their true demand. If buyers purchase less than the equilibrium quantity during the forward markets, then they will make less profit (buy less at a higher price). On the other hand, what they can buy during the forward markets is limited by the quantity the sellers supply, so they can never increase the quantity offered by the sellers. This effectively makes the demand side competitive.

Below we first look at the results from our quantity setting duopolies. Then we examine the exogenous and endogenous close forward markets. We evaluate hypotheses concerning the effect of inertia caused by the initial quantity setting game on: profits and surplus share, the no-arbitrage condition, and predictions under both EXO and ENDO conditions.

3.1 Cournot duopolies

The broad result from quantity setting experiments is that obtaining successful collusion in oligopolies is difficult. Most experiments find that the non-cooperative Nash-Cournot equilibrium is a good predictor of the quantity choices under random matching (Holt, 1985; Huck et al., 2001; and Huck et al., 2004). Fouraker and Siegel (1963) meanwhile showed that information on rival outputs and profits makes the market more competitive. Successful collusion only sometimes emerges with duopolies under fixed matching while quadropolies result in outcomes that are much more competitive than predicted. Further, outcomes under asymmetric costs outcomes are relatively more competitive (Mason et al., 1992; Fischer and Normann, 2019).

Both the endogenous and exogenous close treatments started with 25 periods of quantity competition. We first checked whether there was any statistically significant difference between the two subsamples and found none. We then pooled these data. We

\textsuperscript{10} We could only obtain 11 markets as these were more cumbersome and difficult to conduct compared to the exogenous close and required longer durations.
had a total 27 independently run Cournot oligopoly experiments, with an average quantity of 54.11, which is 90.2% of the Nash-Cournot prediction of 60. Using the Wilcoxon signed-rank test, the difference is statistically significant at \( p = 0.01 \). Accordingly, relative to theory, prices and seller profits were lower and consequently buyer surplus was higher. Of course, the differences with respect to theoretical values were equally significant. These results are generally in line with other experiments where it has been shown that fixed-pair duopolies sometimes collude.

<table>
<thead>
<tr>
<th>Table 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summary statistics</strong></td>
</tr>
<tr>
<td><strong>Cournot-only periods (1-25)</strong></td>
</tr>
<tr>
<td><strong>Average (standard dev.)</strong></td>
</tr>
<tr>
<td><strong>Theory</strong></td>
</tr>
<tr>
<td>Quantity</td>
</tr>
<tr>
<td>Price</td>
</tr>
<tr>
<td>Sellers’ surplus (market total)</td>
</tr>
<tr>
<td>Buyers’ surplus (market total)</td>
</tr>
</tbody>
</table>

### 3.2 Exogenously determined fixed number (2) of forward markets (EXO)

#### 3.2.1 Theory

Alaz and Vila (1993) introduce a forward market in a Cournot model of oligopolistic competition in the following way. Say two firms 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 \( s_i = \frac{A - F}{3} \) in this spot market, where \( F = f_1 + f_2 \) is the total of quantities sold in the forward market by both firms. The equilibrium price is \( p_s = \frac{A - F}{3} \). Knowing this, firms will choose their quantities in the forward market solving

\[
\max_{f_i} f_i p_f + s_i p_s \\
\text{s.t. } s_i = \frac{A - F}{3}, p_s = \frac{A - F}{3}, \text{ and } p_f = p_s,
\]

which gives

\[
f_i = s_i = p_s = \frac{A}{5}.
\]

If the forward market is open \( T \) times before the spot market, the equilibrium is

\[
f_i^T = s_i = p_s = \frac{A}{3 + 2T}, \text{ where } f_i^T \text{ is the forward quantity sold by Firm } i \text{ in the forward}
market at \( t \). Total quantity (forward plus spot) is \( q = \frac{2+2T}{3+2T} A \). Notice that price and total quantity converge to the competitive case as \( T \) increases. Notice also that the no-arbitrage condition is imposed in the restrictions of the problem. In a previous work, Alaz (1992) showed that a competitive demand side in the forward markets may be replaced with this condition to get the same equilibrium price and quantities. Adding a positive constant marginal cost \( c \) identical for both firms changes the formulae to \( f^t_i = s_i = \frac{A-c}{3+2T} \) and \( p_s - c = \frac{A-c}{3+2T} \). In the exogenous close experiment, we have \( A = 102 \), \( T = 2 \), and \( c = 12 \). Theoretical predictions are summarized in Table 2. Note that F1 stands for the first forward market, F2 for the second.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Theoretical predictions: 2 forward-plus-spot periods (26-75)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity (all sellers)</td>
<td>25.71</td>
</tr>
<tr>
<td>Price</td>
<td>24.86</td>
</tr>
<tr>
<td>Sellers’ surplus (all sellers)</td>
<td>330.76</td>
</tr>
<tr>
<td>Buyers’ surplus (all buyers)</td>
<td>1653.06</td>
</tr>
</tbody>
</table>

**Hypotheses-Exogenous Close (EXO)**

Given the predictions from the theoretical models above we outline our testable hypotheses for the exogenous close of 2 forward markets (EXO) below:

**EXO1 - Output and prices**

1a. Total quantity is higher than Cournot, while the price is lower.

1b. Quantity sold in each forward market and the spot market are equal.

**EXO2 - Profits and surplus sharing**

2a. Seller profits decrease while buyer profits increase relative to Cournot. The predicted shares are 1/3:2/3.

2b. Total surplus generated is higher than in Cournot.

**EXO3 - Inertia (implicit hypothesis)**

3. Under the rationality assumption, theory predicts an equilibrium in the Cournot-only periods which is different than in the forward+spot periods, with no inertia from the initial Cournot phase into the subsequent EXO forward market phase. We will test this rationality assumption vs adaptive behavior.

**EXO4 – No-arbitrage condition**

4. Prices in all forward and spot markets are equal.

**EXO5 - Guesses**

5. Subject price guesses are accurate.
3.2.2 EXO Results

EXO1 - Output and prices:

Given demand and costs, the theoretical prediction for the first 25 periods of quantity setting duopolies is of 60, while Allaz and Vila’s prediction for the next 50 periods is 77.14, with 25.71 being shared equally across the two forward and spot periods (Table 2). Figure 1 shows the average of the observed quantities for all periods.

The total quantity in the forward-plus-spot periods (periods 26-75) is not significantly different from the Alaz and Vila theoretical prediction (77.14 vs. 78.91; tables 2 and 3). A corollary of this result, that forward markets enhance competition, is met. This can be seen easily if we formulate the null hypothesis that the total quantities in the Cournot-only periods and in the forward-plus-spot periods is the same, which is rejected with a $p$-value of zero in a one-sided test suggested by the model.

Next, we examine the division of quantity between the forward and spot markets (in periods 26-50). Table 3 shows the summary of the results. According to the theory, equilibrium quantities in every day are $F1 = F2 = Spot = 25.71$ (Table 2). However, the appropriate comparison is between the observed and the theoretical quantity in the relevant subgame, given the observed quantity in the periods before. For example, notice that the theoretical quantity for $F1$ is 25.71. However, the actual observed quantity in the first forward market is 32.58. Given this, the equilibrium quantity in $F2$, in the subgame after 32.58, is 22.96 (and not 25.71)\(^{11}\). These subgame-relevant theoretical quantities are shown in Table 4.

Our tests show that quantities are close to theoretical predictions. In particular, the hypothesis that Forward ($F1+F2$), Spot and Total quantities are equal to the theoretical ones cannot be rejected. What differs from the theoretical result is how the forward quantity is divided between the two forward markets: quantity in $F1$ is different from the theoretical quantity and the difference is not statistically significant ($p$-value of 0.1). While the hypothesis that in $F2$ the theoretical prediction is the same as the observed average is rejected beyond a 1% of confidence.

\(^{11}\) This would be the equilibrium quantity if subjects chose 25.71 in $F1$.  

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Experimental observations

EXO forward-plus-spot periods (26-75)

Average (standard dev.): */**/*** means reject Th=Obs at p=0.1/0.05/0.01

<table>
<thead>
<tr>
<th></th>
<th>F1</th>
<th>F2</th>
<th>Spot</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity</td>
<td>32.59*</td>
<td>15.42 ***</td>
<td>30.9</td>
<td>78.91</td>
</tr>
<tr>
<td></td>
<td>(13.82)</td>
<td>(5.39)</td>
<td>(10.75)</td>
<td>(9.16)</td>
</tr>
<tr>
<td>Price</td>
<td>29.8**</td>
<td>23.99</td>
<td>23.33</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(8.13)</td>
<td>(5.83)</td>
<td>(8.65)</td>
<td></td>
</tr>
<tr>
<td>Sellers’ surplus (market total)</td>
<td>547.72***</td>
<td>237.56</td>
<td>316.32</td>
<td>1101.59**</td>
</tr>
<tr>
<td></td>
<td>(256.1)</td>
<td>(146.82)</td>
<td>(465.47)</td>
<td>(324.84)</td>
</tr>
<tr>
<td>Buyers’ surplus (market total)</td>
<td>1473.9</td>
<td>884.65***</td>
<td>286.6***</td>
<td>2645.22***</td>
</tr>
<tr>
<td></td>
<td>(697.2)</td>
<td>(394.37)</td>
<td>(215.1)</td>
<td>(472.04)</td>
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</tbody>
</table>

*Result 1a*: We reject the null hypothesis that overall quantity sold is equal to the observed under Cournot competition. Hypothesis 1a is thus validated.

*Result 1b*: We do not reject the null hypothesis that the observed total forward quantity is equal to the theoretical prediction. We reject the null hypothesis that the forward quantity in the first day is equal to the forward quantity in the second day. Hypothesis 1b is partially validated.
EXO2 - Profits and surplus sharing

A discussion on total surplus and surplus sharing is relevant especially in the context of forward markets as they are supposed to result in competitive outcomes. We find that the total surplus is very close to the ex-ante theoretical prediction. This was expected as we already know that the total quantity is not significantly different from the theoretical prediction.

<table>
<thead>
<tr>
<th>Table 4 Subgame-relevant theory predictions EXO forward-plus-spot periods (26-75)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>Quantity (all sellers)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Price</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Sellers’ surplus (all sellers)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Buyers’ surplus (all buyers)</td>
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<tr>
<td></td>
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</tbody>
</table>

The share of the surplus for buyers and sellers, however, does not correspond to the theoretical outcomes. Comparing the last two rows in tables 2 and 3, we see that, while sellers make greater profits (1101 compared to 992), buyers make less (2645 compared to 2974). Regardless, seller profits are much lower than those in the Cournot-only scenario. In the same vein, buyer profits are also much higher than without forward markets (the Cournot-only observed profits for sellers and buyers are 1622 and 1664, respectively, as shown in Table 1). In other words, forward markets are beneficial to buyers even if sellers take a higher than theoretical share of the surplus. As we see next, in the study of the inertia hypothesis, this discrepancy with the theory is higher in the earlier periods of the experiment. During the later periods, the sharing of profits tends toward the theoretical distribution (see Figure 2).

Result 2a: We reject the null hypotheses that the seller share of the surplus does not decline with respect to the Cournot and that the buyer share does not increase. Hypothesis 2a is validated.

Result 2b: We cannot reject the null hypothesis that total observed profits are equal to the theoretical prediction. Hypothesis 2b is validated.

EXO3 - Inertia
In Ferreira et al. (2015), which lacked a prior Cournot-only phase, no particular effect was found in the total quantities during the first periods of play. By contrast, Brandts et al. (2006) do find that some learning is needed until subjects’ behavior stabilizes after ten periods. However, the experiments in this later work use a more complicated market simulation, as they introduce quadratic costs. In our experiments forward markets are introduced after subjects had played twenty-five rounds of Cournot play. We can check whether this results in inertia, in the sense that once the forward markets are introduced subjects’ behavior is closer to Cournot in earlier rather than later periods.

If behavior is restricted to quantity choice, the hypothesis that there is a positive slope in the total quantities in the forward plus spot markets periods is rejected. This implies that no inertia is detected. A simple regression shows a measured slope equal to -0.0005 which is not significantly different from zero. If there is any inertia, it lasts only for one period as the first period shows an average total quantity of 70.94, while in the second period the average total is 82. Recall that the average total quantity for all periods is 79.91. However, we do find that prices show some inertia in the forward stages, in the sense that they are higher in the first periods than in the later ones. Note that we have only three prices, one for each day of the week, so the comparison with the Cournot prices is not very informative.

A better way of presenting the information is embedded in the way profits are divided between buyers and sellers. Since the quantities do not show inertia, and since profits are calculated multiplying net price times quantities, total profits will not show inertia, but the manner in which profits are split reflect any inertia due to prices.

Figure 2 shows that there is indeed some inertia. During the 25 Cournot-only periods, sellers obtain an average of 811 each, while buyers get 832 (theoretical Cournot profits are 900 for each buyer and each seller). In the forward-plus-spot periods, sellers make an average profit of 550 and buyers make 1323 (theoretical predictions are 496 and 1487 respectively). For sellers, profits decrease steadily for 10 weeks until they settle around the average. For buyers there is a corresponding increase. For the total number of weeks, a simple regression analysis shows a significant slope of -4.34 for sellers’ profits and of 12.28 for buyers.

Result 3: Our results reject the null hypothesis that there is no inertia in the sharing of profits, but do not reject the null hypothesis that there is no inertia in quantities. Thus, Hypothesis 3 is partially validated.
Of special importance is whether the no-arbitrage hypothesis, that asserts that prices in all markets must be equal, is satisfied. We find that prices are close to theoretical, although the exact prediction is not met for F1 (Table 3). The data show arbitrage opportunities between F1 and F2 ($p = 0.01$), and between F1 and the Spot market ($p = 0.05$). No arbitrage possibilities are found between F2 and the Spot. We thus reject the no-arbitrage hypothesis between F1 and F2 and, F1 and the spot market. These results are presented in Table 5.

<table>
<thead>
<tr>
<th>Tests</th>
<th>F1=F2***</th>
<th>F1=Spot**</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>29,8 (8.13)</td>
<td></td>
</tr>
<tr>
<td>F2</td>
<td>23.99 (5.83)</td>
<td></td>
</tr>
<tr>
<td>Spot</td>
<td>23.33 (8.65)</td>
<td></td>
</tr>
</tbody>
</table>

* 10%, ** 5%, *** 1%.

Result 4: The hypothesis that prices are the same in all days of a week, is rejected: there are significant arbitrage opportunities between F1 and F2 ($p=0.01$), and between F1 and the Spot market ($p=0.05$).

EXO5: Guesses
As earlier mentioned, sellers were asked to estimate quantities, whereas buyers were asked to estimate prices. Even though these were not incentivized, asking participants for guesses can potentially help in decision making as it forces the participants to think about future earnings. Tables 6 and 7 summarize these results.

The total quantities guessed at F1 are closer to the actual quantities than the total quantities guessed at F2 where the difference is statistically significant. This is surprising since at F2 subjects have more information than at F1. Subjects show systematic overconfidence in the quantities they “think you will sell” relative to the quantities they “think your rival will sell”. Given that their actual sales are lower than what they guess and closer to equilibrium values, it seems like they are thinking more optimistically than they are acting.

Buyers underestimate the price in the Cournot-only weeks, where they take no action. They make better guesses in the forward+spot periods, where they are active. However, the fact that buyers can guess the price in F2 when they are at F1 is at odds with the fact that there are arbitrage opportunities between these two markets, as shown earlier. It seems that they predict the future price better than they anticipate the current price. This is contrary to the result for quantities where guesses in F1 are better than in F2. There seems to be a clear difference between how they guess prices vs quantities.

**Result 5:** *We reject the null hypothesis that guessed prices and quantities are equal to actual ones. Thus, Hypothesis 5 is not validated: sellers overstate their quantity guesses while buyers understate prices. Buyers seem to predict future prices better than present.*

### Table 6

<table>
<thead>
<tr>
<th>Sellers’ quantity guesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual</td>
</tr>
<tr>
<td>Rival’s Q in Cournot only</td>
</tr>
<tr>
<td>(standard dev)</td>
</tr>
<tr>
<td>(7.54)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total market Q in Cournot +Forward</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual</td>
</tr>
<tr>
<td>78.9</td>
</tr>
<tr>
<td>(9.2)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Own total Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual</td>
</tr>
<tr>
<td>39.5</td>
</tr>
<tr>
<td>(13.3)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other’s total Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual</td>
</tr>
<tr>
<td>39.5</td>
</tr>
<tr>
<td>(13.3)</td>
</tr>
</tbody>
</table>
Table 7
Buyers’ price guesses

<table>
<thead>
<tr>
<th></th>
<th>Actual</th>
<th>Guessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price in Cournot only</td>
<td>46.7 (8.0)</td>
<td>42.7*** (10.3)</td>
</tr>
<tr>
<td>Price for F2 (in F1)</td>
<td>24.1 (5.8)</td>
<td>25.2 (9.13)</td>
</tr>
<tr>
<td>Price for Spot (in F2)</td>
<td>23.1 (8.6)</td>
<td>18.1*** (8.8)</td>
</tr>
</tbody>
</table>

3.3. Endogenously determined number of forward markets (ENDO)

3.3.1 Theory

Allaz and Vila (1993) show that, as the number of forward markets increases, total quantity and price approach the perfectly competitive ones. On the other hand, Ferreira (2003) argues that if the forward market has infinitely many moments in which trade is allowed, any price (and quantity) between Cournot and perfect competition can be sustained in equilibrium. As in many other instances, the limit of the equilibria in finite games may not exhaust all the equilibria in the infinite game. In fact, something similar to a Folk Theorem is obtained if the infinite case is analyzed directly. In this case, any total quantity and corresponding market price between competitive and Cournot can be observed in equilibrium.

Note that 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 (2003) 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.

For operational reasons, we implement an adaptation of the specification in Ferreira (2003). As we cannot have infinitely many forward markets periods in our experimental setup, we replace the condition in the model with the following adaptation: a forward market is opened in day 1, beginning with day \( t = 2 \), a new forward market is opened in day \( t \), as long as total trades during day \( t-1 \) were positive. Otherwise, the forward market phase closes and day \( t \) becomes the spot market. This adaption implements an indefinitely repeated version of Ferreira (2003) that, as we show below, does not change the predictions.

Our second implementation adaptation has to do with the integer problem, as subjects cannot enter quantities with decimals. This changes the model, but only in the sense that the results in Ferreira (2003) are approximations of the results in the model with the integer restriction. For the sake of completeness, we now show that under the endogenous close rule both Cournot and competitive prices can be sustained in a subgame perfect equilibrium in the adapted model in the same fashion as they are sustained in the original model.

Consider the case of one forward market before the spot market with demand given by \( p = n - q \) where \( n \) is a natural number. The forward market opens at discrete times, and each time firms can choose to sell any amount in the market (after observing the previous positions). A forward market opens at time \( t \) if some quantity was traded at \( t-1 \), otherwise period \( t \) becomes the spot market. Firms’ strategy choices are \( f_i^t, s_i \in \{0,1, \ldots, n\} \), where \( f_i^t \) is the forward quantity sold by Firm \( i \) in forward period \( t \) and \( s_i \) is the spot quantity sold by Firm \( i \).

\textit{The Competitive Equilibrium}

In the forward market firms play the following manner:

(i) Firm \( i \) chooses \( f_i^t = \frac{n - \Sigma_{t-k} f_{k}^{t-1}}{2} \) if \( n - \Sigma_{k,t} f_{k}^{t-1} \geq 2 \) and even,

(ii) Firm \( i \) chooses \( f_i^t = \frac{n - \Sigma_{t-k} f_{k}^{t-1} + 1}{2} \), and Firm \( j \) chooses \( f_j^t = \frac{n - \Sigma_{t-k} f_{k}^{t-1} - 1}{2} \), if \( n - \Sigma_{k,t} f_{k}^{t-1} \geq 2 \) and odd,

(iii) Firm \( i \) chooses \( f_i^t = 1 \), and Firm \( j \) chooses \( f_j^t = 0 \) if \( n - \Sigma_{k,t} f_{k}^{t-1} = 1 \),

(iv) both firms choose \( f_i^t = 0 \) if \( n - \Sigma_{k,t} f_{k}^{t-1} = 0 \).
In the spot market firms play Cournot in the residual demand which, in the equilibrium path, is \( s_1 = s_2 = 0 \). In all cases, forward and spot market prices are \( p_f^t = p_s = p = 0 \), and profits are also zero. Given the strategy chosen by one’s opponent, changing the forward quantities does not change the price and no positive profits can be expected in any market.

**The Cournot Equilibrium**

In the forward market firms play:

(i) \( f_1^t = 0 \),

(ii) at \( t > 1 \) play as in the competitive equilibrium,

(iii) in the spot market play Cournot in the residual demand so, in the equilibrium path, firms play one of the integers closest to \( \frac{n}{3} \).

Clearly, by following the strategy, firms get a non-negative profit (positive if \( n \geq 3 \)). Any deviation in the forward market results in zero profits. In the spot market firms play according to the Cournot equilibrium.

**Hypotheses-Endogenous close (ENDO)**

The alternative theoretical models yield the following testable hypotheses for the Endogenous (ENDO) number of forward markets. In all hypotheses below (i) gives the competitive prediction, and (ii) gives the Cournot prediction.

**ENDO1**

6a: Output and Prices

6a-i: Equal the competitive outcome.

6a-ii: Equal the Cournot outcome.

6b: Forward market use:

6b-i: All quantity is sold in forward markets at marginal cost.

6b-ii: All quantity is sold only in the spot market at the Cournot price.

**ENDO2 - Surplus and surplus sharing**

Relative to the exogenously determined number of forward markets:

7-i: Total surplus will be higher.

7-ii: Total surplus will be lower with surplus shared equally by buyers and sellers.

**ENDO3 - Inertia**

8: No inertia when transitioning from spot only periods to forward-plus-spot periods. This is an implicit hypothesis as the theory gives different equilibria.
under each market condition, assuming rationality. We will test this rationality assumption vs adaptive behaviour.

**ENDO4 – No-arbitrage condition**
- 9a-i: Prices in all forward markets are equal.
- 9b-ii: There is no use of the forward market, and no prices are defined there.

**ENDO5 - Guesses**
- 10. Assuming subjects have rational expectations, their price guesses are correct.

### 3.3.2 Results

**ENDO1 - Output and prices**

We find that the endogenous close treatment yields competitive outcomes. This could be due to the fact that coordinating on output is difficult in the endogenous close environment. Figure 3 shows the average observations of the Cournot-only (first 25 periods) and the forward-plus-Cournot (last 50 periods) phases of the experiment. In 3, we can see that the theoretical quantity is the Cournot quantity for the first 25 periods and the perfect competition quantity for the last 50 periods (these quantities are 60 and 90, respectively). Although the theory allows for multiple equilibria, the observed data suggest that our results favor the competitive outcome.

<table>
<thead>
<tr>
<th>Table 8</th>
<th>Theory and observation forward-plus-spot periods (26-75)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cournot</td>
</tr>
<tr>
<td>Quantity (all sellers)</td>
<td>60</td>
</tr>
<tr>
<td>Price</td>
<td>42</td>
</tr>
</tbody>
</table>

*There is a different price for every forward and spot openings. Here we show the average price weighted by the quantities.

We now look at the Alaz and Vila, and the Cournot hypotheses in the forward+spot market periods. According to theory, there are a multiplicity of equilibria in the endogenous close model, of which, the more salient and extreme ones that yield the competitive and Cournot outcomes. In all the competitive equilibria, which is the limit of the finite Alaz and Vila model, the price is equal to the marginal cost in all forward markets and the residual demand for the spot market is zero. The Cournot outcome is achieved if subjects refrain from using the forward market and go directly to compete *a la* Cournot in the spot market.
While the Cournot hypothesis is strongly rejected (1% significant level), we weakly reject the competitive hypothesis (5% significance level). The average total quantity sold is 83.26, which is 92.5% of the competitive quantity of 90, but well above the Cournot quantity of 60. This average total quantity is equivalent to the theoretical quantity of a Cournot spot market with six previous periods of forward markets.\(^{12}\)

A pro-competitive hypothesis -that the opening of forward markets results in higher total quantity than the Cournot quantity- is validated. More precisely, the test that the quantity in the Cournot plus forward periods is no smaller than the quantity in the Cournot-only periods is rejected. Furthermore, the aggregate quantities observed are significantly higher and prices lower (both at \(p = 0.01\)) than in the exogenous close case, further supporting a pro-competitive hypothesis for additional forward markets.

Now, we look at the division between the forward and spot markets under the endogenous close of forward markets. As mentioned before, in the endogenous close model, the competitive outcome is one of the multiple equilibrium possibilities. In all the equilibria that give the competitive outcome, the price is zero in all forward markets and the residual demand for the spot market is zero. The way the competitive quantity is shared among the different forward market openings is undetermined, although the limit of the finite versions of the game yields a uniform distribution. The Cournot outcome is only achieved if subjects refrain from using the forward market and go directly to

\[83.26 = \frac{2 + 2T}{3 + 2T} \cdot 90.\]

\(^{12}\) Solving for \(T\) in the formula for the total quantity:
compete a la Cournot in the spot market. Neither case is observed. What we observed is an average of total forward positions of 58.22 and an average of spot sales of 25.04. As seen in Figure 3, although both quantities fluctuate across the periods, the sum is remarkably constant around the average of 83.26.

Now consider the Cournot hypothesis in the spot market. After the forward markets close, the spot market becomes a Cournot game, where firms decide how much quantity to sell to the residual passive demand. The average aggregate forward quantities sold is 58.22, leaving an average residual demand of 25.04 for the spot market, compared to the theoretical competitive and Cournot quantities of 31.78 and 21.19, respectively. The difference with the theoretical Cournot after the observed quantities sold in the forward markets is only marginally statistically significant (5% level, Wilcoxon rank sum test-table 9). One can see that in Table 9, where the Theory column is the Cournot equilibrium in the Cournot-only periods, and perfect competition in the forward-plus-spot periods. The column Theory in the subgame is the Cournot equilibrium in the spot market after 58.22 units sold in the forward markets. This quantity varies as different duopolies sell different quantities in the forward markets.

It is interesting to note that the same subjects who under-competed in the Cournot-only periods, over-compete in the spot market, which is also a Cournot game. It seems that having competed in the forward markets induces sellers to compete more

![Figure 3](image-url)
in the Cournot spot market. Looking at the distribution of the forward market quantities we find that the average market quantity is not uniform (i.e., equally distributed). About half of the forward market sales are conducted in the first market. Posterior openings of the forward market register about half the sales of the previous opening. Figure 4 provides the average sales per market opening, where forward markets are openings 1 through 11, and the spot market is opening 12 (in no case did the forward market open more than 11 times). This is different from the findings in the experiments with no active buyers, where no quantities were left to trade in the spot market, as the competitive quantity was already sold in the forward markets (Ferreira et al., 2016). We summarize our results below.

<table>
<thead>
<tr>
<th>Table 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory and observations</td>
</tr>
<tr>
<td>Endogenous close</td>
</tr>
<tr>
<td>Cournot-only periods</td>
</tr>
<tr>
<td>Theory</td>
</tr>
<tr>
<td>60</td>
</tr>
<tr>
<td>Forward-plus-spot periods</td>
</tr>
<tr>
<td>Total forward quantities</td>
</tr>
<tr>
<td>Spot quantities</td>
</tr>
<tr>
<td>Total quantities</td>
</tr>
</tbody>
</table>

Result 6a: The null hypothesis that the observed quantity is the competitive one is weakly rejected, while the null hypothesis that the observed quantity is the Cournot outcome is strongly rejected. Quantity is significantly higher and prices lower than in the exogenous case supporting a pro-competitive hypothesis for additional forward markets.

Result 6b: The null hypotheses (6b-i) that the forward, and (6b-ii) spot quantities are respectively zero is rejected. We observe sales in both forward and spot markets.

**ENDO2 - Surplus sharing**

Total quantity is closer to perfect competition than to theoretical Cournot, and consequently, so are other variables. A competitive output results in higher efficiency with the observed market surplus being 3928, while the competitive and Cournot market surpluses are 4050 and 3600, respectively. The total surplus is much closer to perfect competition (marginally significant at 5% levels) than to Cournot. According to the model, perfect competition would imply that all the surplus goes to the buyer, while
Cournot would imply an equal share. However, the observed profits are 2598 for the buyers (1299 each), and 1330 for the sellers (665 each), which is very close to 1/3 for sellers and 2/3 for the buyers. Thus, although the forward markets make trade very competitive, the sellers find a way to maintain a big part of the surplus they enjoyed without them. This is shown in Table 10. Below we present our results.

**Result 7-i:**
- The null hypothesis that total surplus is not higher than under exogenous close is rejected (and, a fortiori, the hypothesis that the surplus is not higher than in Cournot is also rejected).
- The null hypothesis that the total surplus is equal to the competitive outcome is rejected.
- The null hypothesis that sellers obtain no surplus is also rejected, although buyers obtain more surplus than sellers (2/3 vs 1/3 respectively).

**Result 7-ii:**
- The null hypothesis that total surplus is equal to the Cournot outcome is rejected.
- The null that the surplus is shared equally by buyers and sellers is also rejected.
- Both the Cournot and competitive hypotheses on surplus sharing are rejected, however, total surplus and surplus share are closer to perfect competition.
Table 10

<table>
<thead>
<tr>
<th></th>
<th>Cournot</th>
<th>Perfect competition</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cournot-only periods</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sellers’ surplus</td>
<td>1800</td>
<td>-</td>
<td>1579.46</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(190.77)</td>
</tr>
<tr>
<td>Buyers’ surplus</td>
<td>1800</td>
<td>-</td>
<td>1728.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(402.34)</td>
</tr>
<tr>
<td><strong>Forward-plus-spot periods</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sellers’ surplus</td>
<td>1800</td>
<td>0</td>
<td>1330.73</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(209.99)</td>
</tr>
<tr>
<td>Buyers’ surplus</td>
<td>1800</td>
<td>4050</td>
<td>2597.94</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(256.83)</td>
</tr>
<tr>
<td>Total surplus</td>
<td>3600</td>
<td>4050</td>
<td>3928.67**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(272.02)</td>
</tr>
</tbody>
</table>

** all observations are significantly different from quantities in any hypothesis at 0.01, except observed total surplus vs total surplus under perfect competition, which is rejected only at 0.05.

**ENDO3 - The inertia hypothesis**

As in the exogenous close case, no inertia is detected, and the hypothesis that there is a positive slope in the total quantities in the forward plus spot markets periods is rejected. The function of total quantities with respect to time has a slope of 0.00067, which is not significantly different from zero. If there is any inertia, it quickly disappears after two periods (with average quantities of 71.36 and 78.36). In the third period of forward plus spot markets, the total quantity average is already 82.64, very close to 83.26, the average for all periods.

There is some inertia in the sharing of profits once players enter in the periods of forward plus spot markets. Profits during the Cournot-only periods are close to the theoretical prediction, but lower, as we also saw in the exogenous case (in this case, sellers make an average of 790 each, and buyers an average of 864, while the theoretical Cournot profits are 900 each). The observed inertia is a small, but steady decline of the sellers’ surplus. A simple linear regression to fit the 50 periods of forward-plus-spot periods give a slope of -3.03, which is statistically significant with a $p$-value of 0.002 and errors normally distributed ($p$-value of 0.15). See Figure 5.

Result 8: No inertia is detected for quantities, with no positive slope being detected in the forward and spot markets. Inertia is, however, observed for seller profits with profits steadily declining.

**ENDO4 - The no-arbitrage hypothesis**

Parallel to what we observed with quantities, prices decrease along openings of the forward markets following the quantities to increase in the spot market. This is
shown in Figure 6, where 1-11 are the forward market openings, and 12 is the Spot market. The no-arbitrage hypothesis is rejected from one opening of the market to the next, except between the openings 6 and 7. Not surprisingly, due to the decreasing prices that start above the spot market price and end below, only the prices in central forward market openings are not significantly different from the spot market price. Buyers should have bought more quantities in the later periods, and sellers should have been less patient. This is shown in Table 11, where only the first 8 opening markets are shown, as not all oligopolies have openings after that, and we lose data points.

Result 9: The no-arbitrage hypothesis is rejected.

**ENDO5 - Guesses**

As in the exogenous close treatment, in the endogenous close, buyers were asked to guess future prices and sellers were asked to guess both prices and quantities\(^\text{13}\) at all market openings. Recall that in every period, futures markets open as long as they are used. If at a given opening of the futures market there is no trade, then the futures market closes and the game goes to the spot market, thus finishing that period. Therefore, different oligopolies will have a different number of opening of the futures market. To pool the data for the different oligopolies, we proceed as in the case of the actual prices and consider that for the days the futures market is not open, the guesses are the same in the last day it opened. These guesses show the same decreasing tendency as markets open until the last opening of futures markets. The most remarkable difference is that subjects never anticipate the increase in the price for the spot market. The most likely explanation is that they fail to anticipate that the futures markets will close the next period, and that they always make their guesses thinking that the future market will open one more period. No guesses are asked during the spot market.

\(^\text{13}\) They were not rewarded for anticipating them correctly.
Compared to the actual prices, guesses are consistently lower at the beginning, and higher at the end of the period, with the exception of the last guess as discussed above. In addition, we observe that seller’s guesses are consistently lower than buyers. Guesses show a lower variability compared to actual prices. Still, subjects are aware that prices will decline, although they do not take full advantage of the convenience of buying later or selling earlier. This is shown in Table 12 and Figure 7. Also guesses did not improve with the passing of the weeks as the experiment advanced. A simple regression analysis for the guesses in each day against the week of the experiment shows a very small, non-statistically significant, slope, sometimes positive and sometimes negative.
Table 12
Actual vs guessed price

<table>
<thead>
<tr>
<th></th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
<th>F4</th>
<th>F5</th>
<th>F6</th>
<th>F7</th>
<th>F8</th>
<th>Spot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual price</td>
<td>34.66</td>
<td>26.77</td>
<td>22.55</td>
<td>17.34</td>
<td>15.02</td>
<td>9.6</td>
<td>10.94</td>
<td>4</td>
<td>17.5</td>
</tr>
<tr>
<td>Buyer’ guess</td>
<td>21.1</td>
<td>17.34</td>
<td>14.07</td>
<td>11.52</td>
<td>9.11</td>
<td>7.72</td>
<td>6.93</td>
<td>5.92</td>
<td>6.28</td>
</tr>
<tr>
<td>Seller’ guess</td>
<td>15.8</td>
<td>12.29</td>
<td>9.35</td>
<td>8.29</td>
<td>7.12</td>
<td>6.03</td>
<td>4.91</td>
<td>4.29</td>
<td>4.55</td>
</tr>
</tbody>
</table>

Sellers were also asked to make guesses about their own and the rival’s quantities. One of these guesses is about the total quantity they thought they will be selling in the market (both in the forward and spot markets), and they could update their guess at every forward market opening. These guesses did not change too much from one market opening to the next, probably they just made a first guess and made only minor adjustments (if any) in the subsequent market openings. They guessed an average of 50.83 units, while the average actual value was 41.63, showing optimistic expectations that did not decrease as the experiment progressed. The average rivals’ expected production, 42.89, is very close to the actual choices. Thus, individuals think they will sell more than the rival, a quantity that they correctly foresee, and fail to see themselves as they are seen by the rival.

Result 10: The null hypotheses that quantity and price guesses are correct are rejected. Subject price guesses are consistently lower at the beginning, and higher at the end of the sequence of forward markets. Participants never anticipate the increase in the price for the spot market. Similar to the exogenous case, sellers guess that they will sell more than the rival.
4. Conclusion
While the procompetitive effects of forward markets as proposed by Allaz and Vila (1993) are by now quite well documented in the experimental literature, our experiments advance the present literature by making two improvements to the well-known structure. First, our subjects participate in a series of Cournot spot market duopolies previous to the introduction of the forward markets. This is done to establish a foundation for the real-world phenomenon where forward markets are introduced in existing spot markets. This allows us to study whether there is any inertia between the Cournot-only spot markets and markets that include forward positions. Second, and more importantly, we introduce real buyers in the forward markets. This allows us to check for the no-arbitrage hypothesis on which many of the early experiments are based.

We find that subjects behave close to theory in the Cournot spot only phase and sell about 90% of theoretical Nash equilibrium prediction. In the case of the exogenous close, with two periods of forward markets, we find total quantity observed is closer to the theoretical prediction, demonstrating a pro-competitive effect of the forward market. The total quantity divided between the forward and spot markets is close to theory, however, the way the forward quantity is divided between the two forward markets is not as the theory predicts. While, according to theory, they should be equal, we observe twice as many sales in the first forward market than in the second. The proportion in
which total surplus is divided between sellers and buyers is close to the theoretical prediction: this clearly benefits the buyers.

We do not observe any significant inertia between the first phase of Cournot-only spot competition and the following phase in which forward markets are added. Subjects adapt quickly. Importantly, the no-arbitrage condition is not satisfied. In theory there cannot be arbitrage, but, as reflected by their own guesses, our subjects seem to be aware of the differences in prices between markets during the experiment. However, they are unable to fully adapt their behavior to that knowledge. Although they do not act optimally on their guesses as they sell less, sellers remain optimistic with regard to the quantities they will sell.

The endogenous case has indefinitely many forward markets. This implies that we have multiple equilibria according to the theory, with the Cournot and the competitive ones being the extremes. Our experiments provide results that are somewhere in between the two salient predictions, but much closer to the competitive outcome. For instance, total quantity, the most important variable, is $83.26 \approx 22.5\% \times \text{Cournot} + 77.5\% \times \text{Perfect Competition}$. As a consequence, total surplus is also much closer to perfect competition than to Cournot.

However, the observed price, as an average over the forward and spot markets, is midway between the Cournot and the perfect competition price, and higher than the price given by the demand at the observed quantity of 83.26. This is possible because the quantities in the forward markets are sold at high prices. In the perfectly competitive equilibrium, all the surplus goes to the buyer. However, we find that in the experiment sellers manage to maintain 1/3 of the total surplus as sellers manage to keep the price up for the units they sale in the forward markets.

In the perfectly competitive equilibrium sellers should sell everything in the forward markets, however, our experimental sellers abandon the forward market when there is some residual demand that is then satisfied in the spot market. Almost a third of the total quantity is sold in the spot market (in the Cournot equilibrium, all sales occur in the spot market). Again, we find almost no inertia, as subjects adapt very quickly from the Cournot-only markets to the addition of forward markets. Subjects seem to be aware of the price difference among the different market openings but do not take full advantage of this, with the result that the no-arbitrage condition is not satisfied. Sellers anticipate correctly their rivals’ total sale quantities, but over-optimistically predict they will sell more than they do.
References:


Appendix-Instructions

Instructions (Buyers)-EXOGENOUS

Page 1

Introduction
This is an experiment on decision-making. You can earn money if you follow the instructions and make decisions carefully. You will be paid in cash at the end of the session. You can raise your hand to ask questions related to the experiment at any time.

Page 2

Overview
You will be a buyer in this experiment. There are #NumSellers# sellers and #NumBuyers# buyers in your market.

This experiment is divided into two parts. During the first part, you will not be making any decisions, but you will be able to learn about the experiment. In the second part, you will be making decisions. Paying close attention during the first part will help you make better choices during the second part.

First we will explain Part I of the experiment and then we will explain your computer screen. Finally, we will explain Part II of the experiment.

Page 3

Part I Instructions

As a buyer, you will not make any buying decisions during Part I. You will simply observe #numPart1Weeks# consecutive weeks of seller decisions and your computer will automatically buy units for you.

During Part I, each seller will independently decide how many units to sell. The total quantity of units that the sellers decide to sell will dictate the price.

- If sellers choose to sell only a few units, the market price will be high.
- If sellers choose to sell a lot of units, the market price will be low.

Once all the sellers decide how many units to sell, you will see the total amount of units the sellers chose to sell and the corresponding market price.

Page 4 [Load Figure 1 on client interface]

What is your Demand?

Each week you are assigned a certain number of units which give you value. For example, suppose you have value for 3 units. The first unit gives you a value of 25, the second unit gives you a value of 15 and the last unit gives you a value of 5.

Your demand can then be graphically represented with three steps as shown on the right.
Suppose that the market price is 8, represented by the line that crosses at 8. It shows you whether the market price is higher or lower than your unit values. Your profits are shown by the shaded area.

Your profit for each unit equals your value (25, 15, or 5) minus the market price (8) you must pay. Because the value of your third unit (5) is worth less than the market price (8), you should not buy it. Your earnings are shown as the shaded portion of the graph and can be calculated as:

\[(25-8) + (15-8) = 17 + 7 = 24\]

You make money in this experiment by purchasing units that have values above the market price.
Multi-Unit Demand

You will actually have values for many more than 3 units, unlike our simple example above. Because there will be so many units demanded (50 in the following example), you will no longer be able to distinguish the individual steps in the graph, but the interpretation of this multi-unit demand is exactly the same as before:
Maximizing Profit

Remember, during Part I your computer will automatically buy the quantity that gives you the highest earnings. If your demand is like the one in the graph and the market price is 20, then your computer will buy 40 units, because each of those units has a value greater than 20. The shaded area would represent your total earnings of 1600, which is 40 units times an average profit of \( \frac{1}{2} \times (100-20) \).

Page 8 [Show Computer Status Box]

Your Computer Screen

Now that we have explained Part I of the experiment, let’s discuss your computer screen. Throughout the experiment, the Status Box will always be on the top-right part of your computer screen.

The Status box will show you the:

- Time Remaining in each Day
- Week number
- Your earnings in dollars

In Part 1, there will be # numPart1Weeks# consecutive weeks.
Your Computer Screen

The numbers in the My Choice Box at the bottom of your screen provide you with information about the relationship between the quantity you buy, the market price, and your profit.

On this screen during Part I, you may enter your estimate of the next market price. This will have no effect on your earnings whatsoever, but it will help you learn to accurately estimate prices which will be needed during Part II.

- If your estimate is correct, then the numbers you see will show the exact quantity you will buy and the earnings you will make when your computer automatically buys the quantity that maximizes your earnings.

- If the actual market price is higher than your estimate, then both the quantity you buy and your earnings will be lower than what you estimated.

- If the actual market price is lower than your estimate, then both the quantity you buy and your earnings will be higher than what you estimated.

The green shaded area gives the size of your earnings for the estimated price and quantity.

Page 10 [End part I instructions]

You have now finished the instructions for the first part of the experiment. Please wait patiently while the remaining participants finish.

Page 11 [Load Weeks and Days boxes instead of Week Num. in Client Status Box]

Instructions for Part II

Now we will explain Part II of the experiment. There will be #numPart2Weeks# weeks during Part II. Each week is divided into #numDays# days. You will have an opportunity to purchase units in each day of the week.
You must make decisions about how to distribute your purchases across the different days of the week, given your total demand.

If you decide to buy some units before the last day of the market week, then these units will be subtracted from your total demand.

On the last day of the market your computer will automatically buy every unit of demand that you have remaining that has a value above the market price. This maximizes your profit.

Notice that the market price may be different each day of the market week, and you are always better off buying at low rather than high prices.

**Page 12 [Load Figure 5]**

**Week Example**

Say you begin with a demand for 50 units, and on day 1 you buy 10 units at a price of 40. Suppose that on day 2 you buy 15 more units at a price of 20.

Your remaining demand for the rest of the week is 25 units (50-10-15), with the highest remaining units valued at 50 and the lowest one valued at 0. Your remaining demand is represented on the graph to the right by the blue part of the original demand.

Also notice in the graph you can see the quantity you purchased and what price you paid for day 1 and day 2. Finally, your profits for day 1 (500) and day 2 (675) are shaded in gray and green respectively.
How You Buy Units

To buy units (except on the last day), you must enter both a quantity and the price per unit that you are willing to pay for exactly that many units.

- If the market price is the **same** as the price you submitted, you will buy exactly the quantity you asked for.
- If the market price is **lower** than the price you submitted, then you will buy more than the quantity you asked for.
- If the market price is **higher** than the price you submitted, then you will buy less than the quantity you asked for.

How is the Market Price Determined?

The market price is determined by comparing the prices you and other buyers are willing to pay for units to the price the sellers are willing the sell their units, and finding the single “market” price that maximizes the number of sales.

How You Buy Units

Now let’s go through an example. Suppose you have a total demand for at most 50 units, and you submit a price of 30 and a quantity of 20 on the first day. That information creates your **submitted demand**, shown with the dark blue line. Your actual purchase will always be somewhere along the dark blue line that represents your submitted demand. Notice your submitted demand says that you would be willing to purchase 1 unit at a price of 50, or 2 units at a price of 49, …or 20 units at a price of 30, … or 50 units at a price of 1.
You are not required to purchase units every day. But you make the largest profit by buying units on the day or days when the price is the lowest.

Daily Market Results

Suppose that on the first day you actually buy 15 units at a price of 35. For the next day the screen will display a graph like the one you see to the right. In the graph, the past results are shown as grayed out with the darker area showing your previous day’s profit. Your remaining demand for the rest of the days in the market is shown in color:

Your true demand

Your submitted demand
(Your next day purchase will also be somewhere along this line, unless you move it by selecting a new price and quantity that adjust your submitted demand).

Notice the My Choice Box at the bottom right of the screen. It provides you with information about quantity, price, and earnings from day to day.

To help you make your decisions, the screen shows you information about the past days (grayed out), and allows you to enter your quantity and price for today (except on the last day), and also allows you to make an estimate about the future market price.

As you try different combinations of these numbers, you can see what your expected future quantity purchased and earnings would be. If you don’t press the “submit” button to finally submit your demand (quantity and price) for the current day, it will be assumed that you do not want to buy anything today.
On the last day of the market you will not be able to submit your demand (quantity and price) as your computer will automatically buy any of your remaining true demand that has a value above the market price.

Page 19 [Allow subjects to follow steps laid out in pg. 19 – pg 21]

We will now walk you through a 3-day practice week. Please follow the instructions as they may help you understand how to participate in Part II of this experiment.

Page 20

- You begin in Day 1 of the three day market week.
- In the “Today” line enter a PRICE of 30.
- In the “Future” line enter a PRICE of 40.
  - This means you are estimating that today’s price will be lower than the future price (40 > 30), so you might try buying something today.
- In the “Today” line enter a QUANTITY of 20.
  - The numbers in the “Today” line mean that if the actual price today is 30, you will buy the 20 units you entered, and will make earnings of 980.
- The numbers in the “Future” line show that 10 units will be your best purchase on the last day if the future price on that day turns out to be 40, and you buy nothing else in addition to today’s purchase before the last day. It also shows the earnings (90) that you can expect to make on the last day if your entries are accurate.
- Press SUBMIT now to finalize your entries.
Page 21

- Notice that the actual price was 24 (less than you estimated), so you bought 26 units (more than you estimated), and you made 1300 in earnings (more than your expected earnings of 980). These numbers appear in the “Past” line.

- Now you are in Day 2, and must again choose a price and a quantity. Notice that your estimated price for today is set at 24 (yesterday’s market price) by default. Now you may change this price.

- In the “Today” line enter a PRICE of 25.

- In the “Future” line enter a PRICE of 30 (this implies that you are estimating that today’s price will be lower than the future price (25 < 30)).

- In the “Today” line enter a QUANTITY of 9. Press SUBMIT now.

Page 22

- Notice that the market price was 35 (more than you estimated) so you bought only 3 units (<9) and made 7.5 in earnings.

- You are now in the last market day, day 3. On the last day, the only thing you can do is to estimate the final price because the computer will automatically buy the optimal quantity given the actual price that occurs.

- In the “Today” line enter a PRICE of 30.

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- The actual price was 20, so you overestimated the price. However, your earnings do not depend on the overestimation. Your computer automatically bought 11 units for you and you earned 121.

- Your total earnings for the three day market week are:

\[ 1300 + 7.50 + 121 = 1428.50 \]
Page 24 [Allow subjects to follow steps below between pgs. 22-24]

We will now walk you through a different 3-day practice week. Again, please pay attention to the instructions as they may help you understand how to participate in Part II of this experiment. In the “Today” line enter a PRICE of 40.
• In the “Future” line enter a PRICE of 20.
  o This means that you estimating that today’s price will be higher than in the future.

• In the “Today” line enter a QUANTITY of 5.
  o The numbers in the “Today” line mean that if the actual price today is 40, you will buy the 5 units you entered, and you will earn 275.

• The numbers in the “Future” line show that 35 units is your best purchase quantity on the last day if the future price on that day is actually 20 and you buy nothing else in addition to today’s purchase before the last day. It also shows the earnings (90) that you can expect on the last day if your entries are accurate.

• Press SUBMIT now to finalize your entries.

Page 25

• Notice that, in this practice round, the price was 50 (more than you estimated), so you bought 0 units (less than you estimated), and you made 0 in earnings (less than your expected 980). These numbers appear in the “Past” line.

• Now you are in day 2 and must again choose a price and a quantity. Notice that the price today is set at 50 (yesterday’s market price) by default. Now you may change this price.

• In the “Today” line enter a PRICE of 25.

• In the “Future” line enter a PRICE of 30 (this implies that you are estimating that today’s price will be lower than in the future).

• In the “Today” line enter a QUANTITY of 30. Notice that if your estimates about the prices are correct you will make 1900 in earnings today and 25 in the future.

• Press SUBMIT now.

Page 26

• The actual price was 30 (higher than your estimate of 25), you bought 26 units (less than your estimate of 30), and actually earned 1144 in Day 2.

• You are now in the last market day, day 3. In any last day, the only thing you can do is to estimate the price. Remember that in the last day your computer will buy your optimal quantity given the market price.
• In the “Today” line enter a PRICE of 30.

Page 27

• The actual price was 20. This means that you overestimated the price. Your earnings however do not depend on the overestimation. Your computer bought 10 units and you made 100 in earnings.

• Your total earnings for the week are:

\[0 + 1144 + 100 = 1244.\]

Page 28 [End Instructions]

You have now finished the instructions for the second part of the experiment. Please wait patiently while the remaining participants finish.
Instructions (Sellers)-EXOGENOUS

Page 1

Introduction

This is an experiment on decision-making. You can earn money if you follow the instructions and make decisions carefully. You will be paid in cash at the end of the session. You can raise your hand to ask questions related to the experiment at any time.

Page 2

Overview

You will be a seller in this experiment. There are #NumSellers# sellers and #NumBuyers# buyers in your market.

This experiment is divided into two parts. The first part will be simpler, but paying close attention during the first part will help you make better decisions during the second part.

First we will explain Part I of the experiment and then we will explain your computer screen. Finally, we will explain Part II of the experiment.

Page 3

Part I Instructions

As a seller, you will participate in #numPart1Weeks# consecutive weeks where you can sell your goods to buyers in order to make a profit. Every unit you sell will cost you #productionCost#.

During Part I, you and the other sellers will each choose how many units to sell. Units that you and the other sellers choose to sell will automatically be sold at the highest price at which they will all sell. Therefore, the total quantity of units that you and the other sellers decide to sell will dictate the price.

• If you and the other sellers choose to sell only a few units, the market price will be high.
• If you and the other sellers choose to sell a lot of units, the market price will be low.

Once all the sellers decide how many units to sell, you will see the total amount of units the sellers chose to sell and the corresponding market price.
How is Price Determined?

Each week, buyers are assigned a certain number of units which give them value. For example, suppose there are 3 buyers, each with a value for one unit. The total number of units demanded is 3. Suppose the first buyer has a unit value of 25, the second buyer has a unit value of 15 and the last buyer has a unit value of 5.

The buyers’ demand could then be graphically represented with three steps as shown on the right.

If one seller offers to sell only one unit and the rest of the sellers offer to sell none, then that one unit offered will be sold at the price of 25.

If the sellers offer to sell a total of 2 units, each unit will be sold at a price of 15.

If the sellers offer to sell a total of 3 units, each unit will be sold at a price of 5.

How are Earnings Determined?

The red line at #productionCost# represents your cost of producing each unit.

Now, suppose that you offer to sell one unit and the other sellers offer to sell one unit in total. This means that the total amount of units offered for sale is 2. The market price will be 15 and your earnings will be 5 (market price - your cost = 15 – 10 = 5).
Your earnings are represented by the dotted area in the figure on the right.

The other sellers will also make a profit of 5, as they sold only one unit at the same price and they have the same cost. Their earnings are represented in the shaded area.

Notice that the price and cost will be the same for all sellers. However, the number of units each seller decides to sell may be different.

You **make money** in this experiment by selling units above your cost.

**Figure 2**

Buyers will actually have values for many more than 3 units, unlike our simple example above. Because there will be **so many** units demanded (*100 in the following example*), you will no longer be able to distinguish the individual steps in the graph, but the interpretation of this multi-unit demand is exactly the same as before:

---

**Multi-Unit Demand**

Buyers will actually have values for many more than 3 units, unlike our simple example above. Because there will be so many units demanded (*100 in the following example*), you will no longer be able to distinguish the individual steps in the graph, but the interpretation of this multi-unit demand is exactly the same as before:
Multi-Unit Demand & Price

If you offer to sell 25 units (shown with the brown arrow) and the other sellers offer to sell an additional 45 units (shown with the yellow arrow), then there will be a total of 70 units offered for sale ($25 + 45 = 70$). From the figure we can see that the market price will be 30.

If you sell 25 units at a price of 30 and each unit costs you #productionCost# to produce, then your earnings will be $25 \times (30 - #productionCost#) = #profit#.
Your Computer Screen

Now that we have explained Part I of the experiment, let’s discuss your computer screen. Throughout the experiment, the Status Box will always be on the top-right part of your computer screen.

The Status box will show you the:

- Time Remaining in each week
- Week number
- Your earnings in dollars

In Part I, there will be # numPart1Weeks# consecutive weeks.
Page 9 [Show My Choice Box, let the user interface with the screen, have Ready to Go On button enabled instead of Next Button]

Your Computer Screen

The numbers in the My Choice Box at the bottom of your screen provide you with information about the quantity you and the other sellers may sell, the market price, and your profit.

On this screen during Part I, you may enter the number of units you wish to sell and your estimate about how many units the other sellers will offer to sell.

- If you correctly estimate what the other sellers choose to offer, then the market price and your earnings will be as shown in the graph.

- If the actual quantity sold by others is higher than your estimate, then the actual market price at which you will sell your units will be lower than what you estimated.

- If the actual quantity sold by others is lower than your estimate, then the actual market price at which you will sell your units will be higher than what you estimated.

The green shaded area gives the size of your earnings for the estimated price and quantities.

Page 10 [End part I instructions]

You have now finished the instructions for the first part of the experiment. Please wait patiently while the other participants finish.

[DO PART I]
[When Part I is finished, send notification to client and begin Part II instructions]

Page 11 [Load Weeks and Days boxes instead of Week Num. in Client Status Box]

Instructions for Part II

Now we will explain Part II of the experiment. There will be #numPart2Weeks# weeks during Part II. Each week is divided into #numDays# days. You will have an opportunity to sell units in each day of the week.

You must make decisions about how to distribute your sales across the different days of the week, given the buyers’ total demand.
If you or any of the other sellers decide to sell units before the last day of the market week, then these units will be subtracted from the buyers’ total demand for the remainder of the week.

Notice that the market price may be different each day of the market week, and you are always better off selling units at high rather than low prices.

**Page 12**

**Should You Sell Each Day?**

- If you think that the price today will be **higher** than the price in the future, you should sell now.
- If you think that the price today will be **lower** than the price in the future, you should wait until the day you expect the price to be the highest.
- If you are **unsure** about the future market price, you may try selling some units now and some later.

**Page 13 [Load Figure 5]**

**Two-Day Market Example**

Suppose a total of 100 units are demanded by the buyers. If 25 units are sold the first day, then 75 units is what remains of the buyers’ demand. The remaining 75 units demanded are shown by the blue line on the graph.

Now suppose 45 units are sold on the last day. This means a total of 70 of the 100 units have been sold (25 + 45 = 70). In this case, the units sold on the last day are sold at a price of 30.

The 25 units sold on the first day could have been sold at any price. The price on the first day is determined by how many units are for sale that day and whether the buyers prefer to buy more now or later.
How You Sell Units

To sell units, you must enter both a maximum quantity and the minimum price you will accept per unit. You will receive the market price for any units you sell.

- If the market price is lower than the price you submitted, then you will not sell any of the units you offered.
- If the market price is higher than the price you submitted, then you will sell all the units you offered.
- If the market price is the same as the price you submitted, you will sell some of the quantity you offered.

How is the Market Price Determined?

The market price for any day depends on two things:

1. The quantities and prices offered by all sellers.
2. The decisions of buyers on how much to buy now.

The market price is determined by finding the price at which the number of units willing to be bought is equal to the number of units willing to be sold. It is possible that no units will be sold if an agreeable price for buyers and sellers cannot be found.

How are your Earnings Determined?
Suppose that you offered 15 units at a minimum price of 20 and the other sellers submitted an additional 40 units at various other prices. Suppose that the buyers were willing to buy and the sellers willing to sell at total of 35 units at a market price of 50. Because the market price is above your minimum price of 20, you sell all 15 of your units and receive the market price (50) for each unit.

Your earnings (shown in the dotted area) are:

\[
\text{Earnings} = (\text{price} - \text{cost}) \times \text{number of units} \\
= (50 - 10) \times 15 \\
= 600
\]

On the following day you will see a screen like the one below. Notice that a total of 35 units have been sold and the light gray demand above those units shows their actual values to the buyers who purchased them. The remaining demand (the blue line) for the following day is now smaller (100-35 = 65 units), and its values are lower. The results of past days are always shown in grey, and the remaining demand for the rest of the week is shown in color.

Page 17 [Allow subjects to follow steps laid out in pg. 18 – pg 20]

We will now walk you through a 3-day practice week. Please follow the instructions as they may help you understand how to participate in Part II of this experiment.

Page 18

- You begin in Day 1 of the 3-day market week.
• In the “Today” line enter 15 in MY QUANTITY and 30 in PRICE. These are the numbers that matter, as they can determine your sales for today.

• You can also enter an estimate of what you think the others are willing to sell today. In the “Today” line enter 10 in OTHERS’ QUANTITY.

• Notice the “Final” line has been filled for you with today’s offer. You can change the “Final” line to reflect what you believe will happen in the future. In the “Final” line enter a MY QUANTITY of 20 and an OTHER’S QUANTITY of 25.

  o Notice that the price on the last day will be 10 if these quantities are actually sold. This is shown in the price box of the “Final” line.

• Press SUBMIT now to finalize your entries.

Page 19

• Notice that for this practice round the actual price was 35 (more than your minimum of 30), so you sold 15 units and earned 375. These numbers appear in the “Past” line. Notice that OTHERS sold 5 (less than your estimate of 10).

• Now you are in Day 2 and you must choose a price and a quantity again. Notice that the price today is set at 35 by default (which is the last period’s price). Now you may change this price.

• In the “Today” line enter 5 in MY QUANTITY and 25 in PRICE. Enter 10 for OTHERS’ QUANTITY.

• Press SUBMIT now.

Page 20

• Notice that the actual price was 20 (less than your minimum of 25). This implies that you did not sell anything today, but others sold 15.

• You are now in the last market day, Day 3. In any last day you can only submit a quantity (and not a price). Everyone will sell all that they offer and the price will only depend only on the total quantity offered. You may try to estimate OTHERS’ QUANTITY and then see what the resulting market price will be if your estimate is correct.

• In the “Today” line enter 10 in MY QUANTITY and 10 in OTHERS’ QUANTITY. Notice that the market price will be 20 if your estimate is correct. Press SUBMIT.

Page 21
The actual price was 15. You sold your 10 units and made a profit of 50 (remember that it costs 10 to produce each unit.) The other sellers sold 15 units.

Your total earnings for the three days of the week are: $375 + 0 + 50 = 425$.

Page 22

We will now guide you through a second 3-day practice week.

- As in the earlier practice round, in the “Future” line enter 35 in MY QUANTITY.

- In the “Today” line enter 20 in MY QUANTITY and 27 in PRICE.

- Also enter your estimate regarding what the others are willing to sell today. In the “Today” line enter 15 in OTHERS’ QUANTITY.

- Now, press SUBMIT.

Page 23

- Notice that the actual price is 25 (less than your minimum of 27), so you sold 0 units and had 0 earnings. These numbers appear in the “Past” line. Notice that OTHERS sold 10 (less than your guess of 15).

- Now, you are in Day 2 of the 3-day market week. You must now choose a price and a quantity again. Notice that the price today is again set at 25 by default. This is done to remind you about the last day’s price. You can change this price. Notice also that the “Final” line displays the same numbers as in Day 1. You can also change this.

- In the “Today” line enter 20 in MY QUANTITY, and 20 in PRICE. Also enter 20 for OTHERS’ QUANTITY.

- Now, press SUBMIT.

Page 24

- Notice that the actual price was 25 (more than your minimum offer price of 20). You sold 20 units today, with earnings of 300 and other sellers sold nothing.
• You are now in the last market day, Day 3. After choosing MY QUANTITY you may try to estimate OTHERS’ QUANTITY and see what the market price will be if your estimate is correct.

• In the “Today” line enter 20 in MY QUANTITY and 25 in OTHERS’ QUANTITY. Notice that the price will be 25 if your estimate is correct. Press SUBMIT.

Page 25

• The actual price was 20. You sold your 20 units and with earnings of 200 (remember that it costs 10 to produce one unit.) Others sold 30 units.

• Your total earnings for the three-day week are: 0 + 300 + 200 = 500.

Page 26 [End Instructions]

You have now finished the instructions for the second part of the experiment. Please wait patiently while the other participants finish.
Instructions (Buyers)

Page 1

Introduction

This is an experiment on decision-making. You can earn money if you follow the instructions and make decisions carefully. You will be paid in cash at the end of the session. You can raise your hand to ask questions related to the experiment at any time.

Page 2

Overview

You will be a buyer in this experiment. There are #NumSellers# sellers and #NumBuyers# buyers in your market.

This experiment is divided into two parts. During the first part, you will not be making any decisions, but you will be able to learn about the experiment. In the second part, you will be making decisions. Paying close attention during the first part will help you make better choices during the second part.

First we will explain Part I of the experiment and then we will explain your computer screen. Finally, we will explain Part II of the experiment.

Page 3

Part I Instructions

As a buyer, you will not make any buying decisions during Part I. You will simply observe #numPart1Weeks# consecutive weeks of seller decisions and your computer will automatically buy units for you.

During Part I, each seller will independently decide how many units to sell. The total quantity of units that the sellers decide to sell will dictate the price.

- If sellers choose to sell only a few units, the market price will be high.
- If sellers choose to sell a lot of units, the market price will be low.

Once all the sellers decide how many units to sell, you will see the total amount of units the sellers chose to sell and the corresponding market price.

Page 4 [Load Figure 1 on client interface]
What is your Demand?

Each week you are assigned a certain number of units which give you value. For example, suppose you have value for 3 units. The first unit gives you a value of 25, the second unit gives you a value of 15 and the last unit gives you a value of 5.

Your demand can then be graphically represented with three steps as shown on the right.

Figure 3

Suppose that the market price is 8, represented by the line that crosses at 8. It shows you whether the market price is higher or lower than your unit values. Your profits are shown by the shaded area.

Your profit for each unit equals your value (25, 15, or 5) minus the market price (8) you must pay. Because the value of your third unit (5) is worth less than the market price (8), you should not buy it. Your earnings are shown as the shaded portion of the graph and can be calculated as:

\[(25-8) + (15-8) = 17 + 7 = 24\]

You **make money** in this experiment by purchasing units that have values above the market price.
Multi-Unit Demand

You will actually have values for many more than 3 units, unlike our simple example above. Because there will be so many units demanded (50 in the following example), you will no longer be able to distinguish the individual steps in the graph, but the interpretation of this multi-unit demand is exactly the same as before:

Figure 3

Page 7 [Load figure 4]
Maximizing Profit

Remember, during Part I your computer will automatically buy the quantity that gives you the highest earnings. If your demand is like the one in the graph and the market price is 20, then your computer will buy 40 units, because each of those units has a value greater than 20. The shaded area would represent your total earnings of 1600, which is 40 units times an average profit of $\frac{1}{2} \times (100-20)$.

Page 8 [Show Computer Status Box]

Your Computer Screen

Now that we have explained Part I of the experiment, let’s discuss your computer screen. Throughout the experiment, the Status Box will always be on the top-right part of your computer screen.

The Status box will show you the:

- Time Remaining in each Day
- Week number
- Your earnings in dollars

In Part 1, there will be # numPart1Weeks# consecutive weeks.
Your Computer Screen

The numbers in the My Choice Box at the bottom of your screen provide you with information about the relationship between the quantity you buy, the market price, and your profit.

On this screen during Part I, you may enter your estimate of the next market price. This will have no effect on your earnings whatsoever, but it will help you learn to accurately estimate prices which will be needed during Part II.

- If your estimate is correct, then the numbers you see will show the exact quantity you will buy and the earnings you will make when your computer automatically buys the quantity that maximizes your earnings.

- If the actual market price is higher than your estimate, then both the quantity you buy and your earnings will be lower than what you estimated.

- If the actual market price is lower than your estimate, then both the quantity you buy and your earnings will be higher than what you estimated.

The green shaded area gives the size of your earnings for the estimated price and quantity.

Page 10 [End part I instructions]

You have now finished the instructions for the first part of the experiment. Please wait patiently while the remaining participants finish.

Page 11 [Load Weeks and Days boxes instead of Week Num. in Client Status Box]

Instructions for Part II

Now we will explain Part II of the experiment. There will be #numPart2Weeks# weeks during Part II. Each week is divided into #numDays# days. You will have an opportunity to purchase units in each day of the week.
You must make decisions about how to distribute your purchases across the different days of the week, given your total demand.

If you decide to buy some units before the last day of the market week, then these units will be subtracted from your total demand.

On the last day of the market your computer will automatically buy every unit of demand that you have remaining that has a value above the market price. This maximizes your profit.

Notice that the market price may be different each day of the market week, and you are always better off buying at low rather than high prices.

Week Example

Say you begin with a demand for 50 units, and on day 1 you buy 10 units at a price of 40. Suppose that on day 2 you buy 15 more units at a price of 20.

Your remaining demand for the rest of the week is 25 units (50-10-15), with the highest remaining units valued at 50 and the lowest one valued at 0. Your remaining demand is represented on the graph to the right by the blue part of the original demand.

Also notice in the graph you can see the quantity you purchased and what price you paid for day 1 and day 2. Finally, your profits for day 1 (500) and day 2 (675) are shaded in gray and green respectively.
How You Buy Units

To buy units (except on the last day), you must enter both a quantity and the price per unit that you are willing to pay for exactly that many units.

- If the market price is the same as the price you submitted, you will buy exactly the quantity you asked for.
- If the market price is lower than the price you submitted, then you will buy more than the quantity you asked for.
- If the market price is higher than the price you submitted, then you will buy less than the quantity you asked for.

How is the Market Price Determined?

The market price is determined by comparing the prices you and other buyers are willing to pay for units to the price the sellers are willing to sell their units, and finding the single “market” price that maximizes the number of sales.
How You Buy Units

Now let’s go through an example. Suppose you have a total demand for at most 50 units, and you submit a price of 30 and a quantity of 20 on the first day. That information creates your **submitted demand**, shown with the dark blue line. Your actual purchase will always be somewhere along the dark blue line that represents your submitted demand. Notice your submitted demand says that you would be willing to purchase 1 unit at a price of 50, or 2 units at a price of 49, …or 20 units at a price of 30, … or 50 units at a price of 1.

**Figure 6**

You are not required to purchase units every day. But you make the largest profit by buying units on the day or days when the price is the lowest.
Daily Market Results

Suppose that on the first day you actually buy 15 units at a price of 35. For the next day the screen will display a graph like the one you see to the right. In the graph, the past results are shown as grayed out with the darker area showing your previous day’s profit. Your remaining demand for the rest of the days in the market is shown in color:

![Graph of market results with price and quantity axes, showing true demand and submitted demand areas.]

Complete Screen Image

Notice the My Choice Box at the bottom right of the screen. It provides you with information about quantity, price, and earnings from day to day.

To help you make your decisions, the screen shows you information about the past days (grayed out), and allows you to enter your quantity and price for today (except on the last day), and also allows you to make an estimate about the future market price.

As you try different combinations of these numbers, you can see what your expected future quantity purchased and earnings would be. If you don’t press the “submit” button to finally submit your demand (quantity and price) for the current day, it will be assumed that you do not want to buy anything today.

On the last day of the market you will not be able to submit your demand (quantity and price) as your computer will automatically buy any of your remaining true demand that has a value above the market price.
We will now walk you through a 3-day practice week. Please follow the instructions as they may help you understand how to participate in Part II of this experiment.

Page 20

- You begin in Day 1 of the three day market week.
- In the “Today” line enter a PRICE of 30.
- In the “Future” line enter a PRICE of 40.
  - This means you are estimating that today’s price will be lower than the future price (40 > 30), so you might try buying something today.
- In the “Today” line enter a QUANTITY of 20.
  - The numbers in the “Today” line mean that if the actual price today is 30, you will buy the 20 units you entered, and will make earnings of 980.
- The numbers in the “Future” line show that 10 units will be your best purchase on the last day if the future price on that day turns out to be 40, and you buy nothing else in addition to today’s purchase before the last day. It also shows the earnings (90) that you can expect to make on the last day if your entries are accurate.
- Press SUBMIT now to finalize your entries.
Page 21

- Notice that the actual price was 24 (less than you estimated), so you bought 26 units (more than you estimated), and you made 1300 in earnings (more than your expected earnings of 980). These numbers appear in the “Past” line.

- Now you are in Day 2, and must again choose a price and a quantity. Notice that your estimated price for today is set at 24 (yesterday’s market price) by default. Now you may change this price.

- In the “Today” line enter a PRICE of 25.

- In the “Future” line enter a PRICE of 30 (this implies that you are estimating that today’s price will be lower than the future price (25 < 30)).

- In the “Today” line enter a QUANTITY of 9. Press SUBMIT now.

Page 22

- Notice that the market price was 35 (more than you estimated) so you bought only 3 units (<9) and made 7.5 in earnings.

- You are now in the last market day, day 3. On the last day, the only thing you can do is to estimate the final price because the computer will automatically buy the optimal quantity given the actual price that occurs.

- In the “Today” line enter a PRICE of 30.

Page 23

- The actual price was 20, so you overestimated the price. However, your earnings do not depend on the overestimation. Your computer automatically bought 11 units for you and you earned 121.

- Your total earnings for the three day market week are:

  \[ 1300 + 7.50 + 121 = 1428.50 \]
We will now walk you through a different 3-day practice week. Again, please pay attention to the instructions as they may help you understand how to participate in Part II of this experiment.
• In the “Today” line enter a PRICE of 40.

• In the “Future” line enter a PRICE of 20.
  o This means that you estimating that today’s price will be higher than in the future.

• In the “Today” line enter a QUANTITY of 5.
  o The numbers in the “Today” line mean that if the actual price today is 40, you will buy the 5 units you entered, and you will earn 275.

• The numbers in the “Future” line show that 35 units is your best purchase quantity on the last day if the future price on that day is actually 20 and you buy nothing else in addition to today’s purchase before the last day. It also shows the earnings (90) that you can expect on the last day if your entries are accurate.

• Press SUBMIT now to finalize your entries.

**Page 25**

• Notice that, in this practice round, the price was 50 (more than you estimated), so you bought 0 units (less than you estimated), and you made 0 in earnings (less than your expected 980). These numbers appear in the “Past” line.

• Now you are in day 2 and must again choose a price and a quantity. Notice that the price today is set at 50 (yesterday’s market price) by default. Now you may change this price.

• In the “Today” line enter a PRICE of 25.

• In the “Future” line enter a PRICE of 30 (this implies that you are estimating that today’s price will be lower than in the future).

• In the “Today” line enter a QUANTITY of 30. Notice that if your estimates about the prices are correct you will make 1900 in earnings today and 25 in the future.

• Press SUBMIT now.

**Page 26**

• The actual price was 30 (higher than your estimate of 25), you bought 26 units (less than your estimate of 30), and actually earned 1144 in Day 2.
You are now in the last market day, day 3. In any last day, the only thing you can do is to estimate the price. Remember that in the last day your computer will buy your optimal quantity given the market price.

In the “Today” line enter a PRICE of 30.

Page 27

The actual price was 20. This means that you overestimated the price. Your earnings however do not depend on the overestimation. Your computer bought 10 units and you made 100 in earnings.

Your total earnings for the week are:

\[0 + 1144 + 100 = 1244.\]

Page 28 [End Instructions]

You have now finished the instructions for the second part of the experiment. Please wait patiently while the remaining participants finish.
Instructions (Buyers)-ENDOGENOUS

Page 1

Introduction

This is an experiment on decision-making. You can earn money if you follow the instructions and make decisions carefully. You will be paid in cash at the end of the session. You can raise your hand to ask questions related to the experiment at any time.

Page 2

Overview

You will be a buyer in this experiment. There are #NumSellers# sellers and #NumBuyers# buyers in your market.

This experiment is divided into two parts. During the first part, you will not be making any decisions, but you will be able to learn about the experiment. In the second part, you will be making decisions. Paying close attention during the first part will help you make better choices during the second part.

First we will explain Part I of the experiment and then we will explain your computer screen. Finally, we will explain Part II of the experiment.

Page 3

Part I Instructions

As a buyer, you will not make any buying decisions during Part I. You will simply observe #numPart1Weeks# consecutive weeks of seller decisions and your computer will automatically buy units for you.

During Part I, each seller will independently decide how many units to sell. The total quantity of units that the sellers decide to sell will dictate the price.

- If sellers choose to sell only a few units, the market price will be high.
- If sellers choose to sell a lot of units, the market price will be low.

Once all the sellers decide how many units to sell, you will see the total amount of units the sellers chose to sell and the corresponding market price.

Page 4 [Load Figure 1 on client interface]
What is your Demand?

Each week you are assigned a certain number of units which give you value. For example, suppose you have value for 3 units. The first unit gives you a value of 25, the second unit gives you a value of 15 and the last unit gives you a value of 5.

Your demand can then be graphically represented with three steps as shown on the right.

Figure 4

Suppose that the market price is 8, represented by the line that crosses at 8. It shows you whether the market price is higher or lower than your unit values. Your profits are shown by the shaded area.

Your profit for each unit equals your value (25, 15, or 5) minus the market price (8) you must pay. Because the value of your third unit (5) is worth less than the market price (8), you should not buy it. Your earnings are shown as the shaded portion of the graph and can be calculated as:

\[(25-8) + (15-8) = 17 + 7 = 24\]

You **make money** in this experiment by purchasing units that have values above the market price.
Multi-Unit Demand

You will actually have values for many more than 3 units, unlike our simple example above. Because there will be so many units demanded (50 in the following example), you will no longer be able to distinguish the individual steps in the graph, but the interpretation of this multi-unit demand is exactly the same as before:
Maximizing Profit

Remember, during Part I your computer will automatically buy the quantity that gives you the highest earnings. If your demand is like the one in the graph and the market price is 20, then your computer will buy 40 units, because each of those units has a value greater than 20. The shaded area would represent your total earnings of 1600, which is 40 units times an average profit of \( \frac{1}{2} \times (100-20) \).

Figure 4

![Graph showing demand and market price with shaded area representing earnings.](image)

Page 8 [Show Computer Status Box]

Your Computer Screen

Now that we have explained Part I of the experiment, let’s discuss your computer screen. Throughout the experiment, the Status Box will always be on the top-right part of your computer screen.

The Status box will show you the:

- Time Remaining in each Day
- Week number
- Your earnings in dollars

In Part 1, there will be # numPart1Weeks# consecutive weeks.
Your Computer Screen

The numbers in the My Choice Box at the bottom of your screen provide you with information about the relationship between the quantity you buy, the market price, and your profit.

On this screen during Part I, you may enter your estimate of the next market price. This will have no effect on your earnings whatsoever, but it will help you learn to accurately estimate prices which will be needed during Part II.

- If your estimate is correct, then the numbers you see will show the exact quantity you will buy and the earnings you will make when your computer automatically buys the quantity that maximizes your earnings.
- If the actual market price is higher than your estimate, then both the quantity you buy and your earnings will be lower than what you estimated.
- If the actual market price is lower than your estimate, then both the quantity you buy and your earnings will be higher than what you estimated.

The green shaded area gives the size of your earnings for the estimated price and quantity.

Page 10 [End part I instructions]

You have now finished the instructions for the first part of the experiment. Please wait patiently while the remaining participants finish.

Page 11 [Load Weeks and Days boxes instead of Week Num. in Client Status Box]

Instructions for Part II

Now we will explain Part II of the experiment. Each week is divided into several days. The number of days are determined whether units are sold or not in any certain day.
You will have an opportunity to buy units in different days of the week with the following rule: The number of days depends on whether some quantity is sold or not in the market:

1. There is a first day in the week.
2. If nothing is sold in the market, then there will be just one additional day. This will be the final day of the week.
3. If some quantity is sold on any day (including the first day), there will be a following day.
4. Days will be added as long as some quantities are sold.
5. For example. If some quantity is sold in days 1, 2, and 3, but nothing is sold in day 4, then the market will be open one final day, day 5, and the week end on this day (day 5).

Page 12 [Load Figure 5]

Week Example

Say you begin with a demand for 50 units, and on day 1 you buy 10 units at a price of 40. Suppose that on day 2 you buy 15 more units at a price of 20.

Your remaining demand for the rest of the week is 25 units (50-10-15), with the highest remaining units valued at 50 and the lowest one valued at 0. Your remaining demand is represented on the graph to the right by the blue part of the original demand.

Also notice in the graph you can see the quantity you purchased and what price you paid for day 1 and day 2. Finally, your profits for day 1 (500) and day 2 (675) are shaded in gray and green respectively.
How You Buy Units

To buy units (except on the last day), you must enter both a quantity and the price per unit that you are willing to pay for exactly that many units.

- If the market price is the same as the price you submitted, you will buy exactly the quantity you asked for.

- If the market price is lower than the price you submitted, then you will buy more than the quantity you asked for.

- If the market price is higher than the price you submitted, then you will buy less than the quantity you asked for.

How is the Market Price Determined?

The market price is determined by comparing the prices you and other buyers are willing to pay for units to the price the sellers are willing to sell their units, and finding the single “market” price that maximizes the number of sales.
How You Buy Units

Now let’s go through an example. Suppose you have a total demand for at most 50 units, and you submit a price of 30 and a quantity of 20 on the first day. That information creates your **submitted demand**, shown with the dark blue line. Your actual purchase will always be somewhere along the dark blue line that represents your submitted demand. Notice your submitted demand says that you would be willing to purchase 1 unit at a price of 50, or 2 units at a price of 49, …or 20 units at a price of 30, … or 50 units at a price of 1.

**Figure 6**

You are not required to purchase units every day. But you make the largest profit by buying units on the day or days when the price is the lowest.
Daily Market Results

Suppose that on the first day you actually buy 15 units at a price of 35. For the next day the screen will display a graph like the one you see to the right. In the graph, the past results are shown as grayed out with the darker area showing your previous day’s profit. Your remaining demand for the rest of the days in the market is shown in color:

![Graph showing demand and price](image)

Complete Screen Image

Notice the My Choice Box at the bottom right of the screen. It provides you with information about quantity, price, and earnings from day to day.

To help you make your decisions, the screen shows you information about the past days (grayed out), and allows you to enter your quantity and price for today (except on the last day), and also allows you to make an estimate about the future market price.

As you try different combinations of these numbers, you can see what your expected future quantity purchased and earnings would be. If you don’t press the “submit” button to finally submit your demand (quantity and price) for the current day, it will be assumed that you do not want to buy anything today.

On the last day of the market you will not be able to submit your demand (quantity and price) as your computer will automatically buy any of your remaining true demand that has a value above the market price.
Practice

We will now walk you through a 3-day practice week. Please follow the instructions as they may help you understand how to participate in Part II of this experiment.

Notice that the example is illustrative and does not strictly follow the way the market is structured in today’s experiment. That is, in the actual experiment if there are zero sales any day, the following day is the last day of that week. This will not be the case in the example.

Page 20

- You begin in Day 1 of the three day market week.
- In the “Today” line enter a PRICE of 30.
- In the “Future” line enter a PRICE of 40.
  - This means you are estimating that today’s price will be lower than the future price (40 > 30), so you might try buying something today.
- In the “Today” line enter a QUANTITY of 20.
  - The numbers in the “Today” line mean that if the actual price today is 30, you will buy the 20 units you entered, and will make earnings of 980.
- The numbers in the “Future” line show that 10 units will be your best purchase on the last day if the future price on that day turns out to be 40, and you buy nothing else in addition to today’s purchase before the last day. It also shows the earnings (90) that you can expect to make on the last day if your entries are accurate.
- Press SUBMIT now to finalize your entries.
Page 21

- Notice that the actual price was 24 (less than you estimated), so you bought 26 units (more than you estimated), and you made 1300 in earnings (more than your expected earnings of 980). These numbers appear in the “Past” line.

- Now you are in Day 2, and must again choose a price and a quantity. Notice that your estimated price for today is set at 24 (yesterday’s market price) by default. Now you may change this price.

- In the “Today” line enter a PRICE of 25.

- In the “Future” line enter a PRICE of 30 (this implies that you are estimating that today’s price will be lower than the future price (25 < 30)).

- In the “Today” line enter a QUANTITY of 9. Press SUBMIT now.

Page 22

- Notice that the market price was 35 (more than you estimated) so you bought only 3 units (<9) and made 7.5 in earnings.

- You are now in the last market day, day 3. On the last day, the only thing you can do is to estimate the final price because the computer will automatically buy the optimal quantity given the actual price that occurs.

- In the “Today” line enter a PRICE of 30.

Page 23

- The actual price was 20, so you overestimated the price. However, your earnings do not depend on the overestimation. Your computer automatically bought 11 units for you and you earned 121.

- Your total earnings for the three day market week are:

  \[
  1300 + 7.50 + 121 = 1428.50
  \]
Practice 2

We will now walk you through a different 3-day practice week. Again, please pay attention to the instructions as they may help you understand how to participate in Part II of this experiment.

Notice again that the example is illustrative and does not strictly follow the structure of today’s experiment. That is, if there are zero sales any day in the actual experiment, the following day is the last day of that week.

- In the “Today” line enter a PRICE of 40.
- In the “Today” line enter a QUANTITY of 5.
  - The numbers in the “Today” line mean that if the actual price today is 40, you will buy the 5 units you entered, and you will earn 275.
- In the “Future” line enter a PRICE of 20.
  - This means that you estimating that today’s price will be higher than in the future.
- The numbers in the “Future” line show that 35 units is your best purchase quantity on the last day if the future price on that day is actually 20 and you buy nothing else in addition to today’s purchase before the last day. It also shows the earnings (1225) that you can expect on the last day if your entries are accurate.

Press SUBMIT now to finalize your entries.

Continue to the Next page of instructions.

Page 25

- Notice that, in this practice round, the price was 50 (more than you estimated), so you bought 0 units (less than you estimated), and you made 0 in earnings (less than your expected 980). These numbers appear in the “Past” line.
- Now you are in day 2 and must again choose a price and a quantity. Notice that the price today is set at 50 (yesterday’s market price) by default. Now you may change this price.
- In the “Today” line enter a PRICE of 25.
- In the “Future” line enter a PRICE of 30 (this implies that you are estimating that today’s price will be lower than in the future).
• In the “Today” line enter a QUANTITY of 30. Notice that if your estimates about the prices are correct you will make 1900 in earnings today and 25 in the future.

• Press SUBMIT now.

Page 26

• The actual price was 30 (higher than your estimate of 25), you bought 26 units (less than your estimate of 30), and actually earned 1144 in Day 2.

• You are now in the last market day, day 3. In any last day, the only thing you can do is to estimate the price. Remember that in the last day your computer will buy your optimal quantity given the market price.

• In the “Today” line enter a PRICE of 30.

Page 27

• The actual price was 20. This means that you overestimated the price. Your earnings however do not depend on the overestimation. Your computer bought 10 units and you made 100 in earnings.

• Your total earnings for the week are:

\[ 0 + 1144 + 100 = 1244. \]

Page 28 [End Instructions]

You have now finished the instructions for the second part of the experiment.

Recall that if there are zero sales any day, the following day is the last day of that week.

For example, if there are no sales on day-1, then day-2 is the last day of the week. Similarly if there are no sales on day 3, then day 4 is the last day of the week, and so on.

If you have any questions, please raise your hand and a monitor will come by to answer them. If you are finished with the instructions, please click the Start button. The instructions will remain on your screen until everyone is ready and the experiment starts. Please wait patiently while the remaining participants finish.