Dynamic Pricing Decisions and Seller-Buyer Interactions under Capacity Constraints

SUPPLEMENTARY ONLINE APPENDICES

ONLINE APPENDIX A: Proofs and Additional Theoretical Results

1. Proof of Proposition 1

The proofs of the results are all based on the concept of rational expectations equilibrium. The concept assumes that, in equilibrium as well as in any in- or out-of-equilibrium subgame, from the beginning of period 1 onwards, players form mutually consistent beliefs (expectations) of what each other *will* do in the season – which must be best responses to all the beliefs – conditioned on the history of play (regardless of whether players have been following equilibrium moves) and the information they hold at every stage of the game. For expositional convenience, we also propose the tie-breaking assumption that if a player is indifferent between attempting to purchase now and not doing so, she always chooses the former; note that attempting to purchase may not result in successful purchase if more consumers attempt to purchase than the remaining inventory. Changing the tie-breaking rule has no impact on our results, given the assumption that the consumer population is large.

1.1. Lemmas 1 and 2

We first prove two lemmas that are helpful for proving Proposition 1. We have not limited considerations to only pure-strategy equilibrium when proving both lemmas, so that the proofs apply to any feasible pure- or mixed-strategy equilibria in any subgame; as it turns out (see Proposition 1), all equilibria are in fact in pure strategies.

Lemma 1. *In any subgame that is in- or out-of-equilibrium, if a consumer with valuation v decides to purchase in period t, then any consumer with valuation* $v' \geq v$ *decides to purchase in period* $t' \leq t$.

Proof of Lemma 1. This is obvious when $t = 2$, since the season ends there and the decision to (attempt to) purchase must be based on whether valuation is not lower than the current price or not. As for period 1, consider what happens in that period after a price p_1 is announced but before any attempt to purchase is made. Based on rational expectations, in any equilibrium in the subgame following the posting of p_1 all players form the same beliefs regarding purchases in both periods and the price in period 2. Hence, in any one such equilibrium, we can define $\Pr_1(p_1)$ as the probability that a consumer who attempts purchasing in period 1 will make a successful purchase in that period, given that all other consumers adhere to equilibrium play. Define $\Pr_2(p_1)$ as the probability that the season will proceed to period 2. Define $\sigma(p_2; p_1)$ as the probability, conditioned on there being a period 2, that (a) the seller will post a price p_2 in period 2, *and* (b) a buyer who attempts a purchase at that price in period 2 will be successful, given that the seller and all other consumers act according to equilibrium. Note that all of these probabilities are only dependent on p_1. Then, for a consumer with valuation v, attempting to purchase in period 1 yields expected payoff $\Pr_1(p_1)(v-p_1)$, while not doing so yields (discounted) expected payoff $\delta \Pr_2(p_1)\sum_{v\geq p_2}\sigma(p_2;p_1)(v-p_2)$. The difference between these is:

$$\Delta U = \Pr_1(p_1)(v-p_1) - \delta \Pr_2(p_1)\sum_{v\geq p_2}\sigma(p_2;p_1)(v-p_2),$$

which is strictly increasing in *v* if $\Pr_1(p_1) > \delta \Pr_2(p_1)$, in which case Lemma 1 is proved. Now, it is obvious that $1 \geq \Pr_1(p_1) > 0$ and $1 \geq \Pr_2(p_1) \geq 0$. If $\Pr_1(p_1) = 1$, then we must have $\Pr_1(p_1) > \delta \Pr_2(p_1)$, since we have assumed that $\delta < 1$. If $\Pr_1(p_1) < 1$, then even without counting the consumer whose decision problem we are considering, there must be at least as many consumers who attempt to purchase in period 1 in the subgame equilibrium as there is inventory. But then the season will definitely not proceed to period 2, $\Pr_2(p_1)$ must be zero, and thus $\Pr_1(p_1) > \delta \Pr_2(p_1)$. This completes the proof of Lemma 1.

Discussion. The form of the utility difference ΔU implies that tie-breaking happens only at a very specific valuation, so that assumptions about how the tie is broken are irrelevant when the consumer population is large; more importantly, the fact that ΔU is non-zero for "almost all" of the consumers means that we can effectively rule out considerations of equilibria in which consumers play mixed strategies. Another insight is that, since ΔU is strictly increasing in *v*, the higher the valuation of a consumer the less incentive she has for strategic waiting i.e., holding off purchase in period 1 even though her valuation is higher than the current price. Meanwhile, the seller may be able to carry out some price skimming since, in any two-period selling equilibrium, the valuations of consumers who buy in period 1 are not lower than the valuations of consumers who buy in period 2. However, it is still possible that all the inventory is cleared in period 1 in equilibrium, so that the season does not even proceed to period 2.

Lemma 1 leads to the next lemma:

Lemma 2. *There is no rationing in period 1 with any equilibrium period 1 price. There is no rationing in any equilibrium period 2 subgame, regardless of whether the seller's period 1 price is in- or out-of-equilibrium.*

Proof of Lemma 2. First consider the period 2 subgame. By Lemma 1, the posterior of the valuation distribution of the remaining consumers in period 2 must be a uniform distribution over $[0, v_1]$ for some $v_1 \geq 0$. We also know that the remaining consumers will attempt purchase according to whether their valuations are not lower than the period 2 price p_2. Suppose the remaining inventory is I_2 at the beginning of period 2. Then, a profit-maximizing seller will choose $p_2 < v_1$ that maximizes the objective function $p_2 \min\{I_2, (v_1 - p_2)\}$. This means that, if $v_1 > I_2$, any $p_2 < v_1 - I_2$ will be dominated by a choice of $p_2 = v_1 - I_2$ when just as many consumers as I_2 will attempt purchase and there is no rationing. Conversely, rationing occurs if and only if $p_2 < v_1 - I_2$. Therefore, a profit-maximizing seller will price sufficiently high to make sure that there is no rationing.

To complete the proof of the lemma, we need to prove that there is no rationing in equilibrium in period 1 given an equilibrium period 1 price. The argument is similar as above: if the price in period 1 leads to rationing in the same period, then it must be lower than 1-*I*, and the inventory will be cleared in the same period. Thus, the seller can earn more profit by at least raising the price to 1-*I*, which does not cause any rationing.

Discussion. The idea behind Lemma 2 is that a profit-maximizing seller always sets prices that are high enough to ensure that no more consumers than its current inventory can afford to purchase the good. It is still possible that there is unsold inventory at the end of period 2.

Lemmas 1 and 2 together imply that, given any period 1 price, equilibrium consumer behavior needs at most two critical valuations, v_1 and v_2, to characterize fully, so that consumers with valuations in [v_1,1] decide to (and successfully) purchase in period 1, and consumers with valuations in [v_2, v_1] decide to (and successfully) purchase in period 2. The total demand is 1-$v_2 \leqslant I$, and we must have $p_2 = v_2$ as well. Lastly, by Lemmas 1 and 2, any equilibrium under which selling takes place only in period 1 must be such that p_1 = 1-*I*, and all the *I* consumers who have valuations higher than 1-*I* decide to, and successfully purchase the good, thus closing the market.

1.2. Main Proof of Proposition 1

We first distinguish between three major types of selling scenario, each of which may become the equilibrium outcome:

(1) One-period. All the inventory is sold in period 1. For a profit-maximizing seller, if she chooses to sell in this way at all, her period 1 price must be $p_1 = 1 - I$ and her profit must therefore be $\pi_{\text{one period}} = I(1-I)$.
(2) Type I two-period. Selling takes place over both periods with no leftover inventory.
(3) Type II two-period. Selling takes place over both periods with leftover inventory.

We now look at the two-period selling scenarios (2) and (3). First, notice that, by Lemma 1, in any rational expectations equilibrium the distribution of valuations among consumers who still have not purchased by the beginning of period 2 must be uniform over $[0, v_1]$ with total mass v_1, where v_1 is the critical valuation such that a consumer with valuation v purchases in period 1 if and only if $v \geq v_1$. Note also that the leftover inventory at the beginning of period 2 is $I-(1-v_1)$. Thus, given a price p_2 in period 2, the demand in period 2 must be $\min\{v_1 - p_2, I-(1-v_1)\} = v_1 - \max\{1-I, p_2\}$. This means that profit maximization in the subgame in period 2 yields:

$$p_2 = \arg\max_{p_2} \pi_2 = \arg\max_{p_2} \delta_F\, p_2 (v_1 - \max\{(1-I), p_2\}),$$

that is, in equilibrium,

$$v_2 = p_2 = \max\{(1-I), v_1/2\}.$$

If $v_1/2 \leq 1-I$, then $v_2 = p_2 = 1-I$, then all inventory is eventually sold, and we have a Type I two-period selling scenario. Otherwise, we have a Type II two-period selling scenario.

Now observe that, in a rational expectations equilibrium with two-period selling, v_1, p_1, and p_2 must satisfy $v_1 - p_1 = \delta(v_1 - p_2)$. This implies that, if the equilibrium has a Type I two-period selling outcome, we must have:

$$v_1 - p_1 = \delta(v_1 - p_2) = \delta[v_1 - (1-I)], \text{ or } \ p_1 = (1-\delta)v_1 + \delta(1-I);$$

whereas, if the equilibrium has a Type II two-period selling outcome, we must have:

$$v_1 - p_1 = \delta v_1 / 2, \text{ or } \ p_1 = (2-\delta)v_1 / 2.$$

Hence, the profit function for a Type I two-period selling scenario is:

$$\begin{aligned}\pi_{\text{Type I two-period}} &= p_1(1-v_1) + \delta_F p_2(v_2 - p_2) = p_1(1-v_1) + \delta_F(1-I)[v_1 - (1-I)] \\ &= -(1-\delta)v_1^2 + [(1+\delta_F - 2\delta) - (\delta_F - \delta)I]v_1 + [\delta(1-I) - \delta_F(1-I)^2]\end{aligned}$$

while the profit function for a Type II two-period selling scenario is similarly worked out to be:

$$\begin{aligned}\pi_{\text{Type II two-period}} &= p_1(1-v_1) + \delta_F v_1^2 / 4 \\ &= (2-\delta)v_1/2 - (4 - 2\delta - \delta_F)v_1^2/4.\end{aligned}$$

We then maximize each of these profits in terms of v_1 (which in fact is a one-to-one function of p_1, the real decision variable of the seller; but maximizing with v_1 is just more convenient here) while not overlooking the condition under which the respective selling scenario applies. In short, we perform the following optimization:

$$\max_{v_1} \pi_{\text{Type I two-period}} \quad \text{subject to } \ v_1/2 \le 1-I, \text{ and}$$
$$\max_{v_1} \pi_{\text{Type II two-period}} \quad \text{subject to } \ v_1/2 > 1-I,$$

respectively, from which we get two maximized profit expressions $\pi_{\text{Type I two-period}}*$ and $\pi_{\text{Type II two-period}}*$ that are functions of *I* only. Finally, recall that the one-period selling profit function is:

$$\pi_{\text{one-period}} = \pi_{\text{one-period}}* = I(1-I).$$

Thus, for any given *I*, the equilibrium selling outcome corresponds to the selling outcome with the highest value among $\pi_{\text{one-period}}*$, $\pi_{\text{Type I two-period}}*$ and $\pi_{\text{Type II two-period}}*$, from which we can work out the equilibrium v_1 as well as p_1 and $v_2 = p_2$ (if selling takes place over two periods in equilibrium).

After going through the algebra, the above procedures lead to the regime transitions and equilibrium characteristics in Proposition 1 and Table 1. It can be shown that both I_1 and

I_2 are real, well defined, and that $I_1 < I_2$, under the assumptions $\delta \in [0,1)$, $\delta_F \in (0,1]$ and $\delta \le \delta_F$.

The equilibrium construction procedures also show that the equilibrium is unique given *I* (i.e., there is only one optimal p_1 leading to unique values of v_1 and $v_2 = p_2$ that satisfy all consistency requirements) except at $I = I_2$, when there are two different equilibria, one of Type I two-period and one of Type II two-period (see the categorization in Proposition 1), that yield the same, optimal profit for the seller.

2. Equilibrium Analysis for the Experiment

The experimental setup is a *discretized* version of the model in Section 3 of the main text. That is, buyer valuations in the experiment were distributed discretely but evenly over the set *V*={45, 55, … , 235} to approximate an uniform distribution over *V*; there were also only 20 buyers instead of the continuum assumed in the model. While the overall insights from the model and the proof of Proposition 1 are expected to apply, we need to numerically re-calculate the predictions for the sake of rigor.

Our procedures are essentially backward induction, beginning from an analysis of subgame equilibria in period 2, based on which we construct the subgame rational expectations equilibria given any period 1 price, which generate the price/demand equilibrium paths in Table 2. Finally, the equilibrium path in Table 2 that yields the highest total discounted round profit gives us the equilibrium period 1 price, as highlighted in the table.

Note that, in the experiment, valuations were assigned to buyers without replacement. That is, a buyer who knew his/her private valuation had more information about the other buyers (namely that no other buyer had the same valuation as him/herself) than in the case when valuations were assigned independently. The no-replacement sampling made our laboratory market a better approximation of the non-atomic scenario analyzed in Section 3, since even the ex post distribution of valuations was uniform over the set *V*. This feature also makes the equilibrium behavior in our analysis optimal ex post with respect to valuation assignment.

2.1. Period 2 Analysis

The best response of a buyer in period 2 of our experiment is simple utility consideration: purchase if and only if the buyer's valuation is not less than the current price. For the seller's pricing in period 2, the best response must be dependent on the remaining number of buyers present at the beginning of period 2 in the experiment. If there has been no demand in period 1, then the best response pricing is trivially equivalent to one-period optimal pricing with the starting inventory. Otherwise, the question becomes non-trivial. In principle, the best response in those cases should always be profit-maximizing within period 2 under assumptions of buyer behavior that are consistent with equilibrium purchase behavior when the price path lies along equilibrium play. Accordingly, we state the following:

Assumption A1. *If a round has positive demand in period 1 and proceeds to period 2, then the valuations of the buyers who have not purchased in period 1 must all be less than the valuations of the buyers who have purchased in that period.*

Note that the assumption is relevant only when the round has some sales in period 1 and also has a period 2, which means there must have been no rationing in period 1. If buyers behave in period 1 according to subgame equilibrium given the period 1 price, then, by Lemma 1, the posterior valuation of the remaining buyers in period 2 must abide by Assumption A1. But Assumption A1 more strongly states that, even if the sales in period 1 is out of equilibrium, so that some buyers purchased (or did not purchase) in period 1 when they should not (should), their overall behavior is still assumed to follow the "skimming property" of Lemma 1. This assumption can be justified in the spirit of sequential equilibrium (see e.g., Kreps, D.M., R. Wilson. 1982. Sequential equilibrium. *Econometrica* **50**(4) 863–894), if a buyer with valuation v deviates from her prescribed action in period 1 with probability $\varepsilon^{1+(v-v_1)^2}$, where v^{**} is the cutoff valuation that must exist in period 1 according to Lemma 1 (notated as v_1 in the previous section on the theoretical model). When $\varepsilon \to 0^+$, conditioned on deviations having occurred (which, for the seller, can only be known by their total number but *not* by the specific valuations of buyers who deviated), they must happen with probability one with valuations that are closest to v^{**}, and thus the posterior distribution of v remains as what Assumption A1 prescribes.

With Assumption A1, we can readily work out a set of best response prices in period 2, given the remaining inventory at the beginning of that period. These are as listed in Table A below, which also lists the values of v_{max}, the posited maximum valuation among the *remaining* buyers in period 2 given Assumption A1. In individual cases where there may be multiple best response prices given the remaining inventory, further calculations show that the list in Table A offers the only feasible pure-strategy best response prices that are consistent with rational expectations in period 1.

2.2. Period 1 Analysis

Upon determining the best response period 2 pricing strategy, we can work backwards to calculate equilibrium buyer behavior in period 1, given the period 1 price. This is equivalent to determining the cutoff valuation $v^{**}(p_1)$ in period 1, which is the lowest valuation among purchasing buyers in period 1 given p_1, and which should satisfy $v^{**}(p_1) = v_{max} + 10$ for the v_{max} in the ensuing period 2. We note that the sales in period 1 are $\min\{I, (245- v^{**}(p_1))/10\}$, and hence $I_2 = I - \min\{I, (245- v^{**}(p_1))/10\}$. Thus, the remaining inventory in period 2 as well as the seller's best response price in the period 2 subgame, say $p_2^{**}(v^{**}(p_1))$, can be determined accordingly, the latter with the use of Table A. Lastly, to satisfy rational expectations requirements, we need:

$$v^{**}(p_1) - p_1 \geq 0.5[v^{**}(p_1) - p_2^{**}(v^{**}(p_1)+10)],$$
$$\text{but } (v^{**}(p_1) - 10) - p_1 < 0.5[v^{**}(p_1) - p_2^{**}(v^{**}(p_1))],$$

where the argument $v^{**}(p_1)+10$ in $p_2^{**}(v^{**}(p_1)+10)$ in the first inequality indicates that the deviation by the buyer with valuation $v^{**}(p_1)$ could lead to a change in the seller's optimal price in period 2. The second inequality indicates that the buyer with valuation immediately below $v^{**}(p_1)$ would not buy in period 1.

Using this approach, we obtain the equilibrium characteristics listed in Table 2 in the main text, as well as the overall equilibrium path in each condition.

Discussion. The results of our equilibrium analysis in this section are used as benchmark in our data analysis. Since Assumption A1 is key to our derivations, it is of value to note that the assumption is largely consistent with our data. To demonstrate this, we focus on rounds in the experiment with positive demand in period 1 and also proceeded to period 2, to which Assumption A1 was applicable. We then measure, for each of these rounds, given the realized demand d in period 1, the lowest valuation among purchasing buyers as predicted by Assumption A1 – which should be 245–10d – and the actual lowest valuation among the purchasing buyer subjects; note that the latter could never be higher than the former. We find that their difference was not more than 20 payoff units in 93.2% of the rounds with two periods, and was only 7.97 payoff units on average across both conditions, thus providing support for the applicability of Assumption A1.

Table A. Best response period 2 pricing for the experiment (see also Figure 4).

Condition I9			Condition I16		
Remaining inventory	v_{max}	Best response period 2 price	Remaining inventory	v_{max}	Best response period 2 price
1	85	150	1	85	80
2	95	150	2	95	80
3	105	150	3	105	80
4	115	150	4	115	80
5	125	150	5	125	80
6	135	150	6	135	80
7	145	150	7	145	80
8	155	150	8	155	80
9	165	150	9	165	80
			10	175	90
			11	185	100
			12	195	100
			13	205	100
			14	215	110
			15	225	120
			16	235	120

ONLINE APPENDIX B: Subject Instructions (Condition I9)

Welcome to a decision making experiment. You are about to participate in a computer-controlled experiment on selling and buying perishable goods in a small market. Please read the instructions carefully. If you follow them, you may earn a considerable amount of money. Your earnings depend on your decision and the other participants' decisions as explained below.

The unit of transaction in this experiment is called **point**. At the end of the session, your earnings will be converted to US dollars at the rate of **400** points=US$1.00 and paid to you in cash.

After entering the laboratory, we ask you not to communicate with the other participants in any form. If one or more participants do communicate with one another, then the session will have to be terminated. If you have any questions before or during the experiment, please raise your hand and the experimenter will come to assist you.

Description of the Task

The experiment is concerned with a monopolist (hereafter called **seller**), who wishes to sell **9** units of a perishable good in a market with **20** consumers (hereafter called **buyers**). The selling season (hereafter called **round**) consists of two periods, referred to as **period 1** and **period 2**. On each round every buyer may purchase **at most a single unit** of the good in either period 1 or period 2. The experiment consists of **63** rounds that are structured in exactly the same way.

Period 1

The 21 participants are randomly assigned their role for the round: a single seller and 20 buyers. Then, the seller is provided with an inventory of **9 units** of the good. The inventory size is displayed to all the 20 buyers. Inventory cannot be replenished during the round. If units of the good remain unsold at the end of period 2, then their value to the seller is zero.

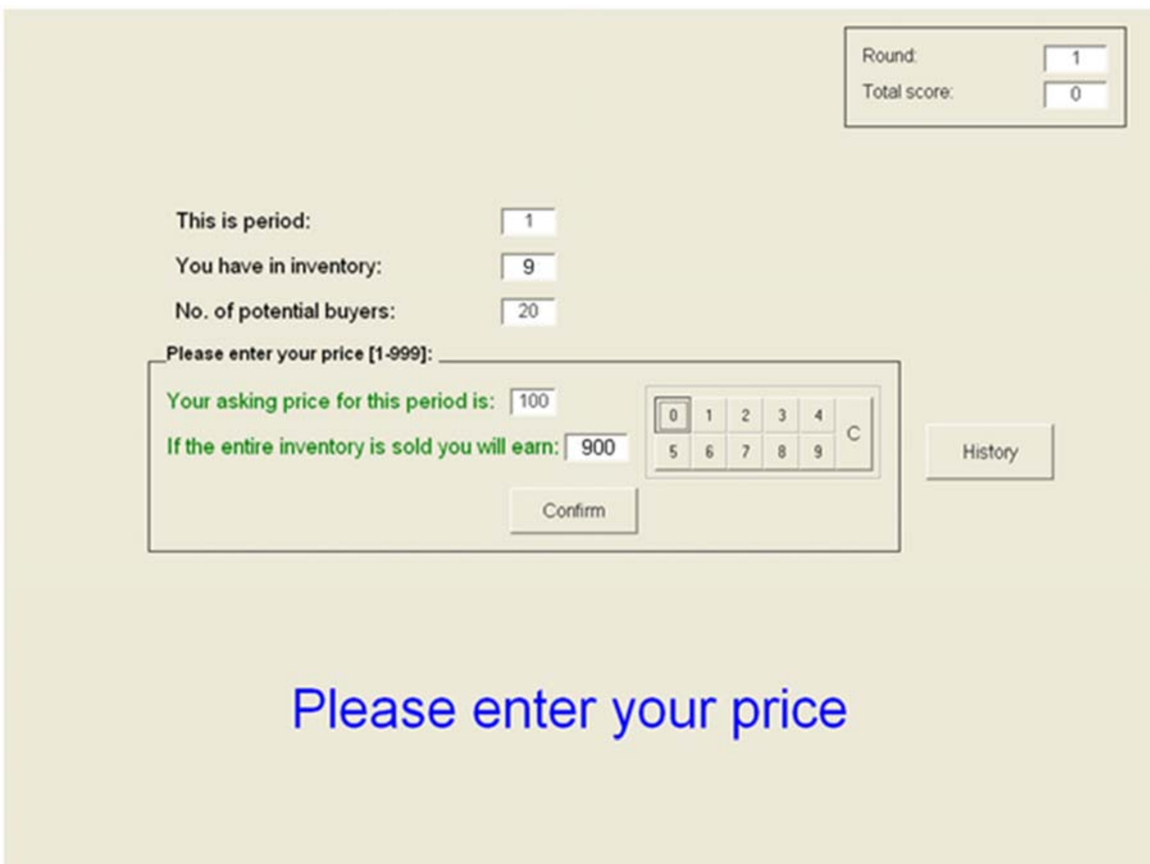
> *Please notice: Role assignments (seller or buyer) are randomly assigned and change from round to round, with the restriction that during the 63 rounds each participant (including you) will be assigned the role of a seller **3** times and the role of a buyer **60** times.*

The task proceeds as follows. At the beginning of period 1, the seller is presented with the following **Period 1 Seller Screen** (see below).

The upper right corner of the screen shows the round number and the cumulative payoff (in points). In the middle of the screen are listed the period number (1 or 2), the starting inventory (9 units), and the number of potential buyers (20 buyers). Below this information is the **Decision Box** in which the seller submits the **asking price** per unit good in period 1, namely, the price he charges for each unit of his inventory (100 points in this example). The seller is also shown his potential earnings with this asking price (9×100=900 in this example).

To submit an asking price, please type your price (one integer at a time) and, if satisfied, press the Confirm button. Your price must be a multiple of 10 (i.e., 0, 10, 20, 30 …). If you wish to change the price before submitting it, please clear the Decision Box by pressing the button C.

Period 1 Seller Screen



Once the seller submits an asking price, each buyer will be presented with a **Period 1 Buyer Screen**, which is illustrated below. The screen displays the period number (1 or 2), the **value** of a unit of good for this particular buyer (205 in this example), the seller's asking price (100 in this example), and the profit for the buyer if she purchases a unit of the good on period 1 (205–100=105 in this example).

*Please notice: As a buyer your value is the **maximum price** you should be willing to pay for a unit good. Buyers' values <u>differ</u> from one buyer to another. In this experiment, buyer values are randomly sampled from a set of values between 45 and 235 in intervals of 10 (i.e., 45, 55, 65, …, 215, 225, 235; twenty different values). In other words, each buyer has an equal chance of being assigned any one of the twenty possible values*

After observing her value and the asking price, each buyer is asked to respond YES or NO to the query whether she wishes to purchase a unit of the good on period 1 for the price charged by the seller.

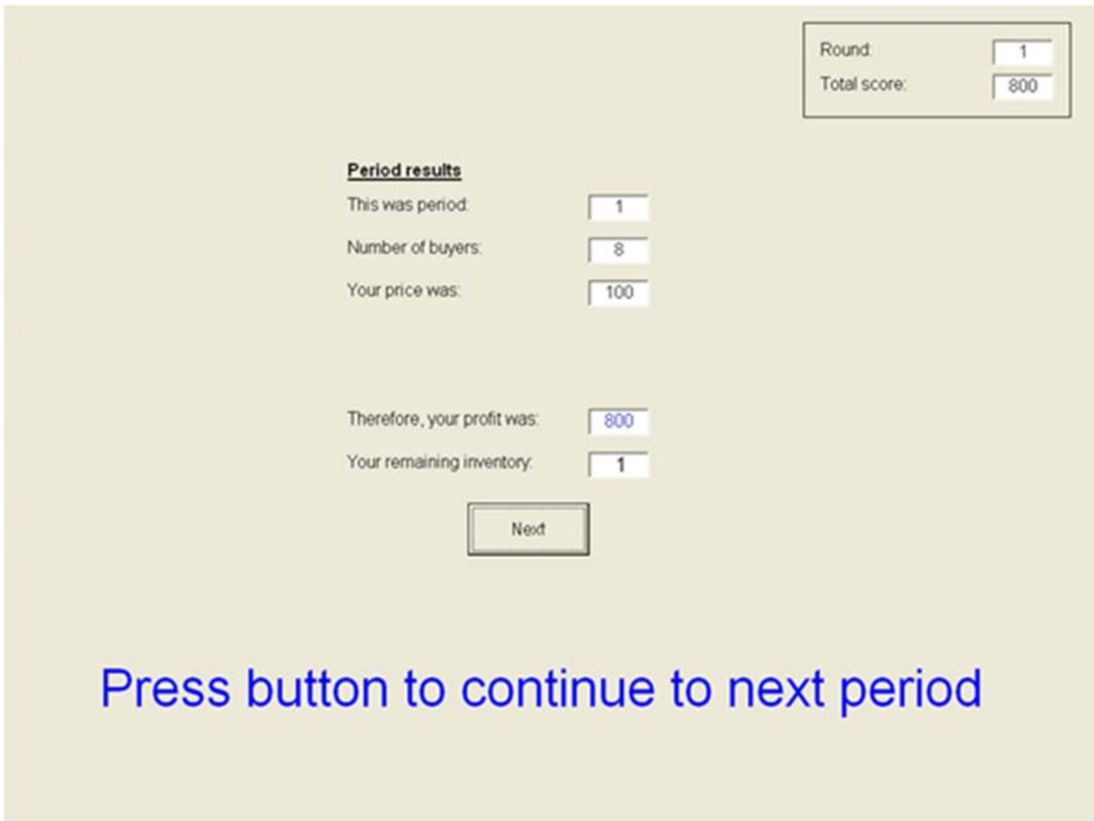
<u>Period 1 Buyer Screen</u>

- If the buyer responds **YES**, then she will purchase a unit of the good if the total number of buyers responding **YES** is equal to or smaller than the seller's inventory (9 units). If more than 9 buyers respond **YES**, then 9 buyers will be randomly chosen among them to purchase the good on period 1.

- If the buyer responds **NO**, then she will have an opportunity to purchase the good (if there are units left) on period 2.

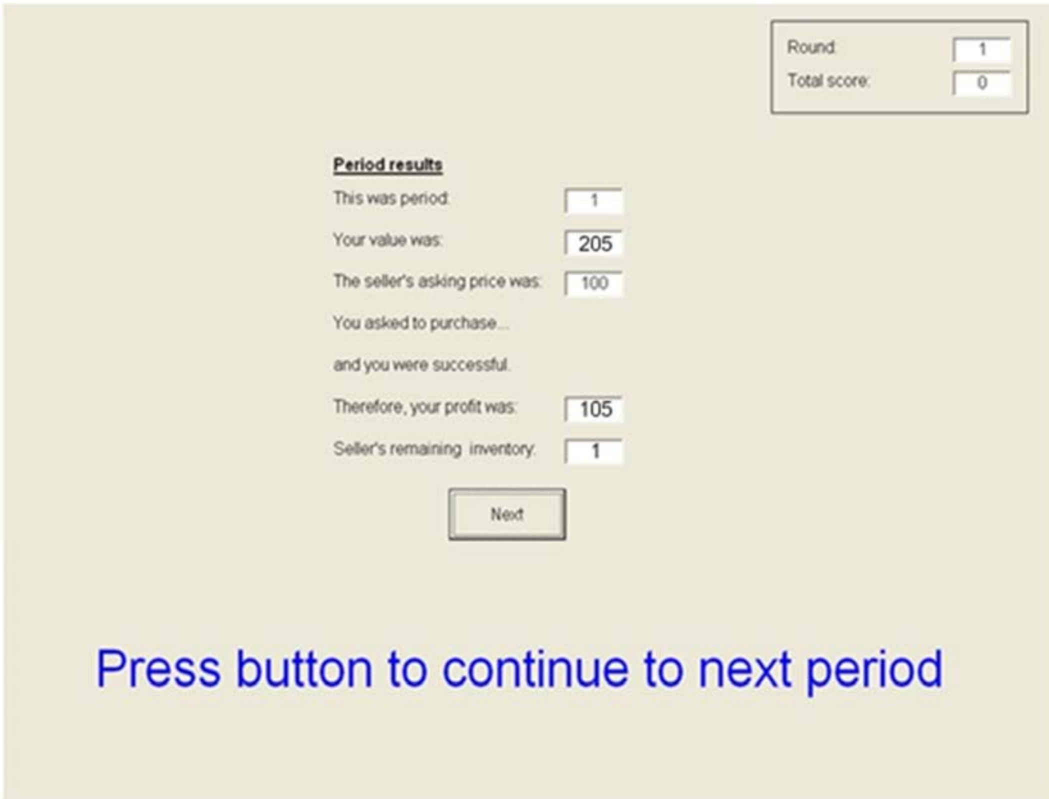
The next screen—the **Period 1 Seller's Result Screen**—shows the information displayed to the seller at the end of period 1. In this example, the seller sold 8 units in period 1 at a price of 100 points per unit. Therefore, his profit is calculated to be 8×100 = 800. The seller has 1 unit left, which he may then try to sell on period 2.

Period 1 Seller's Result Screen



The next screen is the **Period 1 Buyer's Result Screen**. This screen informs the buyer whether he was successful in purchasing the good in period 1 (if he asked to do so) and his earnings for the period. In the present example, the buyer was successful and earned a profit of 105 units, and for him this round is over.

Period 1 Buyer's Result Screen



Summary of Period 1

- The seller is assigned an initial inventory of 9 units of the good.
- The seller submits an asking price per unit of the good {0, 10, 20, 30, …}.
- Each buyer is assigned a value (maximum buying price) of the good randomly distributed between 45 and 235 {i.e., 45, 55, …, 225, 235}.
- The buyer responds **YES** or **NO** to the question whether she wants to purchase the good on period 1.
    - If fewer than 9 buyers ask to buy, then they all purchase the good, and the round moves to period 2 with the remaining inventory.
    - If exactly 9 buyers ask to buy then the entire seller's inventory is sold and the round is over.
    - If more than 9 buyers ask to buy, then 9 of them are randomly chosen to purchase the good, the entire inventory is sold, and the round is over.
- All the participants are fully informed of the outcome of period 1.

Please notice: A buyer has an option to delay her purchase to period 2. Even if she can make a profit on period 1, she may still prefer to wait with a request for purchase to period 2.

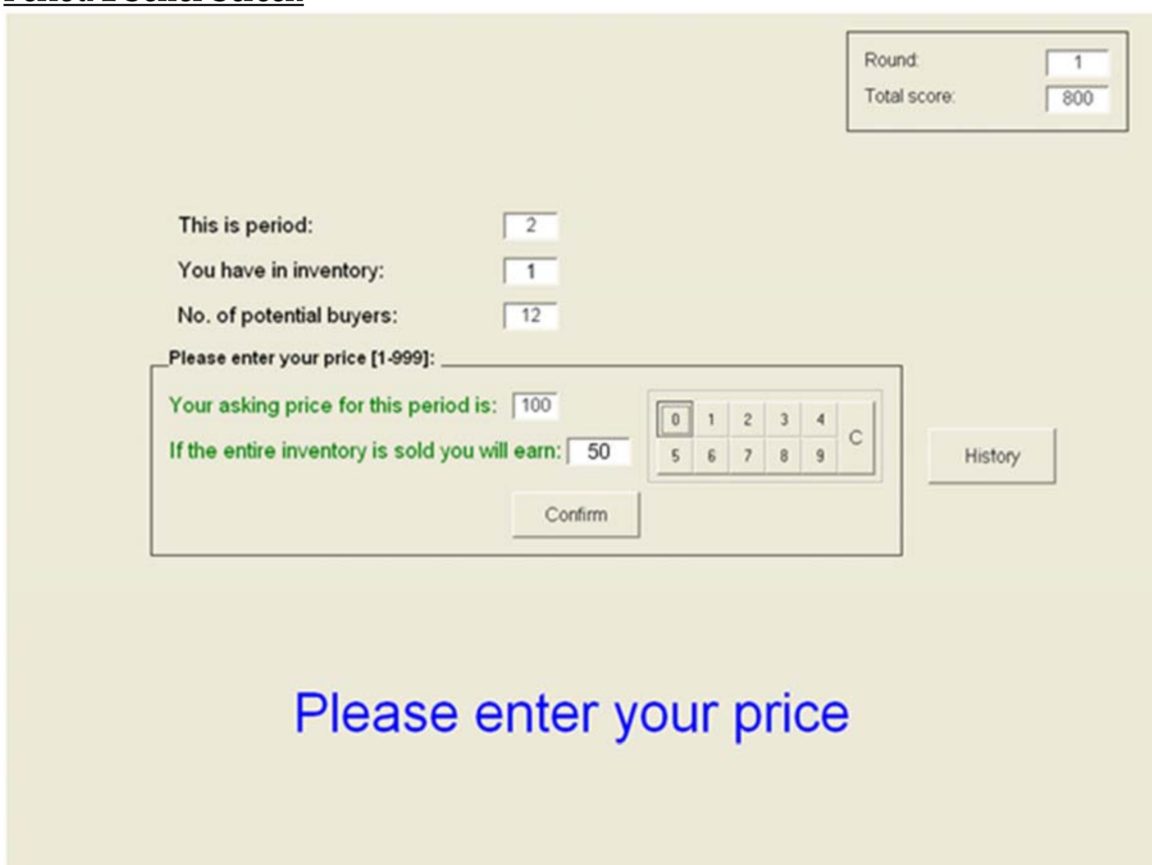
Period 2

> *Please notice: The difference between periods 1 and 2 is that the profits on period 2 are* ***discounted****. In particular, the seller is only paid 50% of her potential profit on period 2, and each buyer who purchases a unit on period 2 is only paid 50% of his potential profit on this round.*

Similar to period 1, the first to make his decision is the seller. The computer displays to the seller the remaining inventory on period 2, and asks her to submit an asking price. The seller can submit any asking price, which may be higher, equal, or smaller than the asking price she submitted on the previous period.

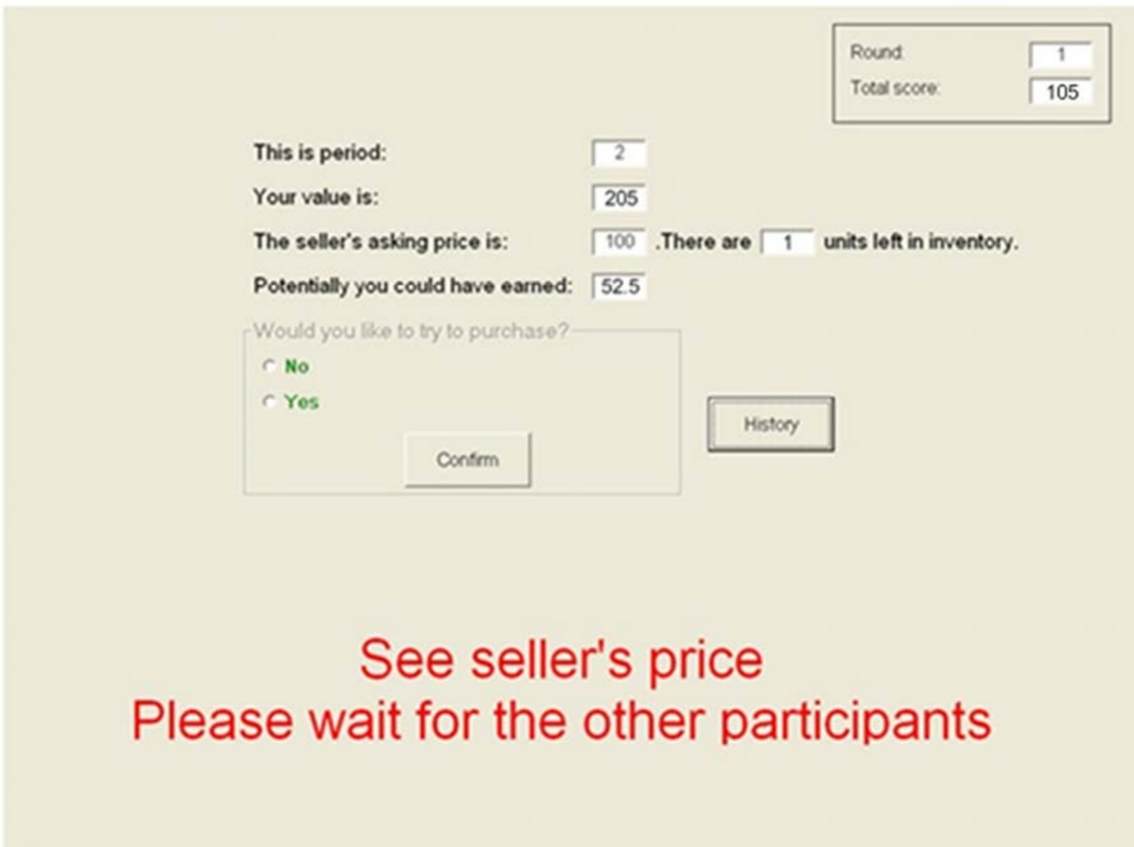
The next screen is the **Period 2 Seller's Screen**. In the example, the number of units left in the seller's inventory is 1. The number of active buyers on period 2 is simply the initial number of buyers (20) minus the number of buyers who made a successful purchase on period 1 (8 in this example). As in period 1, the seller is asked to submit his asking price for each unit left (100 in this example). As mentioned earlier, the seller's potential profits are discounted and hence are 50 (**0.5**×[1×100] = 50). Note that the screen presents the discounted profit.

<u>**Period 2 Seller Screen**</u>



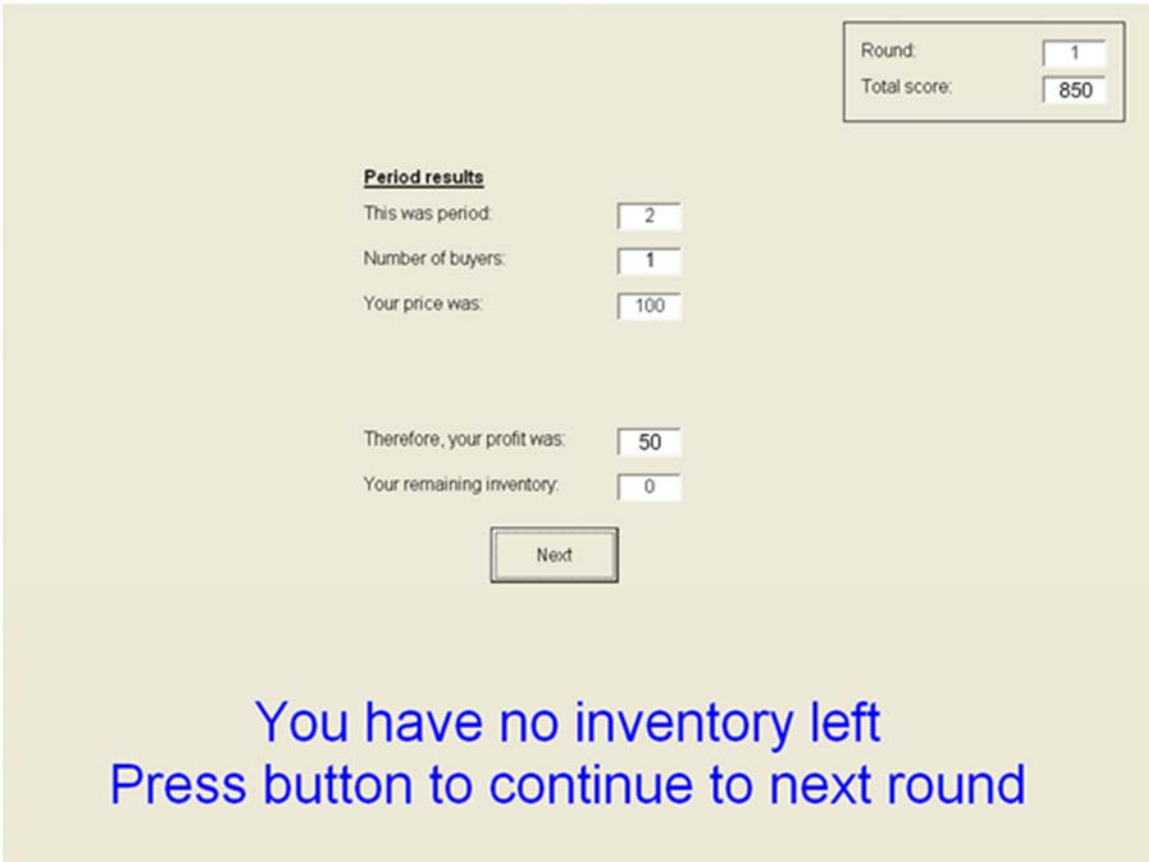
Each of the active buyers is informed of the seller's asking price on period 2, and is asked to respond **YES** or **NO** as before. Buyers who made a purchase on period 1 cannot purchase again on period 2 and remain inactive. They do, however, get to observe the seller's asking price, their potential (discounted) profit, and the period outcome. See below an example **Period 2 Buyer Screen**. This buyer has already purchased a unit in period 1 and is therefore inactive. However, she can observe the seller's asking price (100) and her potential profit had she not purchased in period 1 (0.5×[205–100] = 52.5). Notice that the profit presented is already discounted.

<u>Period 2 Buyer Screen</u>



Once all active buyers make their decision all players are presented with period 2 results. Below is an example of **Period 2 Seller's Results Screen**. In this example, you may observe that the seller sold the remaining 1 units of her inventory on period 2 at the price of 100 each. However due to the period 2 discounting, her profit for this period is only 50% of 100 points, namely 50 points.

Period 2 Seller's Results Screen



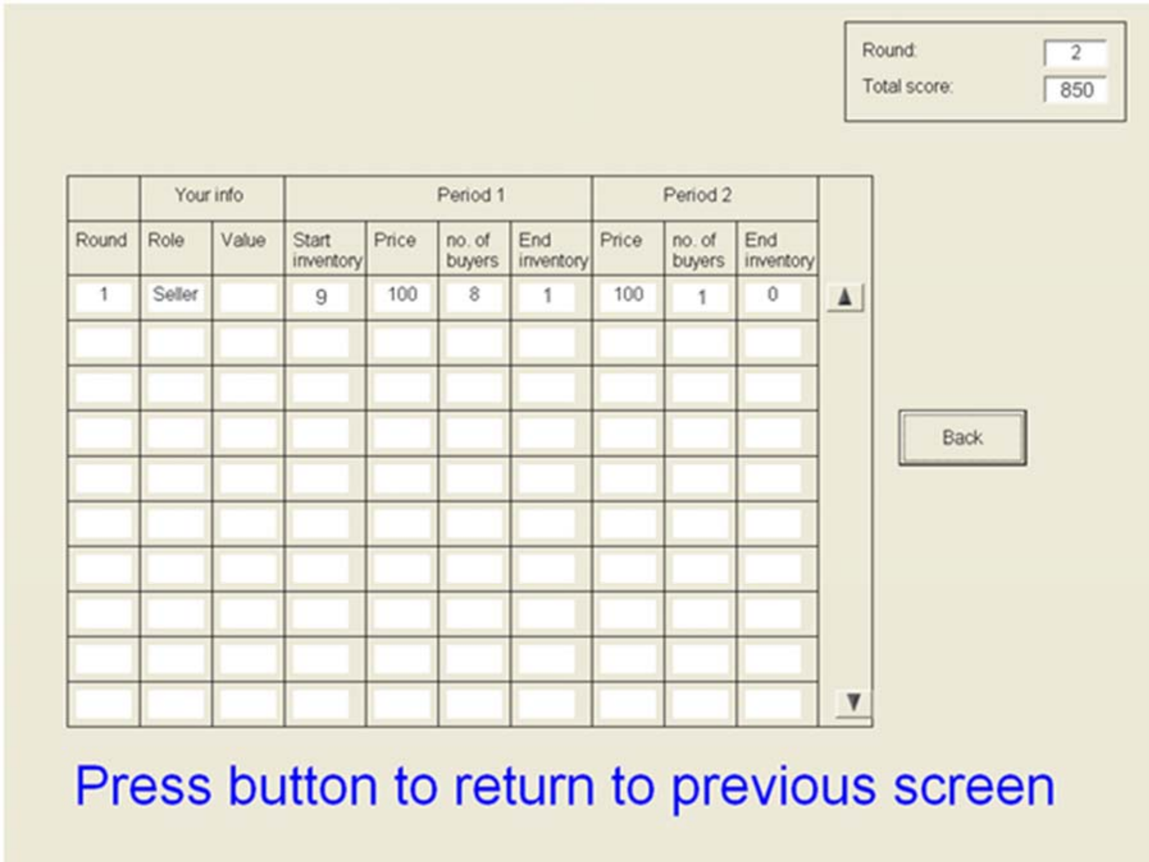
Once period 2 is over, all the participants are informed of the outcome of the round, the cumulative earnings are updated, and the game proceeds to the next round.

History

At any stage during the game you may press the History button in order to review information about your previous decisions and the outcomes of all previous rounds. An example of the History Screen is displayed below. It shows that on round 1, the particular participant was assigned the role of a seller, that she sold 8 of her 9 units of good on period 1 at a price of 100 each and 1 more units on period 2. Her cumulative profit for this round was $8 \times 100 + 0.5 \times (1 \times 100) = 800 + 50 = 850$.

Press the button Back to return to the game after inspecting the past history of your decisions and profits on previous rounds.

History Screen



How will You be Paid?

The session will include 63 identical rounds with roles and values randomly assigned on each round. Your total earnings will be converted to US dollars, added to a $5.00 participation bonus, and paid to you in cash and in private at the end of the session. All the earnings are confidential.

Please place the instructions on the table in front of you to indicate that you have completed reading them. The experiment will begin shortly. Please remember that no communication is allowed during the experiment. If you encounter any difficulties please raise your hand and you will be responded to by the experimenter.

Thank you.

ONLINE APPENDIX C: Additional Data Analysis, Figures, and Table

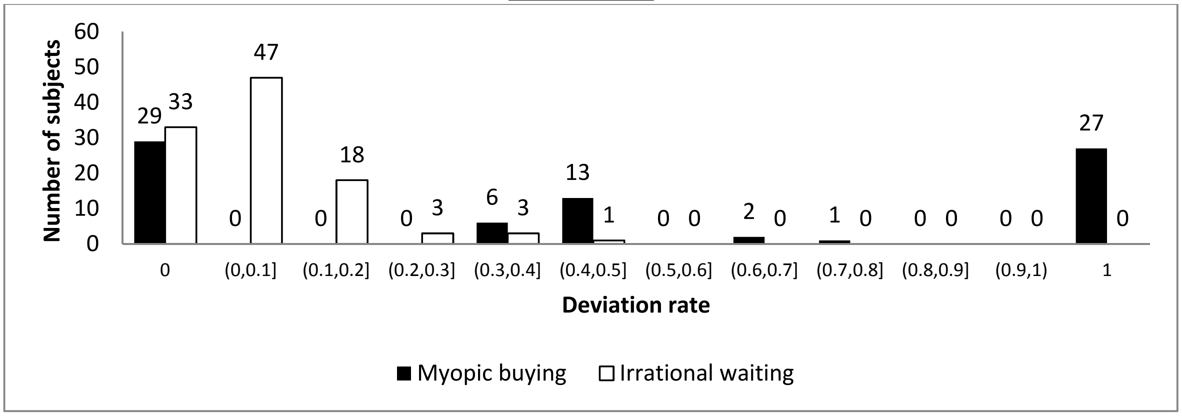
1. Further Analysis of Buyers' Decisions

Apart from the results reported in the main text, we also conducted analysis on an individual-level "deviation rate" among the buyers. The myopic buying deviation rate was calculated as follows: first, for each subject we counted the number of rounds in which the subject's valuation v was such that $v^{**} > v > p_1$, so that the subject was susceptible to exhibiting myopic buying; we then counted the number of times among these rounds when she, indeed, exhibited myopic buying. Dividing the second count by the first count yields a myopic buying deviation rate for the subject. A subject who always made decisions according to equilibrium predictions would have a deviation rate of 0, while a fully myopic subject would have a deviation rate of 1. The irrational waiting deviation rates are similarly calculated. Hence, for example, an irrational waiting deviation rate of 0.13 means that, on average, the subjects irrationally waited 13% of the time that they were supposed to buy in period 1, in the relevant block/condition and at the relevant price level. Figure A1 below displays the results of our analysis in a histogram for each of the two conditions. Consistent with the buyer behavior study of Mak et al. (2014) (reference [13] in the main text), we find that a considerable proportion of buyers exhibited low but non-negligible frequencies of irrational waiting, while a non-negligible minority of buyers in both conditions always exhibited myopic buying when the opportunity arose. In fact, 15 subjects in Condition I9 and 6 in Condition I16 (out of 105 subjects in each condition) exhibited *complete* myopic buying behavior in that they never committed irrational waiting but always committed myopic buying whenever the respective opportunities arose for them. To summarize, *a non-negligible minority of subjects were completely myopic as buyers even with practice.* This finding further reinforces our premise that, at the individual level, subjects in the role of buyers could exhibit significant deviations from equilibrium play; but at an aggregate level these deviations tended to mitigate each other.

Ex post optimality. We also find that the rational expectations equilibrium best responses were overwhelmingly ex post optimal for the buyers, thus justifying their use as a meaningful benchmark of optimality. The ex post optimal decision in our analysis is calculated by comparing the buyer's payoff, given his/her decision in period 1, and the counterfactual payoff had the buyer's decision in period 1 been otherwise. In cases when the buyer purchased in period 1 and the round would have proceeded to period 2 had he/she not purchased, the counterfactual payoff is based on assuming that the seller would have priced optimally in period 2 according to the grey line in Figure 3. Sensitivity analysis for these cases, based on assumptions that the seller would have priced slightly higher or lower than optimally in period 2 in the counterfactual scenario, yields similar conclusions as reported in the main text.

Specifically, we find that in Condition I9 98.7% of the 155 instances when rational expectations equilibrium prescribed strategic waiting (i.e., $v^{**} > v > p_1$), the ex post optimal decision was also to hold off purchase. In 96.1% of the 2795 instances when the equilibrium best response for a buyer was to purchase in period 1 (i.e., $v > v^{**}$), the ex post optimal decision was also to purchase immediately. The corresponding percentages in Condition I16 are 94.9% (out of 740 instances) for strategic waiting and 98.6% (out of 3329 instances) for immediate purchase in period 1. Hence, *equilibrium best responses were almost always ex post optimal for buyers.*

Condition I9



Condition I16

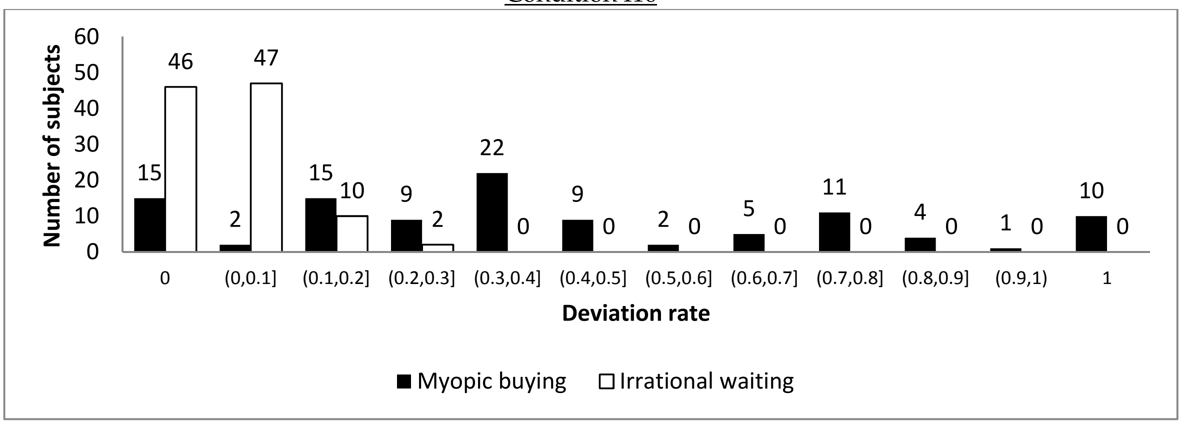
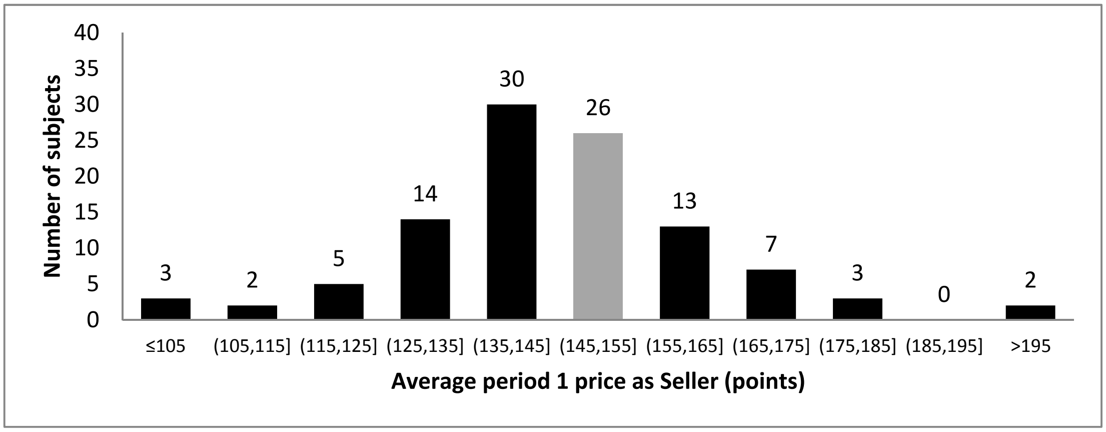


Figure A1. Distributions of subjects' overall deviation rates in myopic buying and irrational waiting in their role as buyers. The total number of subjects is 105 in either condition; in Condition I9, 27 subjects never encountered any round with a period 1 price with which myopic buying could be a deviation from the equilibrium benchmark, and so the corresponding distribution was based on the decisions of only 78 subjects.

Condition I9



Condition I16

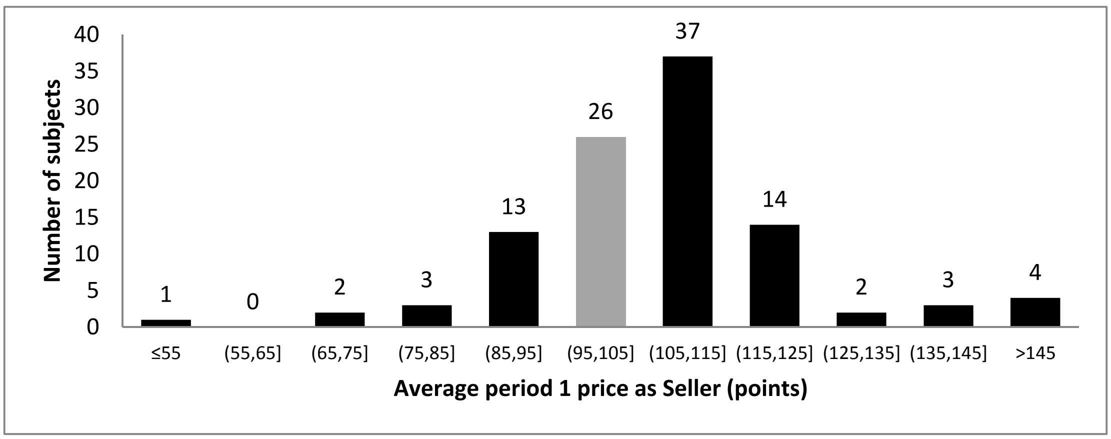


Figure A2. Distributions of subjects' average period 1 prices in their role as sellers. The total number of subjects is 105 in either condition. The gray bar in each panel indicates the category containing the overall equilibrium price. Note also that the average range of prices (i.e., the difference between the maximum and minimum) set by an individual subject is 34.5 in Condition I9 and 26.0 in Condition I16.

Table A1. Observed per round means of seller's profit and buyer's payoff by condition and block (s.d. in parentheses). Where the entry is significantly different from overall equilibrium (see the gray rows in Table 2) according to a *t* test, it is marked by one or more asterisks (* $p \leq 0.05$, ** $p < 0.01$).

	Seller's round profit	Buyer's round payoff
	Condition I9	
Overall equilibrium	**1350**	**20.25**
Block 1	1105.9 (51.35) **	23.96 (1.78) *
Block 2	1210.1 (30.43) **	19.32 (2.86)
Block 3	1196.1 (31.48) **	19.05 (2.14)
	Condition I16	
Overall equilibrium	**1360**	**50**
Block 1	1284.4 (55.46) *	46.52 (5.70)
Block 2	1322.6 (51.23)	47.10 (2.02) *
Block 3	1330.5 (42.29)	44.97 (2.96) *

Note: Block 1 – Rounds 1 to 21; Block 2 – Rounds 22 to 42; Block 3 – Rounds 43 to 63. The *t* tests and other calculations are carried out with session as the unit of analysis to ensure independence of observations.