University of Hawai`i at Mānoa
Department of Economics
Working Paper Series

Saunders Hall 542, 2424 Maile Way,
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Phone: (808) 956 -8496
www.economics.hawaii.edu

Working Paper No. 20-18

Randomized Double Auctions: Gains from Trade, Trader Roles, and Price Discovery

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July 2020

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Gains from Trade, Trader Roles, and Price Discovery[*]

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Abstract

Experimental double-auction commodity markets are known to exhibit robust convergence to competitive equilibria under stable or cyclical supply and demand conditions, but little is known about their performance in truly random environments. We provide a comprehensive study of double auctions in a stochastic setting where the equilibrium prices, trading volumes and gains from trade are highly variable across periods, and with commodity traders who may buy or sell their goods depending on market conditions and their individual outcomes. We find that performance in this stochastic environment is sensitive to underlying market conditions. Efficiency is higher and convergence to the competitive equilibrium stronger when the potential gains from trade are high and when the equilibrium spans a wide range of quantities, implying a large number of marginal trades. Speculative re-trading is prevalent, especially for individual traders who have little to gain under equilibrium pricing, leading to some redistribution of gains from high to low expected earners. Those with the largest expected gains typically earn far less than predicted, while those with little or no predicted earnings gain modestly from speculation. Excessive trading volumes are associated with negative efficiencies in markets with low gains from trade, but not in the high-gains markets, where zero-sum trading and re-trading appear not to obstruct and possibly enforce efficiency and near-equilibrium pricing. Buyers earn more relative to their competitive equilibrium benchmark than sellers do. Introducing trader specialization leads to fewer trading errors and higher market efficiency, but it does not eliminate zero-sum trading and re-trading.

JEL classification code: C92, D02, D41

Key words: economic experiments, double auction markets, gains from trade, speculation.

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[*] Financial support by the International Foundation for Research in Experimental Economics is gratefully acknowledged. We would like to thank Daniel Friedman, John Ledyard, Charles Plott, Vernon Smith and participants of the Economic Science Association meetings for valuable comments and discussion. Sherstyuk is grateful to the participants of 2019 symposium in honor of Charlie Plott at Caltech for inspiration.

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1 Introduction

Experimental laboratory commodity markets are known to converge to the competitive equilibrium under a wide range of conditions, including shifts in supply and demand (Smith, 1962). Double auctions, in particular, have been documented to outperform other market institutions in terms of the speed of convergence to the competitive equilibrium, and market efficiency (Plott, 1982; Davis and Holt, 1993). Certain experimental design elements, however, persist across most laboratory studies, with many alternatives remaining underexplored. In particular, experimental supply and demand conditions often remain fixed over time, and when shifts occur, they tend to be systematic and persist for multiple trading periods. At the same time there are commodity markets outside the lab where supply and demand can shift continuously in unsystematic ways. Trader roles as buyer or seller also tend to be fixed in most experiments, and re-trading is disallowed, reflecting the features of markets for non-durable goods and services (Dickhaut et al., 2012). Yet there exist important classes of markets where traders may change between buyer and seller roles depending on market conditions, and where re-trading is also possible. Do markets function as well in experimental environments with random variation over time and flexible roles for buyers and sellers? How do these design elements affect the market's tendency to converge to equilibrium?

Consider, for example, markets for agricultural goods, which exhibit non-cyclical stochastic supply shocks due to variations in harvest caused by weather or climate variability. Participants in agricultural markets (farmers, processors, speculators and other intermediaries), especially in developing countries, may switch between seller and buyer roles depending on individual outcomes, consumption needs, and trading opportunities. For example, a subsistence farmer in a developing country may look to sell surplus after a bumper crop, but need to purchase food from others after a crop failure. With inelastic food demand and highly variable crop outcomes, individual trading roles, trading volumes, and equilibrium prices might change considerably over time with random weather events.[1] It is unclear whether markets behave as efficiently in such environments.[2]

In this paper we examine the performance of experimental double auction markets under stochastic supply with commodity traders who may buy and sell their goods depending on market conditions and their individual outcomes. We focus on the following questions. First, how well do double auction commodity markets perform in terms of efficiency and convergence to the competitive equilibrium under stochastic market conditions? Do trading volumes and prices converge to equilibria? To what extent are potential gains from trade realized? Second, what can be said about the out-of-equilibrium dynamics? We consider transaction price dynamics, the sequencing of trades, and whether and when individuals trade in the direction consistent with equilibrium prediction, to address this question.

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[1] Malawi has an interesting example of such a market, one that has been facilitated by interventions to aid storage, collateralized loans, and public posting of prices (Edelman et al., 2015; Gondwe et al., 2017).

[2] A key aspect of agricultural and other commodities is storage, consideration of which is also missing from the conventional experimental literature. The experimental design that we develop here can be easily extended to consider storage, which we do in a companion paper. Financial securities, housing, and capital goods markets are also characterized by good durability and re-trading opportunities (Gjerstad and Smith, 2014). We will discuss the connection of our study to asset market experiments below.

Third, does giving each trader an opportunity to both buy and sell, as opposed to having a specialized role, facilitate adjustment to stochastic market equilibria, – e.g., by allowing error-correction,– or does it hinder adjustment, – e.g., by increasing market complexity or by creating speculative opportunities?

We find that market equilibrium forces are strong overall. Double auctions adapt reasonably well to random changes in market conditions, with average efficiencies starting in the range of 65-85%, and increasing in later periods as traders gain experience. Transaction prices converge close to the equilibrium predictions within each market period. Transactions with higher gains from trade generally take place earlier within a period, and in almost 90% of all individual cases traders buy and sell in the direction consistent with the equilibrium prediction. However, transaction volume often exceeds the equilibrium prediction due to extensive re-trading and many trades with zero-sum gains.

Looking across market conditions, we observe significant effects of market characteristics on performance. Market efficiency is lower in periods when potential gains from trade are low, although efficiency is unaffected by equilibrium price level conditional on potential gains from trade. There is more re-trading activity when the predicted trading volume is low, and most re-trading is done by traders with low or zero equilibrium gains from trade. Many excessive trades and re-trades take place when traders have little or no real gains from trade (left) and have nothing else to do.[3] However, we find evidence that zero-sum marginal trading, when consistent with the equilibrium prediction, improves efficiency and facilitates price convergence. Excessive trading is associated with reduced efficiencies in low-gains markets, but not in high-gains markets where efficiencies continue to increase across all trading stages. Thus markets work well when there are “real” gains from trade to be realized, but may result in noisy negative-gain trading if trading gains are low or absent.

Finally, we obtain a novel insight into the role of trader specialization in double auctions. By dividing traders into ex-ante net buyers and net sellers, we observe significantly higher market efficiencies than under identical aggregate market conditions with ex-ante symmetric traders. This suggest a powerful role of trader specialization in fostering market efficiency. However, trader specialization does not eliminate extensive zero-sum trading and re-trading.

2 Related Literature

Several strands of experimental literature are relevant to our investigation. The first considers how competitive markets shift to new equilibria following changes in supply or demand. Double auctions have been demonstrated to quickly adjust to the new competitive equilibria in these cases (Smith, 1962; Plott, 1982; Davis and Holt, 1993). Early studies, however, especially those of non-computerized markets, typically have several periods of fixed conditions to allow for convergence to the new equilibrium (Smith, 1962).[4] Davis et al. (1993) study

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[3] The latter is in line with the active participation hypothesis suggested by Lei et al. (2001) as an explanation for asset market bubble formation.

[4] A related literature investigates competitive commodity markets with cyclical demand with uncertain or unknown shifts in market conditions (Miller et al., 1977; Williams and Smith, 1984; Plott and Agha, 1983; Plott and Turocy, 1997; Jamison and Plott, 1997). These studies focus on the role of inter-temporal speculation in increasing overall market performances across periods, an issue that we do not address here.

non-stationary markets with systematic shifts in supply or demand, and Jamison and Plott (1997) consider unpredictable shifts in demand and supply every period; both report that double auction markets moved towards competitive equilibrium even under those conditions. However, shifts in demand and supply in these studies were not random, and therefore did not cover as wide a range of conditions as can be expected under a sequence of truly random market shocks. In this study, we consider markets with random shifts of demand and supply, which result in highly variable equilibrium prices, trading volumes, and total gains from trade. This design allows us to investigate the effect of all these factors—equilibrium price levels, volume of trade, and potential gains from trade—on market efficiency.

Another related literature considers disequilibrium behavior and the dynamics of market equilibrium convergence, which characterizes most trading activity in double auctions, especially in experimental markets with highly variable conditions. Easley and Ledyard (1993) provide a pioneering contribution to the literature and suggest a simple theory of price adjustment in double auctions with boundedly rational traders: that traders anchor price expectation in each subsequent period on the previous period's prices. Their model, however, may not predict behavior in markets with frequent shifts in supply or demand.[5] We examine whether this prediction can characterize initial expectations and convergence in experimental markets with randomly varying market conditions. The dynamics of market convergence under random supply and demand is further investigated by Cason and Friedman (1996) under fixed buyer-seller roles and low equilibrium trading volume in each period. They report high efficiencies of double auctions under these random conditions, and further document that trades with higher surplus tend to occur earlier in the period—called the Marshallian model of market adjustment—while showing evidence against other theoretical models of price formation. However, they do not consider markets that are affected by both common and idiosyncratic shocks, and where buyer and seller can re-trade goods, as we do in our experiment. Plott et al. (2013) study the behavior of double auction markets with supply and demand that shift symmetrically each period by a constant, such that the equilibrium price changes while equilibrium volume and available gains from trade remain fixed across periods. The authors show evidence that the Marshallian model of market adjustment predicts well the sequence of trades and can therefore explain why disequilibrium trades do not hamper convergence to the competitive equilibrium. While our experimental design differs markedly, we also find evidence that trades with higher gains tend to occur earlier in the period.

The last issue that we investigate concerns the effects of flexible trader roles. While double auctions perform well in commodity market settings with fixed buyer and seller roles, other market contexts, such as asset markets or markets for environmental permits, allow both buying and selling activities for each participant. In such settings, experimental double auction markets may create price bubbles due to speculation, increased market complexity, bounded rationality, or some combination of factors, as demonstrated by Smith et al. (1988), Lei et al. (2001) and others in the context of asset markets.

Unlike asset markets, commodities cannot be stored across periods in the setting we

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[5] Friedman (1984) is among the early theoretical models attributing observed efficiency of double auction markets to traders' utility maximization motive. At the other extreme, Gode and Sunder (1993) demonstrate that double auction markets with non-profit-maximizing zero intelligence robots also converge under a simple discipline of budget constraint.

examine; however, speculative activities are still possible within periods, since we allow for re-trading (e.g., buy at a low price early in the period and sell later at a higher price). An existing application of double auction markets with flexible buyer-seller roles is the market for environmental permits, which has been explored in several studies (Ledyard and Szakaly-Moore, 1994; Godby et al., 1997; Cason and Gangadharan, 2006). These studies report on the efficiency-enhancing effects of environmental permit trading; in fact, Ledyard and Szakaly-Moore (1994) document a superior performance of double auctions over alternative institutions, although the average market efficiency in their study is 85%, which is substantially lower than full efficiency routinely reported for most double auctions under fixed buyer-seller roles.[6] Dickhaut et al. (2012) investigate experimental double auctions with within-period re-trading and cash endowments; they observe lower efficiency and substantially higher volumes of trade in their markets with re-trade as compared to markets with no re-trade and fixed buyer and seller roles.

Finally, Kotani et al. (2019) compare the performance of double auctions and uniform-price auctions with and without re-trading, and find that uniform price auctions out-perform double auctions under re-trading. Double auctions with re-trading have excess trading volumes, prices away from equilibrium and low efficiency. Both Dickhaut et al. (2012) and Kotani et al. (2019), however, investigate stationary market environments, which offer little justification for re-trading. In contrast, we consider a setting where market conditions are stochastic and highly variable across periods, where re-trading may help error-correction and convergence to equilibrium. This highly variable environment allows us to investigate whether and how the shares of efficiency-enhancing and speculative trades vary with market circumstances, such as equilibrium price level, trading volume, and available gains from trade.

We further study if markets with more specialized traders, wherein traders maintaining the same net-buyer or net-seller role across periods, perform any differently than markets with ex-ante symmetric traders, where the role changes randomly from one period to the next. While Dickhaut et al. (2012) identify trader specialization with fixed buyer and seller roles, we demonstrate that specialization improves market efficiency even when re-trading is allowed.

3 Experimental Design

A novel aspect of this study is its experimental design, which can neatly incorporate random shifts, a range of experimental subjects in a session, and may be easily extended to study commodity market behavior with storage. The design combines some characteristics of a traditional double-auction commodity market and some characteristics of a traditional double-auction asset market.

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[6] In contrast, Anderson and Sutinen (2005) report on a poor performance of double auctions in the markets for tradable fishing quotas.

3.1 Assigning Values and Commodity Supply

Eight to twelve subjects participate in each market session. In each period, each subject is given a multi-unit valuation schedule for a fictitious commodity, and is allocated a random supply of this commodity. All traders have the same valuation schedule that gives marginal benefit from consumption, and this schedule stays the same in all market periods (Table 1).

Table 1: Valuation schedule

Unit Number	Value
1	275
2	225
3	175
4	125
5	75
6	25
7+	0

In each period t, the random supply or *yield*, Y_{it}, allocated to each trader i, equals the sum of a common component C_t and an idiosyncratic component E_{it}, such that $Y_{it} = C_t + E_{it}$. The common component represents common factors affecting the yield (such as global weather conditions), and the individual component represents an individual random shock (local weather). Both the common and the idiosyncratic components are drawn from discrete uniform distributions: $C_t \sim U\{0,1,2,3,4,5\}$, $E_{it} \sim U\{0,1,2,3,4,5\}$ for all traders i, making the distribution of Y_{it} a mixture of uniforms with support on {0,1,2,3,4,5,6,7,8,9,10}, and all traders ex-ante identical. Due to the common factor, the correlation of Y_{it} and Y_{jt} equals 0.5 for all $i \neq j$.

Since we assign the same demand curve to all participants, in equilibrium all traders will hold the same number of units equal to the average market yield $\bar{Y}_t = \frac{1}{N}\sum_i Y_{it}$; individual quantities may differ by at most one unit if the average market yield is not an integer. The equilibrium price in each period equates mean supply and mean demand and is determined by the marginal value at the average yield $\bar{Y}_t$ as given in Table 1; see Appendix A for details on equilibrium price and quantity determination. The expected average yield is $E[\bar{Y}_t] = 5$, and the corresponding equilibrium price is $P_t^{eq} \in [25, 75]$, providing no opportunity for any trader to strictly benefit from either buying or selling their equilibrium holdings at any price in this range.[7] Aggregate demand is highly inelastic, by design, in accordance with real-world commodities that are typically stored.[8] Because harvests are i.i.d across periods, prices are

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[7] If $\bar{Y}_t = 5$, each trader will be holding exactly 5 units in equilibrium; their opportunity cost to sell the fifth unit is 75, and their maximal willingness to pay for the sixth unit is 25, giving rise to the equilibrium price range of $[25, 75]$ at which no strictly profitable trades are possible. See Appendix A for details.

[8] The basic setup is similar to that often used in theoretical models of commodity pricing with storage; e.g., Deaton and Laroque (1992). Our focus here is on the performance of commodity markets under highly variable conditions that cannot be smoothed out by instruments such as storage. Stay tuned for our companion paper on markets with storage.

also i.i.d. If $\bar{Y}_t > 6$, the equilibrium price is zero, but price can rise to 275 if $\bar{Y}_t < 1$, which occurs with very small probability. With ten participants, an equilibrium price of 175 or greater occurs with probability 0.16 and the expected price is 68.3, while an equilibrium price of zero occurs with probability of 0.32.

3.2 Net Demand and Net Supply

Gains from trade depend on the spread of individual outcomes driven by variation in E_{it}, as well as the aggregate outcome. Since all participants will almost surely possess some units of the good, we define *net demand* as the schedule of quantities demanded through the market. Net demand will be positive for *net buyers*, i.e., those randomly allocated less than the mean, while subjects randomly assigned more units than average are *net suppliers (sellers)*. Note that the aggregate outcome C_t also influences net supply and net demand, as higher C_t reduces the values for all participants in accordance with the value schedule.

Participants buy and sell through a double auction market, and receive profits from trade according to the value schedule. To make the experimental setting comparable with double auction market experiments with specialized buyer and seller roles, individual earnings are calculated as gains from trade, i.e., they are normalized to zero at no trade. Thus, as in the traditional buyer-seller setting, for a trader selling a unit, the foregone consumption value of unit sold represents their opportunity cost of giving up the unit; for a trader buying a unit, the value of the unit bought represents their consumption value of the unit acquired; and participants earn nothing if they do not trade.

The novelty of the design is the random and highly variable environment, with prices, individual and aggregate net demand, individual and aggregate net supply, and gains from trade all changing markedly with each period. Random assignment allows us to draw causal links between market characteristics and market performance. Although some studies, starting with Smith (1962), consider limited variations in market conditions, to the best of our knowledge, the performance of double auctions under such randomized and highly variable conditions has not been evaluated before.

We show this variability in Figure 1 using outcome data from a representative session. The figure shows the aggregate net demand (in black) and net supply functions (blue) in each period, derived using the common value schedule as given in Table 1, random period realizations of individual yields, and the resulting aggregated net demand and net supply. The efficiency of the market, measured as the percent of potential gains from trade that are realized, is reported in the top-right corner of each panel. Prices of sequential individual trades are also plotted. Depending on random yield outcomes, market conditions vary between low-mean-yield, high-price periods (e.g., periods 7 and 14 on the figure), and high-mean-yield, low-price periods (e.g., periods 2 and 11). Given the demand schedule, the market equilibrium price is zero in any period when the mean yield more than six units (e.g., periods 2, 3, 5, and 6). Periods with lower mean yield and higher variation in individual yields have higher potential gains from trade than periods with higher mean yield and less variation in yields (compare periods 1 and 17 on the figure). A market may have a range of trading volumes $[Q_L, Q_U]$ consistent with equilibrium if zero-gain trades are taken into account, which may be particularly relevant for periods where the equilibrium price is zero (e.g., period 16 or 17 on the figure). Appendix A contains the details on how equilibrium

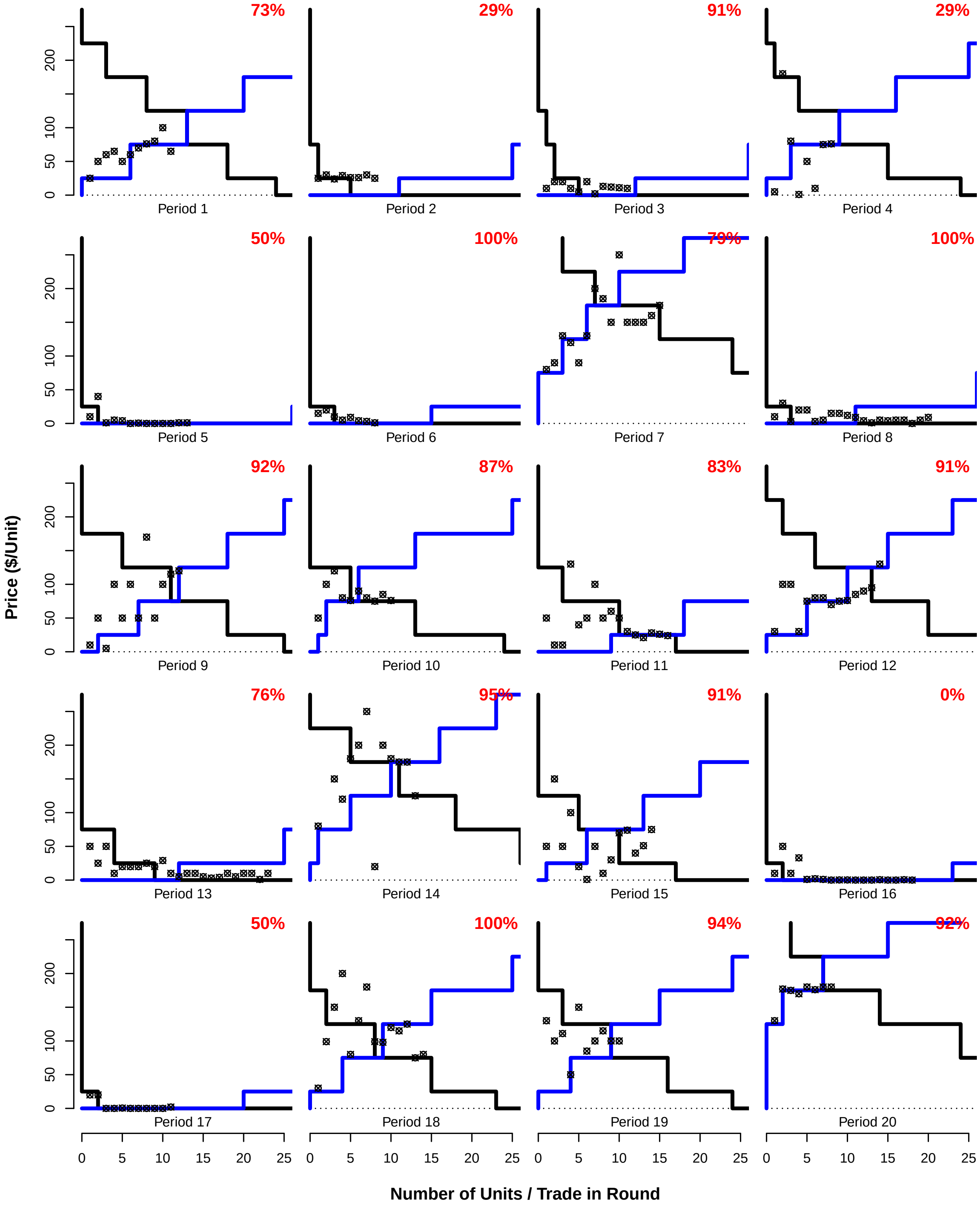

Figure 1: **Net supply and demand schedules and market trades in Session 1.**
Notes: Market efficiency (percent of potential gains from trade actually realized) is displayed in red in the top-right corner. The dots show prices of individual trades, with the transaction order indicated by the horizontal axis.

price and quantity bounds are determined.

The design allows for an easily scaleable number of participants across sessions. A larger number of participants slightly reduces the variances of mean yield and the competitive equilibrium price, but by a factor that is less than the usual $\sqrt{N}$, due to the existence of the common shock C_t.[9] Market size may have a stronger influence on outcomes via other channels, such as the degree of competition and robustness to errors. The experimental design allows us to test for these effects. Our experimental sessions had relatively little variation in the number of participants (between 8 and 12, with standard deviations of about 1.53 and 1.50, respectively), and we found no evidence that the number influenced behavior over this range.

3.3 Flexible Trader Roles

The experimental design lets us examine the effect of flexible trader roles on market performance. In the baseline treatment, a participant faces even odds of receiving a yield that is above or below the mean, and therefore has even odds of being a net seller or net buyer. We refer to this baseline as the *symmetric* treatment, since all traders are ex-ante identical. While there is a certain elegance in the symmetric treatment, it also creates an extra level of complexity for participants as compared to the traditional setting with fixed buyer-seller roles. Each participant must decide, at each instance during trading, whether to buy or sell or do nothing. Participants are also allowed to re-trade units, buying and selling within a period, opening a door to speculative trading. The option of reselling also ensures that, unlike in the traditional experimental commodity markets design, the competitive equilibrium is not influenced by the order in which trades occur.

While uncommon in commodity double auction experiments (exceptions are Dickhaut et al. (2012), Kotani et al. (2019) and environmental permits trading experiments reviewed in Section 2), flexible trader roles are characteristic to some commodity markets, including market intermediaries, speculators, and farmers in developing countries. Our design allows us to examine market efficiency and equilibrium price discovery in this more complex environment with flexible roles. Note that the design also bears some resemblance to stock market experiments which commonly have flexible trader roles.

To draw out the influence of flexible trader roles in comparison to other design elements, such as random variability, we developed an alternative, *asymmetric* treatment. Each session in the asymmetric treatment was matched to a session in the baseline symmetric treatment, employing the same number of traders and the same random individual yield draws. In the asymmetric treatment, however, half of the participants received lower yields than the other half. To keep all else the same as the symmetric treatment, we preserved the same random yield draws and assigned lower half of draws of each period to the low-yield group of participants and the higher half of draws to the high-yield group. Thus, although predicted

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[9] With N traders, the distribution of the aggregate supply of the good is given by the sum of N individual i.i.d. distributions of E_{it} plus a uniformly distributed common shock C_t. The aggregate supply and the mean yield distribution are thus a mixture (sum) of discrete uniform distributions on $\{0,...,5\}$ and a near-normal distribution with a mean of 2.5 and standard deviation of about $\frac{1.44}{\sqrt{N}}$. While the variability of the mean yield will decrease with the root of the number of participants, the lower bound is tied to the variability of C_t, with the standard deviation of 1.44.

trader roles may occasionally switch across periods (if the distribution of yields is sufficiently skewed), most of the time low-yield participants will be net buyers and high-yield participants will be net sellers.

Table 2: Design of matched symmetric and asymmetric treatment sessions: an illustration

	Period 1				Period 2			
Trader	symmetric		asymmetric		symmetric		asymmetric	
ID	yield	role	yield	role	yield	role	yield	role
1	6	seller	2	buyer	5	seller	2	weak buyer
2	2	buyer	4	no-trader	2	weak buyer	2	weak buyer
3	4	no-trader	3	buyer	2	weak buyer	0	buyer
4	6	seller	2	buyer	3	weak seller	1	buyer
5	3	buyer	3	buyer	5	seller	0	buyer
6	5	seller	1	buyer	0	buyer	0	buyer
7	5	seller	6	seller	2	weak buyer	5	seller
8	5	seller	6	seller	2	weak buyer	3	weak seller
9	2	buyer	5	seller	5	seller	5	seller
10	6	seller	5	seller	1	buyer	2	weak buyer
11	3	buyer	5	seller	0	buyer	2	weak buyer
12	1	buyer	6	seller	0	buyer	5	seller
mean	4.00		4.00		2.25		2.25	
stddv	1.76		1.76		1.91		1.91	

Symmetric treatment: trader yields are i.i.d., resulting in random trader roles in every period. Asymmetric treatment: same i.i.d. yield draws are sorted by value; the lowest six are randomly assigned to traders 1-6, making them expected net buyers; the highest six are randomly assigned to traders 7-12, making them expected net sellers. Individuals with realized yields within one unit from the market average are classified ex-post as weak traders, and individuals with yields exactly at the average as no-traders.

We illustrate the design of the matched symmetric-asymmetric sessions in Table 2. The table reports yield draws and implied roles for each trader in two sample periods, under both symmetric and asymmetric treatments. Aggregate market conditions are identical between the two treatments since the distribution of individual yields are the same. In comparison to experimental designs with fixed, assigned roles as buyers or sellers, this design is conducive to one-sided trading but does not force it, and still allows for speculative trading. We can therefore examine whether this induced trader role asymmetry affects speculative trading and market convergence, as well as efficiency and other conventional performance measures.

3.4 Procedures

The laboratory experiment was computerized using z-tree software (Fischbacher, 2007). Participants were recruited from the undergraduate population of the University of Hawaii at Manoa using ORSEE recruitment software (Greiner, 2015). Instructions were shown on the computer screens and were concurrently read aloud by the experimenter.[10] To familiarize the participants with the trading institution and their roles, there were three unpaid practice periods before ten or twenty paid periods, a range we use to assess the effect of learning on market performance.[11] Each market period lasted for 120 seconds, providing ample time to realize all potential gains from trade; the equilibrium trade volume varied between zero and over 20 trades, with an overall average of between 1 to 2 trades per active participant. Each trader was given a small initial capital of 300 experimental dollars at the beginning of the first period; a trader who ran a negative payoff went bankrupt and had to stop trading. Some sessions were conducted using the same pre-drawn sequences of random yields, while others were conducted using newly generated random yields, allowing us to control for possible effects of the chronological sequence of yield draws on market performance. The exchange rate was 1.5 US dollars per 100 experimental dollars. Each session lasted between 1.5 and 2.5 hours, including instructions and practice. Subject payments averaged 21.0 U.S. dollars in twenty-period sessions and U.S. 14.9 dollars in ten-period sessions, including 5 dollars show-up fee.

4 Results

We completed the total of 21 experimental sessions, with 260 market periods, 218 traders and 3012 transactions. Sessions varied in the number of participants (8-12), session length (20 or 10 periods), random draw sequence used to generate yields, and symmetry or asymmetry of yield draws across traders. Thirteen sessions were conducted with inexperienced symmetric traders, and six sessions – with inexperienced asymmetric traders. The yield draws in each asymmetric traders session were matched to the draws in one of symmetric traders sessions. In addition, we conducted one session each with symmetric and asymmetric experienced participants. The session summary is presented in Table 3.

Table 3: Session summary

Yield distribution	Experi-enced traders?	Session duration, periods	Number of sessions		Number of traders	
			total	matched yields	per session	total
symmetric	No	20	5	–	8-12	51
symmetric	No	10	8	6	8-12	83
symmetric	Yes	10	1	–	8	8
asymmetric	No	10	6	6	9-12	64
asymmetric	Yes	10	1	–	12	12
TOTAL NUMBER OF SESSIONS:			21	NUMBER OF TRADERS:		218

There were the total 10 bankruptcies in 21 sessions (five in symmetric inexperienced and five in asymmetric inexperienced sessions), with the number of non-bankrupt traders

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[10] Experimental instructions are available in Supplementary Materials.

[11] Paid periods in ten-period sessions were then followed by another treatment not discussed here.

ranging between 7 and 12 per session. Due to bankruptcies, not all pairs of ex-ante matched symmetric-asymmetric sessions perfectly matched in terms of the number of traders and yield distributions. However, the market characteristics were still very similar between the matched sessions, even after adjustments for bankruptcies. In the regression analyses that follow we use yield sequence fixed effects to control for these similarities.

We start by considering the overall performance of double auctions under random conditions, and then turn to transaction-level and trader-level analyses. On each level, we pay special attention to how the performance is affected by (i) market characteristics, including gains from trade (GFT) available, trade volume, and equilibrium price level; and (ii) assignment of randomized yields (symmetric versus asymmetric).

4.1 Market-level analysis

Average realized prices, which ranged from about 65 to 99, depending on the session, were statistically indistinguishable from the average competitive equilibrium prices. One-third of all markets (87 out of 260 markets) were fully efficient, and one-half of the markets (129 out of 260) achieved efficiency of at least 90 percent. Quantities traded, however, exceeded the lower bound of equilibrium prediction by a factor of two to three, suggesting a substantial degree of re-trading or speculation. We summarize these and other results in Table 4 and elaborate below.

Efficiency How close are the markets to full efficiency? Are efficiencies lower in periods when gains from trade and equilibrium prices are low?

Efficiency averaged 65 percent in the first ten periods of trading for inexperienced subjects, which is less than the near-100 percent efficiency typically observed in double auction commodity markets under the traditional stationary supply-demand conditions and specialized buyer-seller roles (Smith, 1962). Efficiency grew to 78 percent in periods 11-20, and the one session conducted with experienced participants yielded efficiency of nearly 99 percent.

Introducing role specialization across traders by assigning asymmetric yields (and hence dividing them into net buyers and net sellers) resulted in higher efficiency of 85 percent over the first ten periods of trading, in spite of trader inexperience, no explicitly assigned buyer-seller roles, and possibility of re-trading.

The efficiency statistics reported above average over periods in a session. Since some periods have more potential gains from trade than others, an alternative measure weights periods by potential gains, or takes the ratio of total realized gains over total potential gains from trade, summing over a range of market periods. The weighted efficiency measures exceed the unweighted measures: 70 percent in periods 1-10 and rising to 89 percent in period 11-20 for symmetric inexperienced traders; 99 percent for symmetric experienced traders; and 84 and 95 percent for inexperienced and experienced asymmetric sessions (compare with values in Table 4). These results indicate that efficiency tends to be greater when potential gains from trade are higher, as we further demonstrate with regression analysis below.[12]

We use linear regression to assess determinants of market efficiency, with results presented in Table 5. Explanatory variables include: yield asymmetry and trader experience indicators,

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[12] We are grateful to Charles Noussair for suggesting the weighted efficiency measure.

Table 4: Summary statistics, by treatment

Treatment		Efficiency, percent	Price, dollar*		Share of Prices in Eqm Range		Trading Volume**		
			Actual	Dev. from Eqm	entire period	2nd half	Actual, no. of units	Ratio to Eqm	
								Lower Q_L	Upper Q_U
Symmetric, No experience									
-periods 1-10	mean	64.99	60.19	-6.34	0.72	0.82	11.13	2.95	1.24
	sd	57.41	53.04	26.61	0.29	0.3	5.27	3.25	0.59
	No of obs.	130	130	130	130	130	130	130	130
Symmetric, No experience									
-periods 11-20	mean	78.12	78.67	-1.83	0.79	0.91	11.8	2.81	1.16
	sd	51.59	59.53	18.92	0.2	0.18	6.04	3.02	0.44
	No of obs.	50	50	50	50	50	50	50	50
Symmetric, Experienced									
-periods 1-10	mean	98.77	62.71	0.21	0.7	0.8	7.2	3.11	0.88
	sd	3.7	73.23	9.97	0.35	0.32	2.53	3.05	0.45
	No of obs.	9	10	10	10	10	10	9	10
Asymmetric, No experience									
-periods 1-10	mean	85.47	67.25	-2.96	0.77	0.89	13.3	2.7	1.43
	sd	16.15	56.85	20.33	0.23	0.2	4.66	2.11	0.57
	No of obs.	60	60	60	60	60	60	60	60
Asymmetric, Experienced									
-periods 1-10	mean	87.5	98.91	0.16	0.76	0.93	10.5	1.95	1.22
	sd	31.18	61.05	23.64	0.12	0.11	2.01	0.52	0.17
	No of obs.	10	10	10	10	10	10	10	10

*Prices are in experimental dollars.

** Q_L and Q_U are the lower and upper bounds of equilibrium quantities, which may differ due to discreteness of unit values.

the number of traders in session, period and period squared, and market characteristics: potential gains from trade and the difference between upper lower bound of equilibrium quantities, $(Q_U - Q_L)$, both normalized by the number of traders to allow comparison across different-size markets. Instead of price, we include an indicator variable for strictly positive price. To account for possible non-linear effects in markets with extremely low gains form trade, we add an indicator variable for markets with potential gains from trade below 100.[13] In this and all following regressions, standard errors are clustered by session.

Regression results reported in column (1) of Table 5 confirm that efficiency increases in later periods, and is significantly higher in sessions with asymmetric traders. The effect of the number of traders within the observed range (7-12 traders) is not significant. Markets with low potential gains from trade have significantly lower efficiencies, while a larger spread between high and low equilibrium quantity has a positive and significant effect on efficiency. Having equilibrium price of zero does not significantly reduce efficiency. As shown by regression specifications (2) and (3), these findings are robust to including yield sequence and session fixed effects. Because we replicate the same sequence of yield draws for multiple sessions (e.g., symmetric and asymmetric, and with and without experience), the yield sequence fixed effects allows paired comparisons between these session-level treatments. Session fixed effects only allow within-session comparison of individual periods.

Observation 1 *Under stochastic market conditions and symmetric trader endowments, market efficiency with inexperienced traders is initially lower than has been observed under stable supply-demand conditions with specialized buyer-seller roles and no possibility of re-trading; however, efficiency increases in later periods. Overall, one-third of all markets achieved full efficiency, and one-half of all markets achieved efficiency of 90 percent or higher. Efficiency is lower in markets with low gains from trade, and higher in markets with a larger equilibrium quantity spread; zero equilibrium price does not significantly reduce efficiency. Markets with asymmetric trader endowments exhibit significantly higher efficiency than those with symmetric traders.*

Prices Are realized prices close to the equilibrium predictions? How do prices adjust within a period? Does the previous period's closing price have an effect on next period's opening price? Do prices approach the equilibrium in later transactions?

Summary statistics in Table 4 indicate that prices were close to the equilibrium predictions; over 70 percent of all trading prices and over 80 percent of transactions prices in the second half of period transactions fell within the equilibrium price range.[14]

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[13] We attempted alternative specifications with continuous equilibrium price and trading volume variables, but none of these specifications improved the explanatory power of regressions.

[14] As the equilibrium prices fell on point estimates in the overwhelming majority of observed markets (237 out of 260, or 91 percent, of a market periods; see Table 17 in Appendix A), here we loosely denote the "equilibrium price range" as the narrowest price range that allows to fully realize market gains from trade. Graphically, it corresponds to the narrowest vertical (price) gap before the intersection of supply and demand curves; see Figure 1. We do not use this notion elsewhere in the paper; in the price convergence analysis below, we use the point value for the equilibrium price for the markets with the unique price prediction, and midpoint of the equilibrium price range, as given in Table 17 in Appendix A, as the equilibrium price prediction for the markets with the range of equilibrium prices.

Table 5: Efficiency estimation, linear regression

	Dependent Variable: Market Efficiency		
	(1)	(2)	(3)
asymmetric yields	14.338**	15.697***	
	(5.621)	(4.171)	
experience	20.702	9.441	
	(14.003)	(10.699)	
potential GFT, normalized	0.090	0.169*	0.163
	(0.077)	(0.093)	(0.114)
low GFT	-56.624**	-51.859**	-45.585*
	(22.328)	(21.998)	(22.243)
equilibrium price above zero	2.276	-0.651	-1.250
	(8.422)	(9.579)	(11.827)
high-low eqm quantity spread, normalized	31.151**	29.954**	26.665**
	(11.876)	(11.435)	(11.513)
Number of traders	-0.724	1.144	-34.694
	(1.746)	(1.600)	(27.847)
period	6.154***	6.124***	3.491**
	(2.012)	(1.995)	(1.383)
period squared	-0.236***	-0.195***	-0.117
	(0.071)	(0.055)	(0.069)
constant	39.860	8.297	398.339
	(30.870)	(32.413)	(283.391)
Yield sequence fixed effects	N	Y	Y
Session fixed effects	N	N	Y
Number of observations	259	259	259
R-squared	0.150	0.197	0.301

Market efficiency is in percent. Standard errors clustered on session. */**/*** indicate significance at the 10/5/1 percent level.

For symmetric sessions, the average period trading price was within 7 experimental dollars (10 percent) of equilibrium predictions. The average gap between average per period price and the equilibrium prediction decreased from -6.34 in periods 1-10 to -1.83 in periods 11-20; it fell to 0.21 experimental dollars in the session with experienced subjects. For asymmetric traders, the average price was within 3 experimental dollars (5 percent) from equilibrium predictions for inexperienced traders and within 1 experimental dollar (1 percent) for experienced traders.

To consider the evolution of prices within a period, we use a slightly modified dynamic model of price adjustment inspired by Noussair et al. (1995, 1997). Let P_{ist} be the t-th transaction price in session i period s. The model estimates an opening transaction price level B_0 and assumes the subsequent prices follow an adjustment process that eventually converges to a period-specific asymptote, B_1. The opening price and asymptote coefficients are weighted by $1/t$, and $(t-1)/t$, respectively, where t is the transaction number within a period. Building on insights of Easley and Ledyard (1993) and Gode and Sunder (1993), we develop a specification that allows point B_0, the origin, to depend on two potentially relevant variables: the previous period final (closing) price $F_{i(s-1)}$ (compare to Easley and Ledyard (1993)), and the midpoint M_{is} between the highest buyer value and the lowest seller opportunity cost in the current period (compare to Gode and Sunder (1993)); the latter pertains to the predicted first transaction under the Marshallian hypothesis for price convergence (to be discussed below). We allow point B_1, the asymptote, to depend on the market equilibrium price E_{is} in markets with positive equilibrium prices, and to be an arbitrary constant in markets with zero equilibrium price. These assumptions imply the following functional form of price adjustment within each market period:

$$P_{ist} = (B_{01}F_{i(s-1)} + B_{02}M_{is})\frac{1}{t} + (B_{11}D_{is}E_{is} + B_{12}(1-D_{is}))\frac{t-1}{t} + u_{ist}, \qquad (1)$$

where D_{is} is the indicator variable for the positive equilibrium price in a given period, and u_{ist} is the error term. Coefficients B_{01} and B_{02} indicate the dependence of transaction prices on the previous period closing price and the midpoint of the individual values range, respectively. The corresponding hypotheses of dependence to be tested are: $B_{01} \neq 0$ and $B_{02} \neq 0$. The coefficients B_{11} and B_{12} indicate dependence of price asympototes on the equilibrium price prediction for positive and zero equilibrium prices, respectively. The hypotheses of price convergence to the competitive equilibrium to be tested are: $B_{11} = 1$ and $B_{12} = 0$ for periods with positive and zero equilibrium prices, respectively.

We report the results of this price convergence model in Table 6. Tobit regression specification is used to account for many periods with zero equilibrium prices and many price observations near zero.[15] From the estimation performed on the data pooled across all treatments and conditions (first column of the table), both the midpoint of trader values range and the previous-period closing price have a significant relationship with the opening price. For markets where the equilibrium price is above zero, the price asymptote is within seven percent, but significantly below, equilibrium. For markets with the equilibrium price at zero, the estimated price asymptote is not significantly different from the equilibrium level

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[15] Trading prices at or below 0.5 experimental dollars are treated as censored. The estimation results are qualitatively the same for any censoring threshold between 0.1 (the lowest actual transaction price) and 1 experimental dollar.

Table 6: Price convergence estimation, tobit regression

	Dependent Variable: Transaction Price		
	All Data	Low $(Q_U - Q_L)$ spread	High $(Q_U - Q_L)$ spread
Midpoint of trader values range – origin	0.677***	0.667***	0.577***
	(0.050)	(0.053)	(0.128)
Previous closing price – origin	0.167***	0.200***	0.063**
	(0.040)	(0.045)	(0.030)
Positive equilibrium price – asymptote	0.937***	0.936***	0.981***
	(0.017)	(0.018)	(0.042)
Zero equilibrium price – asymptote	0.769	11.590***	1.855
	(2.178)	(3.554)	(1.977)
Root mean squared error	33.358***	36.319***	17.363***
	(1.048)	(1.237)	(3.637)
Number of observations	2,772	2,064	708

Notes: The table reports estimates of equation 1, which calibrates how prices evolve within each trading period. The estimated relationship shows how the first transaction price (the origin) relates to (i) the midpoint between lowest opportunity cost and highest marginal willingness to pay and (ii) the previous period closing price, and how well prices tend to converge (the asymptote) toward the equilibrium price. "Zero Equilibrium Price" is an indicator variable that allows for a discontinuity in the asymptote price when the equilibrium price is zero. Robust standard errors clustered on session are in parentheses. */**/*** indicate significance at the 10/5/1 percent levels.

of zero. These results are strikingly similar for both symmetric and asymmetric treatments (see Table 19 in Appendix B).

We next consider whether price convergence may be affected by market characteristics, specifically, by the the size of the equilibrium quantity spread $(Q_U - Q_L)$. Due to the discrete nature of unit values, some buyers' values and sellers' opportunity costs may equal the equilibrium price, leading to flat, overlapping demand and supply at the equilibrium price; see Figure 1. As a higher spread indicates a higher number of marginal trades, we may conjecture that markets with higher $(Q_U - Q_L)$ may exhibit better convergence; on the other hand, since high $(Q_U - Q_L)$ is often associated with zero equilibrium price and low gains from trade, we may also conjecture the opposite effect of the equilibrium quantity spread on the price dynamics.

The second and third columns in Table 6 display price convergence estimations performed separately for markets with "low" (below the mean) and "high" (above the mean) equilibrium quantity spread.[16] The results indicate that price asymptotes are significantly different from the equilibrium price predictions when the equilibrium quantity spread is low, and are not significantly different when the quantity spread is high. This pattern holds for markets with equilibrium prices both above and at zero; thus, prices converge to equilibrium predictions in the markets with high equilibrium quantity spread, but do not fully converge in the markets with low equilibrium quantity spread.[17] This evidence highlights the role of marginal trades and traders in driving price convergence and navigating markets to the competitive equilibrium.[18]

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[16] The mean equilibrium quantity spread was 4.29 units across all 260 markets. Correspondingly, "low" spread is defined as $(Q_U - Q_L) \leq 4$, and "high" spread as $(Q_U - Q_L) \geq 5$.

[17] As high equilibrium quantity spread is often associated with zero equilibrium price and low gains from trade (Pearson's correlation coefficients are $\rho = 0.67$ and $\rho = 0.68$, respectively), we performed additional price convergence estimations for markets with high and low market gains from trade, and markets with zero and above-zero equilibrium price, each time dividing them into low- and high-equilibrium-quantity spread markets. The findings reported above are robust: the prices converge to the competitive equilibrium in market with high $(Q_U - Q_L)$ irrespective of equilibrium price levels and gains from trade available, whereas price asymptotes are significantly different from equilibrium predictions in markets with low $(Q_U - Q_L)$ irrespective of equilibrium price levels. We could not reject the hypothesis of price convergence to equilibrium for markets with low quantity spread and low gains from trade, likely because of a very small number of markets (six out of 260 total) in this category.

[18] While the role of marginal traders in providing competitive pressures and driving price convergence is commonly accepted, there are not many studies that quantify the effect of the number of marginal trades on market outcomes. Smith (1965) varies the number of excess sellers in markets with extreme rent asymmetries, and documents that "competitive equilibrating tendencies... are weakest when excess supply is small, strongest when excess supply is large" (p. 393). Gode and Sunder (1997) explore analytically the effect of the number of extra-marginal traders and the surplus lost due to a trade with an extra-marginal seller on market efficiency. Makowski and Ostroy (1987) show theoretically that perfect competition can be identified with market "non-manipulability," i.e., the condition that no individual trader is able to change the Walrasian equilibrium price; Friedman and Ostroy (1995) further points out that in experimental laboratory markets with single-unit individual demand and supply, non-manipulability implies a horizontal overlap of supply and demand curves. Charles Plott (personal communication, 2020) summarizes the effect of marginal units as follows: "Typically (many) marginal units ... on the interior of the [price] tunnel and also many marginal units excluded ... will cut down the [price] variance. It will also support high efficiencies since the high surplus units will get traded and those that are not the surplus-starved marginal units." Our data are consistent with Plott's explanation: simple regression analysis indicates that a higher equilibrium quantity spread leads to significantly lower price variance ($p < 0.05$) and significantly lower deviation from the competitive

Observation 2 *Opening transaction prices are influenced significantly by both the previous period closing price, and the range of trader values in the current period. Prices converge close to the equilibrium prediction in the course of trading within each market period in both symmetric and asymmetric endowment treatments, and overall. A larger number of marginal trades, as measured by the equilibrium quantity spread, is associated with improved price convergence irrespective of equilibrium price levels.*

Trading volume How does transaction volume compare to the equilibrium predictions (lower and upper bounds)? Are markets with insufficient or excessive trading volume display lower efficiency and higher price variability than those with trading volume withing the equilibrium bounds? Note that the lower bound, Q_L, is the number of trades necessary to fully realize a given market's gains from trade and Q_U is the largest number of transactions that includes additional number of rational, zero-gain transactions that are consistent with the equilibrium. While these additional, zero-gain, marginal transactions are not surplus-generating under the equilibrium theory, we found that, empirically, their number $(Q_U - Q_L)$ is positively associated with market efficiency and improved price convergence, as documented in Observations 1-2 above.

Summary statistics reported in Table 4 indicate that actual transaction volume is closer to the upper bound of equilibrium quantity Q_U than to the lower bound Q_L: the trade volume ratio to Q_U varies between 0.88 and 1.43 per treatment, whereas the ratio to Q_L is between 1.95 and 3.11 per treatment (with the maximum ratio of 4.67 reached is Session 2). Regression analyses, reported in Table 7, show that while Q_U is a stronger predictor of units traded than Q_L (R^2 of 0.163 vs. 0.048), the average is considerably better than either Q_L or Q_U (R^2 of 0.235). Conditional on $(Q_L + Q_U)/2$, other characteristics have little predictive power. The slope with respect to average quantity is slightly above one, while the intercept is nearly three. The implied excess trading is clear in Figure 2. Regression results in column (5) of Table 7 further indicate that very low market-level potential gains from trade (less than 100 experimental dollars) or a zero equilibrium price may also influence trading volume, adding to the evidence that market performance may differ markedly depending on its underlying characteristics; these two indicator variables, however, are strongly correlated ($\rho = 0.72$), preventing us from drawing inferences about the influence of these characteristics on trading volume. The results suggest that people may continue to trade after all gains from trade have been realized, and often after all marginal trades have been executed as well.

Are markets with trading volumes within the equilibrium quantity range exhibit superior outcomes to those with insufficient or excessive trading volumes? Table 8 displays market performance averages for markets grouped by trading volume: markets with the number of trades below or at the equilibrium lower bound Q_L, within the equilibrium bounds $[Q_L, Q_U]$, and above the equilibrium upper bound Q_U. In addition, the table lists efficiency gains and absolute price deviations from equilibrium by trading stage (for trade orders up to Q_L, between Q_L and Q_U, and above Q_U). Given a large variety of market underlying characteristics, we further sort the markets into types by potential gains from trade ('Low' if GFT$\leq$ 100 or 'Normal' otherwise), and by equilibrium price level (at or above zero). To

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equilibrium price ($p < 0.001$).

Table 7: Units traded in comparison to theoretical equilibrium.

	Dependent variable: Units Traded				
	(1)	(2)	(3)	(4)	(5)
Predicted Q_L	0.449***		0.556***		
	(0.194)		(0.161)		
Predicted Q_U		0.532***	0.574***		
		(0.167)	(0.164)		
$\frac{Q_L+Q_U}{2}$				1.139***	1.167*
				(0.250)	(0.481)
Zero Eqm. Price					2.104*
					(0.985)
Eqm. Price					-0.001
					(0.008)
Low GFT					-2.531**
					(1.362)
Potential GFT					-0.0004
					(0.003)
Period					-0.0005
					(0.071)
Constant	9.095***	6.352***	2.847*	2.820	2.715
	(1.706)	(1.330)	(1.670)	(1.643)	(2.501)
No. of observations	260	260	260	260	260
R-squared	0.048	0.163	0.235	0.235	0.255
Adjusted R-squared	0.044	0.159	0.229	0.232	0.238

Notes: The table reports regressions of units traded in each period against predicted volume and other characteristics. Predicted Q_L is the lowest number of trades needed to achieve equilibrium and full efficiency. Predicted Q_U is the highest number of trades with full efficiency, which can be much larger than Q_L. The average of Q_L and Q_U predicts actual units traded about as well as possible. Other independent variables considered are: an indicator variable for zero equilibrium price; equilibrium price; an indicator for low potential gains from trade (<100); potential gains from trade; and the chronological period number in the session. A plot of the regression in column (4) is shown in figure 2. Robust standard errors, with clusters by session, are reported in parentheses. Indicated significance levels: *p<0.1; **p<0.05; ***p<0.01. Results are broadly similar with session and yield-sequence fixed effects, except Q_L loses statistical significance.

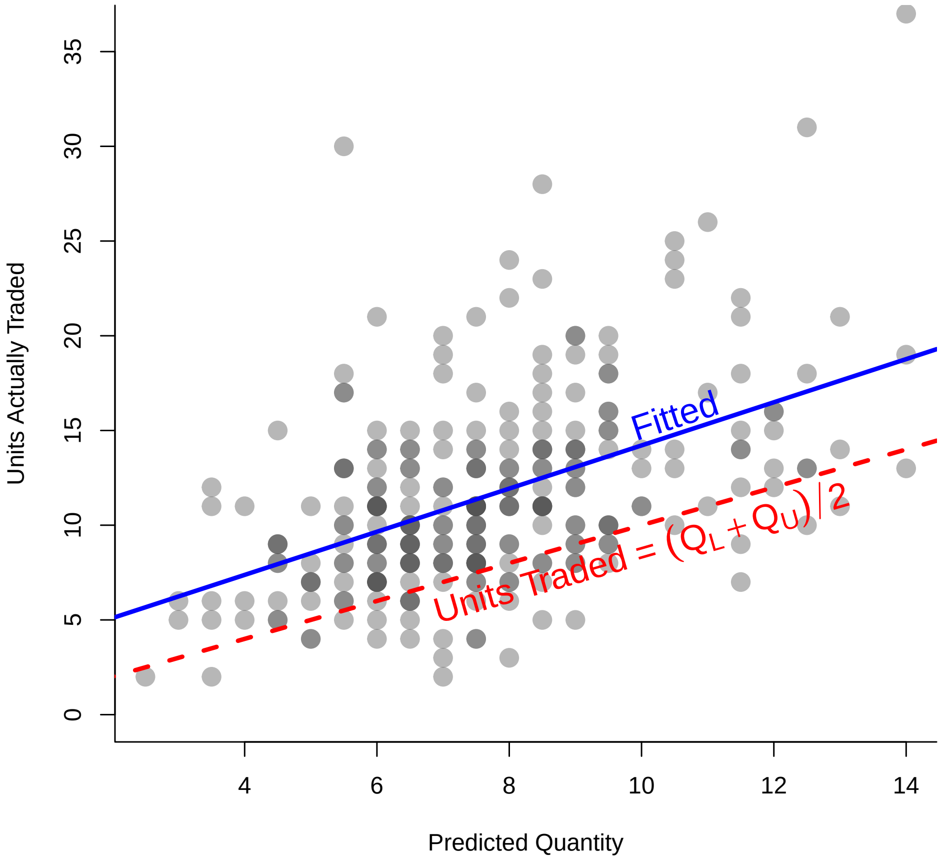

Figure 2: Units traded in relation to predicted quantity $(Q_L + Q_U)/2$.

highlight stark differences between these market types, the leftmost column of the table lists the average equilibrium gains from trade, prices, and bounds on equilibrium trading volumes for each market type.

From Table 8, we first confirm that very few markets have trading volumes at or below the equilibrium lower bound; these markets are characterized by lower efficiency and higher absolute price deviations from equilibrium than markets with trading volumes above Q_L. Most interestingly, there is a qualitative difference in the performance by trading volume between markets with low and normal gains from trade. The majority of markets of 'Low GFT, Zero Price' type have trading volumes within the equilibrium bounds, and only one-third of such markets (14 out of 44) exhibit excessive trading above Q_U. This is likely due to a large range of quantities consistent with equilibrium for this market type, with $[Q_L, Q_U] = [1.8, 15.0]$ on average, allowing for extensive zero-gain within-equilibrium trading. Further, notably, there is clear evidence that excessive trading is associated with efficiency losses for these 'Low GFT, Zero Price' markets: While the markets with trading volumes within the equilibrium bounds display increasing efficiency and prices closer to equilibrium across trading stages (with the average efficiency of 77.38 percent at market closing), the 14 markets with trading volume above Q_U display, on average, a reduction of trading surplus and overall negative market efficiency of -8.33 percent, indicating that excessive trading in such markets is associated with many speculative efficiency-reducing trades.

The picture is quite different for markets with substantial gains from trade available ('Normal GFT' type markets). The trading volume exceeds the equilibrium upper bound in the overwhelming majority (146 out of 214, or two-thirds) of these markets, possibly due to much narrower equilibrium trading volume range: $[Q_L, Q_U] = [6.0, 9.7]$ for 'Normal GFT, Zero Price' markets and $[Q_L, Q_U] = [6.4, 8.7]$ for 'Normal GFT, Positive Price' markets. These markets display steady increases in market efficiencies, and trading prices closer to equilibrium, across all trading stages, including transactions performed after the trading volume reaches Q_U. Thus, efficiency is the lowest (67.78% on average) and price deviation from equilibrium is the highest ($34.58 on average) in markets with trading volume no higher than Q_L; efficiency increases to 72.29% and price deviation is $33.52 on average for the markets with trading volume within $[Q_L, Q_U]$; and efficiency is the highest, (85.52%) and price deviation is the lowest ($25.12) in markets with trading volume above Q_U. The table also documents that on average, efficiency increases and price deviation decreases in each trading stage in these types of markets.[19]

This evidence suggests that in the presence of re-trading opportunities, very low gains from trade available in the market may lead to efficiency-reducing, likely speculative excessive trading, much like what has been observed in asset market experiments (Smith et al., 1988; Lei et al., 2001). In contrast, in markets with substantial gains from trade but highly variable market conditions, trading volume above the equilibrium prediction is associated with higher efficiency and prices closer to equilibrium. Excessive trading in the latter markets may be indicative of traders correcting trading errors, thus allowing to realize remaining gains from trade and navigating markets closer to equilibrium; speculative trading, if or when present,

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[19] Simple regression analyses confirm that efficiency is significantly negatively associated with trading volume above Q_U for markets with low GFT ($p < 0.05$), and is significantly positively associated with trading volume above Q_U for markets with normal GFT ($p < 0.05$).

Table 8: Market performance averages by market type, trading volume and trading stage

			Market Category by Trading Volume							
		Volume	Below or at	Withing Eqm Bounds			Above Eqm Upper Bound			
				Trading stage			Trading stage			
Market Type		All markets	Eqm Q_L	below Q_L	between Q_L, Q_U	All trades	below Q_L	between Q_L, Q_U	above Q_U	All trades
Low GFT, Zero Price										
	efficiency, %	50.00	100.00	60.12	16.67	77.38	17.86	-78.57	52.38	-8.33
$GFT^{av} = 45.5$	abs. price deviation, $	5.39	17.5	11.51	2.37	4.42	11.12	7.59	4.2	6.84
$Eq.price^{av} = 0$	number of trades	12.07	2	1.71	8.24	9.96	2.14	9.93	5.21	17.29
$[Q_L, Q_U] = [1.8, 15.0]$	share of re-trades	0.33	0			0.29				0.43
	number of markets	44	1			29				14
Normal GFT, Zero Price										
	efficiency, %	70.74	44.44	53.37	4.76	58.13	62.61	10.57	3.91	77.10
$GFT^{av} = 254.3$	abs. price deviation, $	19.04	13.33	23.03	19.92	21.89	22.43	18.29	14.08	18.19
$Eq.price^{av} = 0$	number of trades	13.86	6	5.63	3		6.05	3.7	6.6	
$[Q_L, Q_U] = [6.0, 9.7]$	share of re-trades	0.46	0.17			0.31				0.54
	number of markets	29	1			8				20
Normal GFT, Positive Price										
	efficiency, %	80.79	67.78	66.95	5.33	72.29	64.24	13.67	9.56	85.52
$GFT^{av} = 616.7$	abs. price deviation, $	27.92	34.58	37.84	26.2	33.52	35.12	20.51	12.52	25.12
$Eq.price^{av} = 98.9$	number of trades	11.19	6.19	5.95	2.13	8.08	6.45	2.64	4.25	12.97
$[Q_L, Q_U] = [6.4, 8.7]$	share of re-trades	0.37	0.17			0.27				0.43
	number of markets	185	21			38				126

Market type is by equilibrium GFT and price. $GFT \leq 100$ is classified as 'Low'. Two market with low GFT and positive equilibrium price are excluded. Trading stage 'Below Equilibrium Quantity' includes trades up to Q_L inclusive. Trade stage efficiency is calculated as efficiency gain, i.e., gains from trade realized within the stage divided by market potential GFT. For markets with an equilibrium price band, the absolute price deviation from equilibrium is calculated from the closest equilibrium price bound. Market share of re-trades is based on aggregating individual trading statistics to be discussed in Section 4.3.

appears to not obstruct equilibrium convergence for these markets.

Observation 3 *Trading volume is significantly above the minimal level required to fully realize gains from trade, and is often above the maximal number of predicted trades in both symmetric and asymmetric yield sessions. In markets with very low gains from trade and zero price, the excess of trades relative to equilibrium is less common but is associated with reduced and often negative efficiency. In contrast, in markets with normal gains from trade, excessive trading occurs in most markets, and is associated with higher efficiency and prices closer to equilibrium.*

Below we consider transaction- and individual-level results, which will provide insights about the mechanisms behind this excessive trading.

4.2 Transaction analysis

Transaction order Do trades with higher potential gains take place earlier?

This question pertains to the dynamics of price discovery and market convergence, and may also shed light on whether low-gain (and possibly speculative) excessive trading tends to occur in earlier or later transactions within a period. Regression analyses of the dependence of trade order on the transaction surplus, i.e., buyer-seller total gain from trade, presented in Table 9, indicate a strongly significant negative relationship ($p < 0.001$), with the coefficient of 0.023. This coefficient implies than an increase in gains from trade by around 44 experimental dollars is associated with one earlier transaction. To put this number into perspective, the individual value schedule has a step of -50 for each unit between 1 and 6, and is zero for additional units. Note that multiple traders in the market likely have the same marginal unit value. This relationship suggests a "Marshallian path" (Plott et al., 2013), i.e., that highest-value net buyers tend to trade with the lowest-value net sellers first, and the transaction order follows, overall, the differences in values between net buyers and sellers.[20] The regression results are robust to controlling for individual buyer and seller fixed effects (regressions (2) and (4)), and for using buyer and seller predicted earnings (the differences between buyer value and the equilibrium price, and between the equilibrium price and seller opportunity cost, respectively), instead of transaction surplus, as two independent variables (regressions (3)-(4)). On average, 71% of all realized market gains from trade in the symmetric sessions, and 80% in the asymmetric sessions, were obtained in the first half of period transactions.

Observation 4 *Market transaction order is consistent with the Marshallian price-discovery dynamics: transactions with higher gains from trade take place earlier in the period.*

Positive, Negative, and Zero-Sum Trades If many more trades occur than the number needed to fully realize gains from trade, what are these trades like? How often do negative- and zero-sum transactions occur, and who gains and loses from such transactions?

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[20] "The Marshallian path ... suggests that market adjustment follows the path of the most rapid wealth creation. Wealth creation is through realized gains from trade and the Marshallian path has those that represent the greatest gains trading first" (Plott et al., 2013).

Table 9: Effect of transaction surplus on trade order, linear regression

	Dependent variable: Trade Order			
	(1)	(2)	(3)	(4)
transaction surplus	-0.023***	-0.023***		
	(0.002)	(0.003)		
seller predicted earning			-0.020***	-0.020***
			(0.003)	(0.004)
buyer predicted earning			-0.026***	-0.027***
			(0.003)	(0.002)
constant	8.198***	7.699***	8.363***	7.872***
	(0.153)	(0.156)	(0.294)	(0.142)
Yield and session fixed effects	Y	Y	Y	Y
Seller and buyer fixed effects	N	Y	N	Y
Number of of observations	3,012	3,012	3,012	3,012
R-squared	0.228	0.374	0.229	0.376

Standard errors clustered on session. */**/*** indicate significance at the 10/5/1 percent level.

In Table 10 we report the frequencies of each type of transaction and the average gains and losses across buyers and sellers in each case. A number of interesting patterns emerge.

First, out of all transactions (3,012), joint buyer-seller gains are positive in just over a half, or 55.4% (1,668). Such an unusually low (under 60%) share of positive-surplus trades persists in both symmetric and asymmetric treatments, in later periods 11-20 and with experience in the symmetric sessions. The one exception is the experienced asymmetric yields session, where the share of positive-surplus transactions is 68.6%.

Second, there is a notably large share (32.7%) of transactions where joint buyer-seller gains from trade were exactly zero, i.e., the surplus was transferred from one side to the other (in 30.4%, or 917 transactions), or neither party gained or lost (in 2.3%, or 69 transactions); the share was about the same in symmetric and asymmetric sessions. The average seller-buyer gain-loss is only 3.46 experimental dollars in these zero-sum transactions. Such transactions could be errors; or, they could be driven by marginal traders attempting to squeeze any remaining gains out of the markets; finally, they could be also driven by boredom or attempts at speculation by any trader, especially when the remaining gains from trade are low. Below we consider whether the incidence of such transactions is affected by the remaining gains from trade in the market.

Finally, there is a sizeable share of transactions, 11.9% (or 358), where the total gains from trade are negative. These transactions are likely attributable to participant errors, as their frequency declines in later periods and with experienced subjects.

Observation 5 *Just over a half of all trades in both symmetric and asymmetric sessions are efficiency-improving. A sizeable share (about one-third) of transactions across all treatments*

Table 10: Transaction surplus, by treatment

		Transaction surplus			
Treatment	Variable	Positive	Zero	Negative	Total
All	seller gain, $	24.89	3.46	-47.21	9.43
	buyer gain, $	47.83	-3.46	-16.64	23.38
	frequency, %	55.38	32.74	11.89	100
	Number of obs.	1,668	986	358	3,012
Symmetric, no experience periods 1-10	seller gain, $	22.16	4.36	-47.17	6.37
	buyer gain, $	49.32	-4.36	-14.56	22.86
	frequency, %	53.49	31.93	14.58	100
	Number of obs.	774	462	211	1,447
Symmetric, no experience periods 11-20	seller gain, $	29.47	2.93	-43.41	14.64
	buyer gain, $	45.46	-2.93	-21.59	23.45
	frequency, %	57.46	34.92	7.63	100
	Number of obs.	339	206	45	590
Symmetric, experienced periods 1-10	seller gain, $	32.28	-2.57	-10	12.71
	buyer gain, $	34.13	2.57	-40	15.41
	frequency, %	44.44	52.78	2.78	100
	Number of obs.	32	38	2	72
Asymmetric, no experience periods 1-10	seller gain, $	24.43	3.36	-50.07	8.97
	buyer gain, $	49.24	-3.36	-15.62	24.92
	frequency, %	56.52	31.7	11.78	100
	Number of obs.	451	253	94	798
Asymmetric, experienced periods 1-10	seller gain, $	32.35	1.44	14.83	23.4
	buyer gain, $	40.22	-1.44	-60.67	23.74
	frequency, %	68.57	25.71	5.71	100
	Number of obs.	72	27	6	105

*Seller and buyer gains are in experimental dollars, averaged for each transaction surplus category *yield zero gains from trade. A minority of trades (about 12%) are efficiency-decreasing, but these occur less often in later periods and with experienced participants.*

Determinants of efficiency-enhancing trade We next explore factors associated with the probability of efficiency-enhancing (positive-gain), efficiency-neutral (zero-gain), and efficiency-reducing (negative-gain) transactions. Results from a multinomial logit, reported in Table 11, show that trades with negative gains are likely mistakes; they occur less often in later periods, with experienced subjects and under asymmetric yields. They happen more often if the lower bound of the equilibrium quantity Q_L is low, when remaining gains from trade are lower (although this effect is small), and in later transactions within periods.

In comparison, trades with zero gain are less likely to be errors, as they persist with similar frequency through later periods, and under both symmetric and asymmetric yields. They occur more often in later transactions within each period and when remaining gains from trade are low, again providing evidence in support of the Marshallian dynamics. Consistent with the valuation schedule and with the equilibrium theory predictions, zero-gain trades occur more often when the equilibrium price is zero and when the spread between upper and lower equilibrium quantities, $(Q_U - Q_L)$, is large, suggesting that the are likely carried out by marginal traders.

Observation 6 *Efficiency-improving trades take place earlier within a period, as compared to zero-gain and negative-gain trades. Zero- and negative-surplus transactions tend to occur in periods with low equilibrium quantity, and when the remaining gains from trade are low. Zero-gain trades are more likely to take place when they are consistent with the equilibrium prediction. Yield asymmetry is associated with fewer negative-surplus trades.*

The results suggest that people are willing trade for small or zero gains when larger gains are exhausted, possibly in an attempt to squeeze out any remaining gains out of the market, or driven by speculation motive, or out of boredom, leading to excessive trading, as documented above. These attempts to squeeze out the remaining gains are generally successful when there are substantial unrealized gains from trade left, although fewer trades are efficiency-enhancing and some may reduce efficiency, especially when the remaining gains from trade are low. Interestingly, asymmetry significantly reduces the frequency of negative-gain trades, but not zero-gain trades; i.e., people who specialize are less likely to make errors, but they still engage in zero-sum trading.

4.3 Trader behavior

Here we consider patterns of individual behavior and differences between buyer and seller sides of the market. As trader roles are flexible and any trader can both buy and sell, we will use "buyers" and "sellers" to refer to roles in transactions that traders actually make. We will refer to *predicted* roles as "predicted buyers," "predicted sellers," and "predicted no-traders," depending on how individual trader yields relate to the market average (discussed in more detail below). We further consider how individual behavior depends on trader's predicted gains from trade as well as other factors.

Table 11: Determinants of probability of gainful trade, logit estimation

	Dependent variable: Transaction surplus			
	(1)		(2)	
Negative surplus				
asymmetric yields	-0.34**	(0.16)		
experience	-1.13***	(0.22)		
remaining GFT	-0.00***	(0.00)	-0.00***	(0.00)
equilibrium price	0.00	(0.00)	0.00	(0.00)
zero equilibrium price	-0.17	(0.17)	-0.19	(0.18)
lower eqm quantity Q_L	-0.13***	(0.04)	-0.10***	(0.04)
high-low eqm quantity spread $(Q_H - Q_L)$	-0.01	(0.01)	-0.00	(0.01)
trade order	0.11***	(0.02)	0.11***	(0.02)
period	-0.16***	(0.04)	-0.17***	(0.04)
period squared	0.01***	(0.00)	0.01***	(0.00)
constant	0.00	(0.43)	-0.19	(0.45)
Zero surplus				
asymmetric yields	0.03	(0.08)	0.10	(0.10)
experience	-0.42***	(0.14)	-0.68***	(0.15)
remaining GFT	-0.00***	(0.00)	-0.00***	(0.00)
equilibrium price	-0.00	(0.00)	-0.00	(0.00)
zero equilibrium price	0.40***	(0.12)	0.39***	(0.13)
lower eqm quantity Q_L	-0.08**	(0.04)	-0.07	(0.04)
high-low eqm quantity spread $(Q_H - Q_L)$	0.06***	(0.01)	0.07***	(0.01)
trade order	0.08***	(0.03)	0.08***	(0.03)
period	0.00	(0.04)	0.00	(0.04)
period squared	-0.00	(0.00)	-0.00	(0.00)
constant	-0.23	(0.26)	-0.08	(0.31)
Positive surplus	(base outcome)		(base outcome)	
Yield sequence fixed effects	Y		Y	
Session fixed effects	N		Y	
Number of observations	3012		3012	
Pseudo R-squared	0.1787		0.1836	

Standard errors clustered on session. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 12: Frequency of individuals trading towards the equilibrium, by treatment

Treatment	Time interval		Strong trade to eqm			Weak trade to eqm		
			Buy	Sell	All	Buy	Sell	All
Total		frequency	0.44	0.62	0.53	0.89	0.86	0.88
		total no of obs.	3012	3012	6024	3012	3012	6024
Symmetric, no experience	periods 1-10	frequency	0.42	0.58	0.5	0.88	0.85	0.86
		total no of obs.	1447	1447	2894	1447	1447	2894
Symmetric, no experience	periods 11-20	frequency	0.45	0.62	0.54	0.92	0.89	0.9
		total no of obs.	590	590	1180	590	590	1180
Symmetric, experienced	periods 1-10	frequency	0.32	0.5	0.41	0.96	0.99	0.97
		total no of obs.	72	72	144	72	72	144
Asymmetric, no experience	periods 1-10	frequency	0.46	0.64	0.55	0.88	0.85	0.86
		total no of obs.	798	798	1596	798	798	1596
Asymmetric, experienced	periods 1-10	frequency	0.48	0.97	0.72	0.9	0.95	0.92
		total no of obs.	105	105	210	105	105	210

Trading towards equilibrium and buyer and seller earnings by transaction How often do traders buy or sell in the direction predicted by equilibrium? How often do they profit and lose? Are these characteristics the same for buyers and sellers?

Table 12 displays how often individual traders trade "strongly" towards the equilibrium (buy when their quantity is strictly below the equilibrium prediction, and sell when it is strictly above); and trade "weakly" towards, i.e., not counter the equilibrium prediction (do not sell when their quantity is below the lower bound allowed in equilibrium and do not buy when their quantity is above the upper bound). Traders trade strongly towards the equilibrium only 53% of the times, but they trade weakly towards the equilibrium 88% of the times; these numbers closely match the frequencies of positive surplus trades (55%), and non-negative (positive and zero) surplus trades (88%), as given earlier in Table 10. One observation is a striking difference between buying and selling: buyers trade strongly toward equilibrium in only 44% of trades while sellers trade strongly toward equilibrium in 62% of trades. The data show that this difference persists in treatments with both symmetric and asymmetric yield assignments, i.e., irrespective of whether or not each trader tends to maintain the same predicted buyer or predicted sellers role across periods. The difference between buying and selling is statistically significant: a multinomial logit regression estimating the probability a trader trades towards equilibrium, shown in Table 13, confirms that buyers are significantly less likely than sellers to trade towards the equilibrium. Indeed, buyers make positive profits in 60.86% of trades, and lose in 35.09% of their trades, while sellers profit in

79.35% trades and lose in 16.47% of trades.

This pattern may arise due to the nonlinear valuation schedule (refer back to Table 1) which tends to benefit the buyer side of the market: the average per-transaction buyer earnings are 23.38 experimental dollars, while the average seller earnings are only 9.43 experimental dollars (Table 10). Further, buyers lose less in losing transactions than sellers do (a loss of 16.64 experimental dollars for buyers and 47.21 for sellers). At the same time, buyers gain much more in profitable transactions than sellers (an average gain of 47.83 for buyers and 24.89 for sellers). Perhaps sellers behave more cautiously since they have lower potential gains, and thereby trade at a loss less frequently than buyers, whereas buyers, having more ample potential gains from trade, may be lulled into a complacency that leads to error and lower than possible gains. Apparent losses may also result from speculation: buying (or selling) at a loss followed by selling (or buying) with a gain. We will evaluate trader gains from re-trading and possible speculation below.

A multinomial logit estimating the odds of trader gain and loss, also displayed in Table 13, indicates that these odds are similarly associated with characteristics that predict gainful trade and trade toward equilibrium (compare Table 13 and Table 11). We find that experience reduces the odds of trader loss and trading against equilibrium; traders in asymmetric treatment are also less likely to make a loss. Further, trader loss and trading against equilibrium occur more often in later transactions within a period, and, not surprisingly, the odds of trading against equilibrium and of trader loss increase as prices deviate from equilibrium prices.

Observation 7 *Just over a half of individual trading decisions are strong trades towards the equilibrium, but almost 90% of decisions are weakly consistent with equilibrium prediction. Traders in the asymmetric yield treatment are less likely to trade with a loss than traders in the symmetric yield treatment. Traders are more likely to trade strongly towards equilibrium and less likely to trade at a loss when selling, then when buying. However, on average, traders gain more when buying than when selling.*

Individual period-level trading and earnings from net trade and re-trade A trader who buys or sells at a loss in one transaction may do so strategically in the hope of gaining from a subsequent re-trade at a different price (i.e., speculation). Alternatively, the loss may be an error ameliorated with a subsequent re-trade. Here we consider how re-trading affects earnings in comparison to earnings from net trading, i.e., from net changes in quantity.

To begin investigating these issues, we calculated individual period-level earnings, the share of traders who traded ("active traders"), number of trades, and amount of re-trading, and grouped them by each predicted trader role: predicted buyer, predicted seller, or no-trader. We classify a trader as predicted strong buyer (respectively, strong seller) if their individual yield is at least one unit below (respectively, above) the average market yield, implying that they have to trade to get to equilibrium. We classify a trader as predicted weak buyer (seller) if their individual yield is below (above), but within one unit of, the average market yield; some but not all weak buyers (sellers) may have to buy (sell) a unit in the market to reach an equilibrium allocation.[21] Finally, a predicted no-trader is someone

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[21] Weak traders are present in the market if the average market yield falls on a non-integer number; see

Table 13: Determinants of probability of trade towards equilibrium and trader gain, logit estimation

Dependent variable:	*Direction of Trade*		*Trader Gain*	
	Against Equilibrium		Negative gain	
asymmetric yields	-0.24	(0.17)	-0.20**	(0.08)
experience	-0.93***	(0.24)	-0.40***	(0.08)
buying	1.45***	(0.21)	1.12***	(0.16)
potential market GFT per trader	-0.01***	(0.00)	-0.01***	(0.00)
zero equilibrium price	-0.99***	(0.33)	0.24*	(0.13)
absolute price deviation from eqm	0.02***	(0.00)	0.01***	(0.00)
trade order	0.12***	(0.01)	0.08***	(0.02)
period	-0.14***	(0.04)	-0.03*	(0.02)
period squared	0.00*	(0.00)	0.00	(0.00)
constant	-2.49***	(0.36)	-1.64***	(0.22)
	Within Eqm Bounds		Zero gain	
asymmetric yields	-0.07	(0.07)	0.66	(0.44)
experience	-0.22	(0.14)	0.47	(0.56)
buying	0.88***	(0.18)	0.23**	(0.09)
potential market GFT per trader	-0.01***	(0.00)	-0.00	(0.00)
zero equilibrium price	2.04***	(0.10)	-1.43***	(0.33)
absolute price deviation from eqm	-0.00	(0.00)	-0.01*	(0.01)
trade order	0.08***	(0.02)	0.09***	(0.03)
period	0.10**	(0.04)	-0.01	(0.09)
period squared	-0.01**	(0.00)	0.00	(0.00)
constant	-1.53***	(0.22)	-3.11***	(0.60)
(base outcome)	Towards equilibrium		Positive gain	
Yield fixed effects	Y		Y	
Number of observations	6024		6024	
Pseudo R-squared	0.2554		0.1056	

Standard errors clustered on session. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

whose individual yield is exactly equal to the average market yield, i.e., it is already at equilibrium. This implies, in particular, that weak and no-traders' predicted equilibrium earnings are always zero, i.e., all weak traders are marginal.

Summary statistics on individual period-level trading and earnings are shown in Table 14. We find that 92 percent of predicted strong buyers and 95 percent of predicted strong sellers participated in trading, but 79 percent of predicted weak traders and 67 percent of predicted no-traders were active as well. Realized earnings of both strong buyers and strong sellers are below equilibrium levels (by an average of 9.58 and 23.93 experimental dollars, respectively), whereas predicted weak and no-traders earn, on average, small but positive amounts (the mean of 7.94 experimental dollars across these categories), exceeding the equilibrium prediction of zero. Notable also is a huge variance of earning deviations from equilibrium for all trader positions.

One reason why strong buyers' or sellers' earnings may fall short of equilibrium is allocative inefficiency: traders holding too few or too many goods, compared to equilibrium, at the end of trading. Table 14 reports that on average, predicted strong (respectively, weak) buyers held 0.37 (respectively, 0.14) too few units, whereas predicted strong (respectively, weak) sellers held 0.42 (respectively, 0.07) too many units, compared to equilibrium, indicating some net under-trading on both sides of the market; however, this deviation is small on average. The absolute deviation of end-of-trade unit holdings, which accounts for both under-trading and over-trading, is 0.79 units on average for both strong buyers and strong sellers, and 0.4 units for predicted no-traders, suggesting that there was some net over-trading as well, and that some inefficiency is due to reallocation of goods to predicted no-traders.[22]

Another source of earnings loss for strong buyers and sellers could involve redistribution of earnings between traders through re-trading (buying then selling, or vice-versa). Even without changes to final allocations, re-trading could be profitable for some, but loss-generating for others. To measure re-trading activity, we calculate the number of re-trades for an active trader as the difference between their total number of trades and the net number of trades, where the latter is the difference between the number of units they hold at the end and the beginning of period.[23] We find that 60 percent of trades by predicted no-traders and 47 (51) percent of trades by predicted weak buyers (sellers) are re-trades, far more than the 21 and 22 percent re-trades by predicted strong buyers and sellers. In Figure 3 we illustrate the distribution of re-trading frequencies by predicted trader roles, conditional on trading. For the overwhelming majority of predicted strong buyers and sellers, the share of re-trades in all trades is less than 50%; in fact, conditional on trading, 68 (66) percent of predicted strong buyers (sellers) do not re-trade at all. In contrast, for more than half (54 percent) of

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Table 2 for illustration.

[22] Cason and Friedman (1996) distinguish market-level efficiency losses due to trades of extra-marginal units ("EM-inefficiency"), and losses due to profitable trades that do not occur (low volume, or "V-inefficiency"). EM-inefficiency stems from individual traders making too many net trades, and V-inefficiency stems from individual traders making too few net trades compared to equilibrium. Our results imply the presence of both types of inefficiencies, with net under-trading (V-inefficiency) prevailing on average.

[23] Let n_b and n_s be the number of trader's buy and sell transactions, with the total number of trades being $n_{all} = n_b + n_s$. Then the number of net transactions is $n_{net} = \max\{n_b, n_s\} - \min\{n_b, n_s\}$, and the number of re-trade transactions is $n_r = n_{all} - n_{net} = 2 \times \min\{n_b, n_s\}$. See Appendix C for details.

Table 14: Individual trading and earnings by trader-period

Predicted		Earnings, dollar*		Active	Num-	End-of-trade		Re-trade
Role		Actual	Dev. from	traders, share	ber of	units holding, Dev. from eqm		share if
			eqm		trades	mean	abs.	traded
Strong Buyer	mean	64.4	-9.58	0.92	2.31	-0.37	0.79	0.21
	sd	98.15	91.2	0.27	1.84	1.26	1.05	0.32
	No of obs.	940	940	940	940	940	940	865
Weak Buyer	mean	9.67	9.67	0.79	1.83	-0.14	0.61	0.47
	sd	66.26	66.26	0.41	1.94	0.8	0.53	0.45
	No of obs.	391	391	391	391	391	391	308
No-Trader	mean	3.95	3.95	0.67	1.74	-0.12	0.4	0.6
	sd	34.21	34.21	0.48	2.16	0.71	0.59	0.46
	No of obs.	57	57	57	57	57	57	38
Weak Seller	mean	6.55	6.55	0.79	2.01	0.07	0.71	0.51
	sd	42.23	42.23	0.41	1.78	1.09	0.83	0.44
	No of obs.	324	324	324	324	324	324	255
Strong Seller	mean	34.96	-23.93	0.95	2.59	0.42	0.79	0.22
	sd	58.98	67.81	0.23	1.84	1.19	0.98	0.32
	No of obs.	919	919	919	919	919	919	869
All	mean	37.55	-9.45	0.89	2.29	0	0.75	0.29
	sd	77.89	75.05	0.32	1.88	1.19	0.93	0.38
	No of obs.	2631	2631	2631	2631	2631	2631	2335

* Earnings are in experimental dollars. Strong buyers and sellers falling short of equilibrium earnings, along with weak and no-traders' positive earnings, indicate redistribution of earnings from strong traders to weak and no-traders. Unit holdings are in number of units. Negative mean deviation from equilibrium holdings for predicted buyers and positive mean deviation for predicted sellers indicate net under-trading by both sides of the market. Higher absolute deviations imply occurrences of both under- and over- holdings.

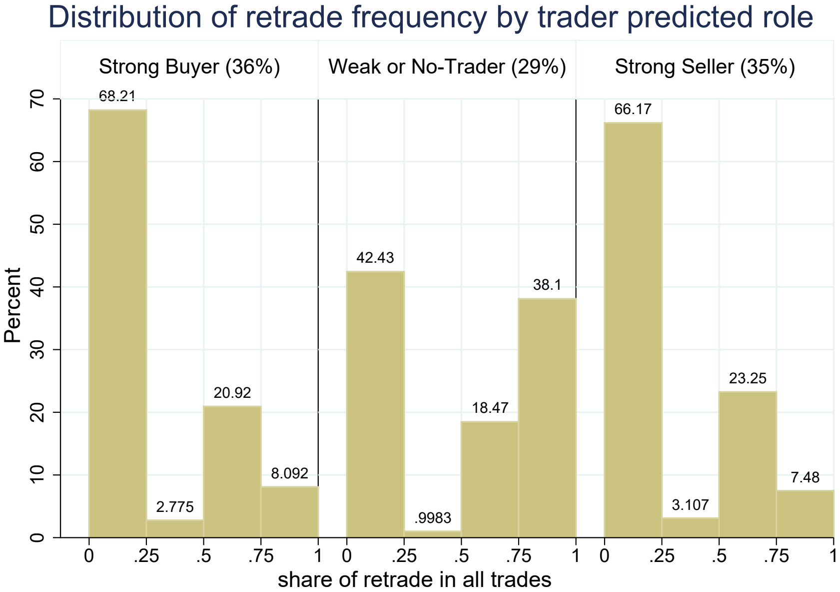

Figure 3: Percent re-trade by trader role

predicted weak and no-traders, the share of re-trades in all trades is 50% or higher.

Because weak traders and no-traders are predicted to earn zero in equilibrium, we conjecture that individual re-trading may be increased by the lack of real potential gains from trade, thus channeling their activity towards speculation. Figure 4 displays the distribution of re-trading frequency of all traders grouped by their equilibrium gains from trade (i.e., predicted earnings). Predicted gains from trade were zero in 41% of individual trader-period observations, medium (between 12.5 and 50 experimental dollars) in 38% of observations, and high (75 experimental dollars or higher) in 21% of observations, with the overall average per period predicted earning of 47 experimental dollars.[24] Indeed, we observe that the overwhelming majority of high-share re-trading is done by traders with zero predicted earnings; regression analysis of re-trading share on individual predicted earnings documents a highly significant negative association ($p < 0.001$). These results do not differ significantly between symmetric and asymmetric treatments.

We further decompose individual trader period earnings into earnings from net trade and re-trade, based on the difference between each trader's average selling and buying prices within a period, and the number of net trades and re-trades, as explained in the footnote to Table 15.[25] As documented in the table, high predicted earners (with equilibrium earnings of 75 or more) under-earn the most compared to the equilibrium prediction, while medium predicted earners earn within one experimental dollar from the prediction, and zero predicted earners gain actually more than they would in equilibrium, albeit slightly. Regarding re-trade earnings, they average overall at 4.14 with a standard deviation of 33.60 experimental dollars. Conditional on engaging in re-trading activity, re-trade earnings are higher but even more

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[24] Because of occurrences of markets with zero equilibrium prices, the predicted gains from trade were zero for 7% of predicted strong buyers and 26% of predicted strong sellers, as well as for all predicted weak and no-traders.

[25] See also Appendix C for more details.

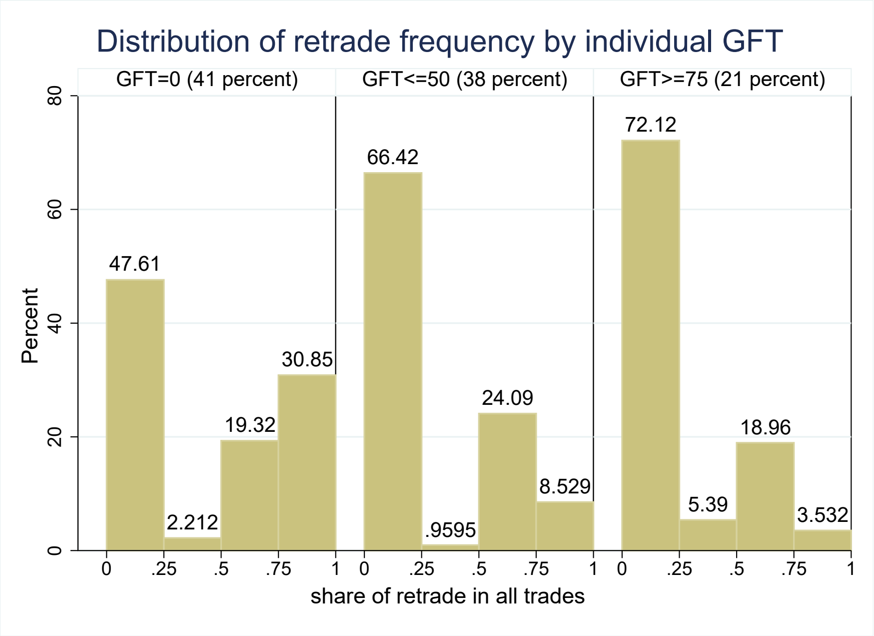

Figure 4: Percent re-trade by trader equilibrium gains from trade

variable, averaging 11.88 with a standard deviation of 56.08. Traders with zero and moderate predicted earnings gain most from re-trade (an average of 10.16 and 19.11 experimental dollars, respectively, conditional on re-trading); whereas high predicted earners hardly gain anything (1.75 on average, with a standard deviation of 71 experimental dollars, conditional on re-trading).

Observation 8 *Predicted strong buyers and sellers earn, on average, less than the equilibrium prediction, with high predicted earners losing the most. The numbers of net trades for predicted buyers and sellers are slightly below equilibrium. Most re-trading activity in the market is carried out by predicted no-traders and buyers and sellers with zero or moderate expected earnings, who earn on average positive, but small and highly variable profits from re-trading.*

We use regression analyses to consider how individual and market-level characteristics and trader behavior are associated with normalized trader earnings (the difference between predicted and actual earnings in the market). Market-level characteristics include potential gains from trade, equilibrium price level (at or above zero), "no marginal trades" indicator for markets with zero equilibrium quantity spread $(Q_U - Q_L)$,[26] as well as period number, and indicators for asymmetric treatment and experienced sessions. Individual characteristics include trader role, predicted earnings (allowing for a differentiated effect between predicted buyers and sellers), and the (lowest) equilibrium number of net trades. Behavioral variables

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[26] We use other traders' average equilibrium earnings as a proxy for market-level gains from trade, to reduce the correlation of this characteristic with trader's own predicted earnings; employing market-level gains from trade instead produces qualitatively identical results. Likewise, using "no marginal trades" indicator avoids high correlation of the equilibrium quantity spread with zero equilibrium price, another explanatory variable included in the regressions.

Table 15: Individual earnings from net trade and re-trade

		Actual Earnings from			Dev	Earnings conditional on		
Predicted Earnings		All trade	Net trade	Re-trade	from Eqm	Any Trade	Net trade	Re-trade
High	mean	88.77	88.3	0.47	-59.49	91.41	92.47	1.75
≥ 75	sd	105.67	94.73	36.86	103.4	106.1	94.93	71
	N obs.	554	554	554	554	538	529	150
Medium	mean	41.32	35.24	6.09	-0.42	43.83	39.3	19.11
≤ 50	sd	68.16	56.5	30.2	66.27	69.41	58.31	51.17
	N obs.	995	995	995	995	938	892	317
Zero	mean	7.86	3.62	4.24	7.86	9.9	6.14	10.16
	sd	50.37	33.29	34.67	50.37	56.36	43.18	53.17
	N obs.	1082	1082	1082	1082	859	638	451
All	mean	37.55	33.41	4.14	-9.45	42.31	42.69	11.88
	sd	77.89	67.45	33.6	75.05	81.46	73.6	56.08
	N obs.	2631	2631	2631	2631	2335	2059	918

*Trader earnings are in experimental dollars, per period. The earnings from net trade and re-trade are calculated as follows. Let Π^{all} be trader total period earnings, n_b and n_s be the number of trader's buy and sell transactions, and $\bar{p}_b$ and $\bar{p}_s$ be the average buying and selling prices for this trader in this period. Then earnings from re-trade are calculated as $\Pi^r = (\bar{p}_s - \bar{p}_b) \times \min\{n_b, n_s\}$, where $\min\{n_b, n_s\}$ is the number of re-trade transaction pairs. The remaining trader earnings are attributed to net trades: $\Pi^{net} = \Pi^{all} - \Pi^r$.

characterize actual net trading and share of re-trading. For net trading, we consider the excess or shortfalls in net trades relative to equilibrium, and predicted loss from under- and over-trading, i.e., the number of extra and insufficient trades evaluated at the equilibrium price. The regression analyses are conducted on all trader-period observations pooled, and separately for traders with zero, medium, and high equilibrium earnings.

Regression results, presented in Table 16, suggest that market, individual and behavioral characteristics are all significantly associated with trader earnings relative to equilibrium. Individual earnings get closer to equilibrium with higher predicted number of net trades, but traders with positive predicted earnings under-earn a significant share of what they would in equilibrium. Moreover, sellers fall short on earnings significantly more than buyers: the coefficient on seller equilibrium earnings is -0.86, which is significantly below the corresponding coefficient of -0.46 on buyer earnings ($p < 0.001$). Separate estimations by earnings categories demonstrate that this earnings gap between buyers and sellers persists across both medium and high predicted earners. We further find that all traders are less short on earnings in markets with higher potential gains from trade, and most traders benefit more in

Table 16: Determinants of trader normalized earnings

		Dependent variable: Normalized earning			
		Trader category by predicted earnings			
		All traders	Zero	Medium ≤ 50	High ≥ 75
Trader characteristics	predicted seller	-4.73	6.94	-10.19	-29.28
		(6.04)	(4.49)	(15.79)	(39.88)
	predicted weak or no-trader	3.99	-4.47		
		(6.23)	(5.67)		
	buyer equilibrium earnings	-0.46***		-0.89**	-0.34
		(0.11)		(0.38)	(0.26)
	seller equilibrium earnings	-0.86***		-1.60***	-0.56***
		(0.05)		(0.30)	(0.09)
	# of net trades in eqm	19.86***	1.60	45.84***	29.29*
		(4.99)	(3.58)	(9.21)	(15.04)
Trader behavior	net trades excess	-8.33**	-5.26*	-26.78***	-65.29
		(3.18)	(2.87)	(6.16)	(43.04)
	net trades shortage	-27.14***	-4.44	-37.85***	-46.34***
		(5.57)	(4.15)	(7.18)	(14.63)
	price of extra trades	-0.12	-0.16	0.00	0.68*
		(0.15)	(0.23)	(0.27)	(0.37)
	price of missing trades	-0.17***		0.08	-0.11
		(0.06)		(0.09)	(0.10)
	share retrade	9.79**	5.08	21.10**	-12.97
		(3.97)	(4.29)	(7.43)	(19.02)
Market characteristics	other traders average GFT	0.40***	0.39***	0.58***	0.05
		(0.05)	(0.12)	(0.09)	(0.22)
	low market GFT	9.31***	-0.68	11.52	
		(2.77)	(3.75)	(8.61)	
	equilibrium price above zero	8.53**	-5.03	39.38***	22.32
		(3.18)	(6.18)	(9.80)	(19.07)
	no marginal trades	0.00	-6.96	-21.31**	22.58***
		(2.43)	(10.31)	(7.88)	(7.93)
	asymmetric yields	2.18	-3.07	-0.72	10.09
		(2.52)	(2.83)	(3.83)	(8.20)
	experienced traders	10.62***	18.81***	13.74*	-9.34
		(3.60)	(4.62)	(7.31)	(13.69)
	period	1.29**	1.88	-0.02	0.24
		(0.55)	(1.48)	(1.20)	(2.48)
	period squared	-0.05**	-0.06	-0.00	-0.01
		(0.02)	(0.09)	(0.05)	(0.09)
	constant	-32.94***	-12.56**	-68.88***	-48.98
		(7.00)	(5.90)	(12.23)	(38.54)
Number of observations		2,333	859	938	536
R-squared		0.21	0.07	0.15	0.20

Standard errors are clustered on session. All regressions include yield sequence fixed effects. */**/*** indicate significance at the 10/5/1 percent level.

markets with positive equilibrium prices. The absence of equilibrium quantity spread in the market (i.e., no marginal trades) has a negligible effect on individual earnings overall, but this is due to high differences across trader categories: the effect is negative and significant (at 5% level) for medium predicted earners, while it is positive and significant (at 1% level) for high predicted earners. Note that a positive equilibrium quantity spread is conducive to re-trading, which we earlier found to particularly benefit medium-range earners (Table 15). In addition, experienced traders earn significantly more, and most traders earn more in later periods.[27]

Turning to trader behavior, the number of net trades in excess and short of the equilibrium are both significant in the pooled regression (at 5% and 1% level, respectively), with the net-trade shortage having a much larger negative effect on earnings than the net-trade excess overall. The value of missing net trades, evaluated at the equilibrium price, is also significantly associated with earnings shortages, based on the pooled regression. Not surprisingly, net trades excesses and shortages particularly harm positive predicted earners, and do not harm zero-earners.

The coefficient on re-trading is positive and significant (at 5% confidence) overall and for medium predicted earners. This finding concurs with our earlier observation that medium earners benefit from environments with positive equilibrium quantity spread that is conducive to speculation and near-equilibrium pricing. For zero-earners, the effect of re-trading is positive on average but insignificant, likely due highly variable rewards of pure speculative trading. In contrast to other earning categories, the high predicted earners are estimated to have, on average, (insignificantly) lower earnings if they engage in re-trading. It could be that high predicted earners use re-trading in an attempt to (partially) correct large trading errors, or are less careful when speculating than lower earners. Recall that high expected earners fall much shorter of their potential earnings as compared to other traders, possibly having been lulled into complacency after an initial windfall.

Observation 9 *Trader earnings are closer to equilibrium in markets with higher potential gains from trade and in markets with positive equilibrium prices. Predicted sellers fall short on earnings significantly more than predicted buyers. Traders earn closer to equilibrium when they are predicted to make more trades, and earn less if they make either too few or too many net trades compared to equilibrium. The share of re-trading has a positive but modest in magnitude effect on trader earnings overall, with medium-earners gaining the most from re-trading.*

In sum, the data suggest that some of predicted buyer and seller earnings shortfalls were due to unrealized gains from trade and trading errors, and some due to re-distribution of these gains to predicted low-earners who were active in trading and re-trading.

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[27] An insignificant coefficient on the asymmetric treatment indicator is likely due to trader heterogeneity. On average, traders in the symmetric treatment fell short of equilibrium earnings by 10 experimental dollars, compared to 7 experimental dollars in the asymmetric treatment. While the difference is insignificant on the individual level, it translates into significantly higher market efficiency of the asymmetric treatment on the aggregate level, as documented in our earlier analysis.

5 Conclusions

Our study of experimental double auctions under random net supply and demand conditions and trader ability to trade on both sides of the market allows to draw several conclusions.

First, equilibrium tendencies are very strong overall. In spite of large variability and truly stochastic nature of market conditions, one-third of our 260 markets are fully efficient, and half of the markets achieved efficiency of at least 90 percent. Efficiency increases in later periods and with experienced subjects. Prices converge to levels near or at the competitive equilibrium, including markets with zero equilibrium price. Almost 90 percent of all individual trades are in the direction consistent with the equilibrium prediction. The trading order roughly follows the Marshallian dynamics, where transactions with higher gains from trade tend to take place earlier in the period.

Second, market performance on both aggregate and individual levels depends on gains from trade available, and on the size of the equilibrium quantity spread. Markets with higher potential gains from trade exhibit more frequent gainful trades, higher overall efficiency, and individual traders earning closer to the equilibrium prediction than in markets with low gains. In contrast, markets with low potential gains are characterized by more transactions with negative transaction surpluses and lower overall efficiencies. A significant minority of low-gains markets have negative efficiencies.

The number of marginal trades in the market (the size of the equilibrium quantity spread) has a significant and positive effect on both market efficiency price convergence: prices in markets with a larger equilibrium quantity spread converge closer to the equilibrium predictions than in markets with a smaller equilibrium quantity spread. This provides clear evidence that low- and zero-surplus marginal trading, which accounts for at least one-third of all observed transactions in our data, helps to drive the price convergence process.

The individual trader performances also differ markedly depending on trader predicted earnings. Higher expected earners trade earlier in the period, but they typically earn less than they would with equilibrium pricing. We may view their role in the market as providing for rapid wealth creation (Plott et al., 2013), which they appear to execute well overall, but not without errors. Lower expected earners trade later in the period, re-trade more and more successfully, and fall less short of equilibrium earnings than high predicted earners. Finally, zero predicted earners tend to trade later and do most of re-trading, while earning a small but positive (on average) payoff; we may view their market role as driving price convergence, which they appear to execute remarkably well in sprite of excessive noisy trading and re-trading. Re-trading activity by medium and low predicted earners also leads to some redistribution of wealth from higher expected earners to lower expected earners.

Third, our study contributes to understanding of the role of re-trading in generating excessive trading volumes, market convergence and market (in)stability. Consistent with Dickhaut et al. (2012); Kotani et al. (2019) and asset market experiments (Smith et al., 1988; Lei et al., 2001), we document excessive trading volumes in our environment with re-trade. Indeed, Table 8 documents that markets with trading volumes above the equilibrium are characterized by higher share of re-trades. However, unlike the above studies, we do not find strong evidence that flexible trader roles and re-trading activity are universally detrimental for market performance under the unpredictable, highly variable conditions we study. We do find evidence that re-trading may lead to excessive volumes and negative efficiencies in markets with very low gains from trade. Yet in markets with substantial trading gains where traders need to discover market equilibrium anew every period, re-trading allows for error-correction and possibly better market convergence by providing an ongoing opportunity for lower-earning and marginal traders to seek any unrealized gains in the market.

The novel links between available gains from trade and market and individual performances has not been explored in the previous literature. Our findings suggest a possible explanation for the sharp contrast observed in the performance of traditional double auction commodity markets (where potential gains from trade are high) and asset markets (with zero gains from trade under the rational expectations). The commodity markets consistently perform very close to the competitive equilibrium prediction, while the asset markets are routinely characterized by excessive trading and price dynamics inconsistent with the rational expectations equilibrium.[28] Our experiment suggests that strong price convergence and high efficiency are driven by realization of gains from trade that are "real" (and not just divergent-expectations-based). With "real" gains from trade available, the markets exhibit fast and robust convergence to equilibrium. When these gains are exhausted, many traders engage in low-gain or zero-sum trading and re-trading. This speculative trading is not in the way of price convergence in our stochastic environments with "real gains," which contrasts with excessive zero-sum and negative-surplus trading that can distort market performance in experimental markets where such real gains are absent.

Further, we observe that trader specialization, which we manipulated by assigning each trader the role of either expected buyer or expected sellers in all market periods, has a positive and significant effect on market efficiency. This finding agrees with Dickhaut et al. (2012) who observe improved market performance under fixed buyer and seller roles with no re-trade. We document the power of specialization under more challenging conditions where specialization is not forced by market rules, but is implied by asymmetric yield assignments. On the transaction and individual levels, we find that traders in the asymmetric yields treatment are less likely to engage in efficiency-reducing negative-gain trades, which translates into higher market-level efficiency. However, specialization does not eliminate extensive trading and re-trading by those with little or no potential gains from trade.

Finally, our study re-establishes, in a complex setting, a puzzling gap in performances between the buyer and seller sides of the market. We find that predicted buyers perform significantly better than predicted sellers in attaining their equilibrium earnings. This gap was first documented by Smith and Williams (1982) in steady double auction environments with no re-trade. In our setting, the gap may be due to the valuation schedule that is biased in favor of expected buyers, providing them with more profitable transaction opportunities. Or, as suggested by Smith and Williams (1982), it may be due to sellers' lower bargaining power, arising from "...the fact that most subjects have much more experience with the role of a buyer that that of a seller" (p. 115). A brief examination of trading prices suggests that both of these phenomena played roles. While average trading prices were lower than predicted by only 4.19 experimental dollars overall (Table 4), the picture is different if we compare markets with high and low predicted seller gains (i.e., the markets with high and

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[28] Considerable cash endowments and good durability, in addition to re-trading, are among other features that distinguish traditional experimental commodity and asset double auction markets. We are exploring the roles of these features in a companion project.

low equilibrium price levels). The average trading price was 18.01 experimental dollars below the equilibrium in markets with high expected gains for sellers (with equilibrium price at or above 75 experimental dollars), while the average price was 9.84 experimental dollars above the equilibrium in markets with low expected seller gains (when the equilibrium price was 50 experimental dollars or below).[29] Because of the value schedule asymmetry, higher than predicted prices in low-equilibrium-price periods did not balance out seller losses (relative to the equilibrium predictions) due to lower prices in high-equilibrium-price periods. In other words, the valuation schedule with many zero-value units together with the actual trading price departures from equilibrium benefited the buyer side of the market and hurt the seller side.

How might these results translate to market outcomes outside the lab? Answers to this question will require further study, but we might draw some inferences and perhaps refine some questions to take to non-experimental markets. First, the traders in our experiments were relatively inexperienced and faced relatively modest incentives compared to traders in the field. The fact that equilibrium forces push strongly toward efficient outcomes in this relatively difficult, stochastic environment bodes well for markets outside the lab. Second, the findings with regard to excess trading may be highly context dependent. It is easy to imagine specialized commodity traders speculating with little social or private benefit when transaction costs for trading are low.[30] It is much more difficult, however, to imagine subsistence farmers passing time buying and selling scarce grains for small stakes.

Lastly, and perhaps most interestingly, we find remarkable individual-level departures from equilibrium earnings, especially for traders with the most to gain. The range of prices allowing profitable trades is often large at the start of trading, allowing buyers with high willingness to pay prices that far exceed equilibrium, and sellers with low opportunity costs to sell for far less than equilibrium prices. As a result, trading prices within the period may be far from equilibrium during early stages of convergence, and individual-level outcomes can be far more variable than the aggregate outcome, with possible implications for equity. We speculate that this pattern might be present in non-experimental emerging markets when traders are not especially experienced or savvy, such as with subsistence farmers. If some of the gains from trade that subsistence farm households might otherwise enjoy from markets are lost to intermediaries, a bit like our "no-traders" who nevertheless seem to speculate through re-trading, then it may dampen enthusiasm and viability of market development in lesser-developed countries. These potential out-of-equilibrium implications for equity, however, need much more study both in the laboratory and in markets outside the lab.

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[29] The equilibrium price was predicted to be at or above 75 experimental dollars in half of all markets, and 50 experimental dollars or below in the other half of markets.

[30] Financial asset markets are another obvious setting where re-trading is prevalent and excessive trading volumes are commonly observed.

Appendix A: Equilibrium predictions

Table 17: Equilibrium price predictions and empirical frequency by average yield realization

Average Yield $\bar{Y}_t$	Equilibrium Price P_t^{eq}	Equilibrium Price Midpoint*	Empirical frequency, % **
$[0, 1)$	275	275	0.00
1	$[225, 275]$	250	0.00
$(1, 2)$	225	225	3.85
2	$[175, 225]$	200	0.77
$(2, 3)$	175	175	11.15
3	$[125, 175]$	150	0.38
$(3, 4)$	125	125	16.92
4	$[75, 125]$	100	5.00
$(4, 5)$	75	75	12.31
5	$[25, 75]$	50	1.15
$(5, 6)$	25	25	18.85
6	$[0, 25]$	12.5	1.54
$(6, 10]$	0	0	28.08
Total number of markets: 260			100.00

*This midpoint value of equilibrium price range is used in the estimation of empirical price asymptotes, as reported in Table 6.

** In 260 observed markets, the average yield varied between 1.25 and 8.3, with the mean of 4.87 and standard deviation of 1.72.

Equilibrium prices Since all traders have the same valuation schedules, the equilibrium price P^{eq} in each period equates mean supply and mean demand, and is determined by the marginal unit value, as given in Table 1, at the average yield $\bar{Y}_t = \frac{1}{N}\sum_i Y_{it}$. The mapping from average market yields to equilibrium prices is displayed in Table 17 above. The equilibrium price spans a range of values when the average yield is an integer between 1 and 6; in this case market supply and demand curves overlap vertically, see, e.g., Figure 1, market periods 1, 4, 19 and 20. The equilibrium price takes a single value for average yields that are non-integer or above 6 units; in this case market supply and demand curves overlap horizontally, yielding a range of equilibrium trading volumes; see Figure 1, other market periods.

Equilibrium trading volumes The equilibrium trading volumes are determined by the intersection of the net market supply and demand curves. If the average market yield is an integer between 1 and 6 units, the market supply and demand curves intersect over a vertical interval, as discussed above, yielding a unique prediction for the equilibrium trading volume:

$$Q^{eq} = \sum_{i:Y_{it}>\bar{Y}_t} (Y_{it} - \bar{Y}_t) = \sum_{j:Y_{jt}<\bar{Y}_t} (\bar{Y}_t - Y_{jt}), \tag{2}$$

where $\{i : Y_{it} > \bar{Y}_t\}$ is the set of net sellers, and $\sum_{i:Y_{it}>\bar{Y}_t}(Y_{it} - \bar{Y}_t)$ is the net market supply; $\{j : Y_{jt} < \bar{Y}_t\}$ is the set of net buyers, and $\sum_{j:Y_{jt}<\bar{Y}_t}(\bar{Y}_t - Y_{jt})$ is the market demand, as predicted by the equilibrium theory.

If the average market yield is not an integer, or is greater than 6 units, the net market supply and demand overlap over a horizontal range, yielding a range of volumes $[Q_L, Q_U]$ consistent with the equilibrium prediction. This happens because of the discrete nature of unit values: while Q_L is the lowest number of trades necessary to fully realize all potential gains from trade, additional marginal trades may be available in equilibrium; traders may be holding units that they are just indifferent between trading and not trading, as any such trade would bring zero profit.

The lower and upper bounds of equilibrium trading volumes, Q_L and Q_U, are given by:

$$Q_L = \max\{\min Q^S, \min Q^D\}, \tag{3}$$

$$Q_U = \min\{\max Q^S, \max Q^D\}. \tag{4}$$

In the above, the bounds on market supply and demand quantities Q^S and Q^D, evaluated at the equilibrium price, are calculated as follows. If $\bar{Y}_t < 6$ then $P^{eq} > 0$. Hence:

$$\min Q^S = \sum_{i:Y_{it}>\bar{Y}_t} (Y_{it} - \lceil \bar{Y}_t \rceil), \quad \max Q^S = \sum_{i:Y_{it}>\bar{Y}_t} (Y_{it} - \lfloor \bar{Y}_t \rfloor), \tag{5}$$

$$\min Q^D = \sum_{j:Y_{jt}<\bar{Y}_t} (\lfloor \bar{Y}_t \rfloor - Y_{jt}), \quad \max Q^D = \sum_{j:Y_{jt}<\bar{Y}_t} (\lceil \bar{Y}_t \rceil - Y_{jt}), \tag{6}$$

where $\lfloor \bar{Y}_t \rfloor \equiv \text{floor}(\bar{Y}_t)$ and $\lceil \bar{Y}_t \rceil \equiv \text{ceil}(\bar{Y}_t)$ denote the floor and the ceiling of $\bar{Y}_t$, respectively.

If $\bar{Y}_t > 6$ then $P^{eq} = 0$, and the market supply Q^S at zero price is bounded from below by zero, while the market demand Q^D is unbounded from above; and the upper bound of supply and the lower bound of demand are determined by the condition that each trader should hold at least 6 units in equilibrium. Hence:

$$\min Q^S = 0, \quad \max Q^S = \sum_{i:Y_{it}>6} (Y_{it} - 6), \tag{7}$$

$$\min Q^D = \sum_{j:Y_{jt}<6} (6 - Y_{jt}), \quad \max Q^D = \infty. \tag{8}$$

Example 1 Consider Session 1, Period 1 individual yields for 12 traders as presented in Table 18. $\bar{Y}_t = 4$, and each trader will hold exactly 4 units in equilibrium; their opportunity cost of selling the fourth unit is 125, and their maximal willingness to pay for the fifth unit is 75 (Table 1), giving rise to the equilibrium price range of $[75, 125]$ at which no strictly profitable trades are possible. The equilibrium trading volume is uniquely determined at 13 units; see Figure 1, Period 1 for illustration.

Table 18: Illustration: market yields and equilibrium predictions

Session 1	Period 1	Period 5	Period 7
Trader ID	Trader Yield Y_{it}		
1	1	8	5
2	5	10	2
3	6	7	2
4	1	6	3
5	2	9	5
6	6	5	0
7	6	10	2
8	6	10	2
9	6	9	5
10	6	9	1
11	2	5	0
12	1	8	0
Average Yield $\bar{Y}_t$	4	8	2.25
Equilibrium Price P^{eq}	$[75, 125]$	0	175
Eqm volume range $[Q_L, Q_U]$	13	$[2, 26]$	$[7, 10]$

Example 2 Now consider Session 1, Period 5 individual yields (Table 18). $\bar{Y}_t = 8$, hence in equilibrium $P^{eq} = 0$, all traders hold at least 6 units, and no strictly profitable trades are available for any trader. The equilibrium trading volume ranges between 2 and 26 units, depending on whether the traders are willing or not to engage in marginal zero-profit trades. See Figure 1, Period 5.

Example 3 Consider further individual yields in Session 1, Period 7 (Table 18). $\bar{Y}_t = 2.25$, with nine traders holding two units, and three traders holding three units in equilibrium. Traders holding two units are willing to buy the third unit at a price no more than their marginal value, 175; traders holding three units are willing to sell their third unit at a price no less than their opportunity cost, 175. Hence the equilibrium price is 175, allowing no strictly profitable trades at an equilibrium allocation. The equilibrium trading volume ranges between 7 and 10 units, depending on whether the traders are willing or not to engage in marginal zero-profit trades. See Figure 1, Period 7.

We emphasize again that if net market supply and demand overlap horizontally, as in Examples 2 and 3 above, then the equilibrium allocation of units among traders is not unique, and marginal zero-gain trades between traders are still possible in equilibrium, as long as such trades lead to another allocation consistent with equilibrium.

Appendix B: Additional price convergence estimations

Table 19: Price convergence estimation, tobit regression

	Dependent variable: Transaction Price		
	All data	Symmetric treatment	Asymmetric treatment
Midpoint of trader values range – origin	0.677***	0.686***	0.652***
	(0.050)	(0.065)	(0.075)
Previous closing price – origin	0.167***	0.150***	0.205***
	(0.040)	(0.055)	(0.047)
Positive equilibrium price – asymptote	0.937***	0.941***	0.931***
	(0.017)	(0.023)	(0.024)
Zero equilibrium price – asymptote	0.769	-0.529	4.987
	(2.178)	(2.610)	(3.864)
Root mean squared error	33.358***	33.646***	32.626***
	(1.048)	(1.177)	(2.331)
Number of obs.	2,772	1,961	811

Notes: The table reports estimates of equation 1, which calibrates how prices evolve within each trading period. Separate regressions were estimated when pooling all sessions, symmetric treatment only, and asymmetric treatment only. In symmetric treatment, all participants have the same random yield distributions. In asymmetric treatment, half of the traders receive the lower half of yield draws and are typically net buyers, while the other half receives the higher yield draws and are typically net sellers. The estimated relationship shows how the first transaction price (the origin) relates to (i) the midpoint between lowest opportunity cost and highest marginal willingness to pay and (ii) the previous period closing price, and how well prices tend to converge (the asymptote) toward the equilibrium price. "Zero Equilibrium Price" is an indicator variable that allows for a discontinuity in the asymptote price when the equilibrium price is zero. Robust standard errors clustered on session are in parentheses. */**/*** indicate significance at the 10/5/1 percent levels.

Appendix C: Net trade and re-trade earnings calculation

The number of each trader's net trade and re-trade transactions in a given period, and her period earnings from net trade and re-trade, are calculated as follows. Let be n_b and n_s the number of trader's buy and sell transactions, and let $n_{all} = n_b + n_s$ be her total number of transactions. Then the number of net trades is:

$$n_{net} = \max\{n_b, n_s\} - \min\{n_b, n_s\}, \tag{9}$$

and the number of re-trades is:

$$n_r = n_{all} - n_{net} = 2 \times \min\{n_b, n_s\}. \tag{10}$$

Further, let Π^{all} be this trader's total earnings in a period, and let $\bar{p}_b$ and $\bar{p}_s$ be her average buying and selling prices. Then her earning from re-trade are calculated as

$$\Pi^r = (n_r/2) \times (\bar{p}_s - \bar{p}_b) = \min\{n_b, n_s\} \times (\bar{p}_s - \bar{p}_b). \tag{11}$$

The remaining trader earnings are attributed to net trades:

$$\Pi^{net} = \Pi^{all} - \Pi^r. \tag{12}$$

Equivalently, the earnings from net trade can be calculated in the following way. Let i be the initial number of units on hand, and let k be the number on hand at the end of trading. Then $k > i$ with $n_{net} = k - i$ for net buyers; $i > k$ with $n_{net} = i - k$, for net sellers; and $i = k$ for net no-traders. Let v_j denote j-th unit value, as presented in Table 1 in the main paper.

The profit from net trade for net buyers is then calculated as:

$$\Pi^{net} = \sum_{j=i+1}^{k} v_j - n_{net} \times \bar{p}_b, \tag{13}$$

and the profit from net trade for net sellers is calculated as:

$$\Pi^{net} = n_{net} \times \bar{p}_s - \sum_{j=k+1}^{i} v_j. \tag{14}$$

The profit from re-trade is then calculated as the difference between total profit and net profit, $\Pi^r = \Pi^{all} - \Pi^{net}$, or, equivalently, using expression 11 above.

For example, suppose a trader initially held $i = 2$ units in a period. She sold two units, $n_s = 2$, at the prices of 130 and 180, and bought three units, $n_b = 3$, at the prices of 150, 100 and 80. This trader is a net buyer with one net trade, $n_{net} = 3 - 2 = 1$, and four re-trades, $n_r = (2 + 3) - 1 = 4$, or two re-trade pairs: $\min\{n_b, n_s\} = 2$, holding $k = 3$ units at the end of trading. The average selling price is $\bar{p}_s = 155$, and the average buying price is $\bar{p}_b = 110$. Trader total earnings in this period are $\Pi^{all} = 105$, with earnings from net trade $\Pi^{net} = v_3 - 1 * (110) = 125 - 110 = 15$, and earnings from re-trade $\Pi^r = 2 * (155 - 110) = 90$.

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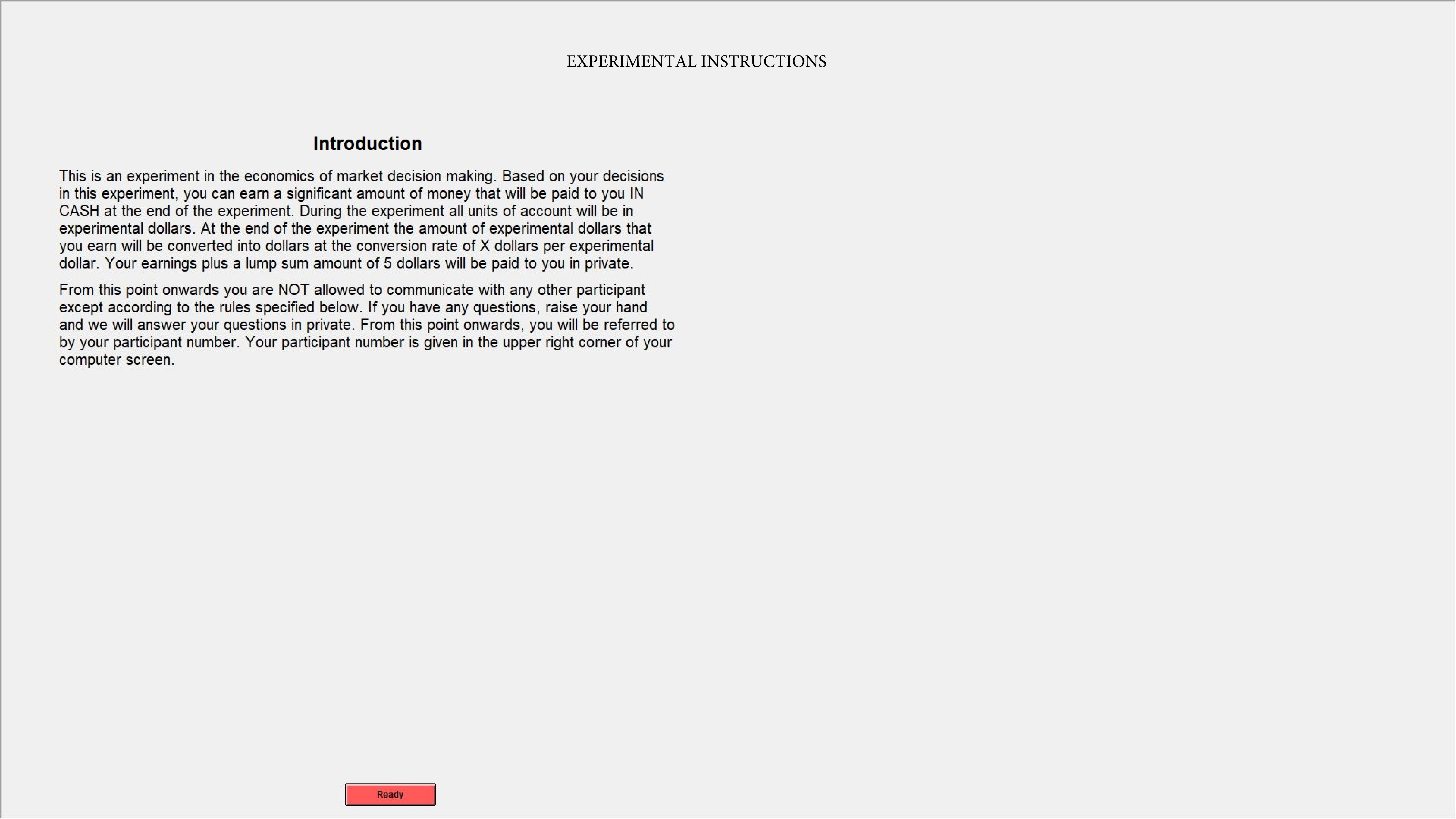
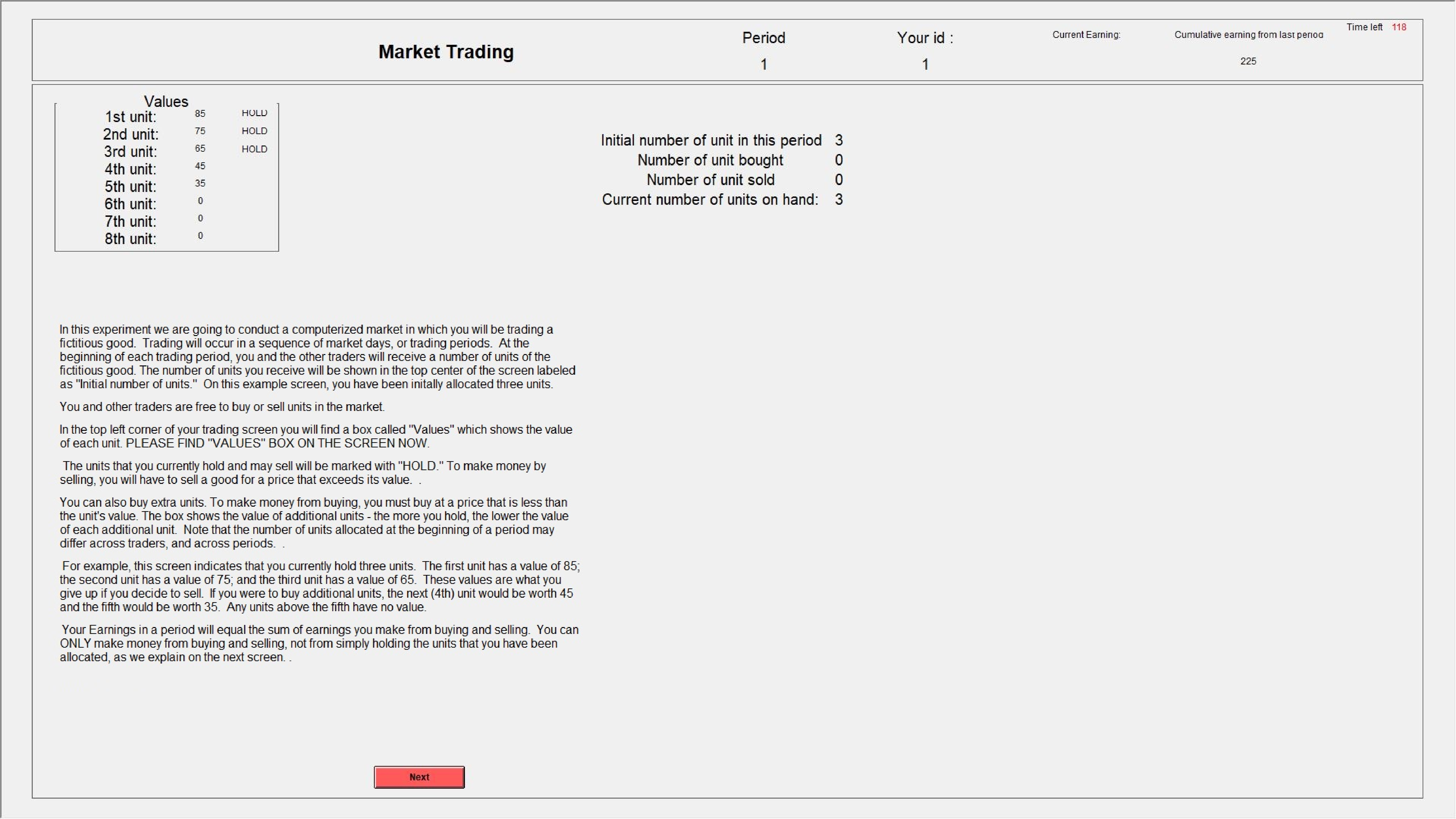
EXPERIMENTAL INSTRUCTIONS



Introduction

This is an experiment in the economics of market decision making. Based on your decisions in this experiment, you can earn a significant amount of money that will be paid to you IN CASH at the end of the experiment. During the experiment all units of account will be in experimental dollars. At the end of the experiment the amount of experimental dollars that you earn will be converted into dollars at the conversion rate of X dollars per experimental dollar. Your earnings plus a lump sum amount of 5 dollars will be paid to you in private.

From this point onwards you are NOT allowed to communicate with any other participant except according to the rules specified below. If you have any questions, raise your hand and we will answer your questions in private. From this point onwards, you will be referred to by your participant number. Your participant number is given in the upper right corner of your computer screen.



Time left 118

Market Trading

Period	Your id :	Current Earning:	Cumulative earning from last period
1	1		225

Values

1st unit:	85	HOLD
2nd unit:	75	HOLD
3rd unit:	65	HOLD
4th unit:	45	
5th unit:	35	
6th unit:	0	
7th unit:	0	
8th unit:	0	

Initial number of unit in this period	3
Number of unit bought	0
Number of unit sold	0
Current number of units on hand:	3

In this experiment we are going to conduct a computerized market in which you will be trading a fictitious good. Trading will occur in a sequence of market days, or trading periods. At the beginning of each trading period, you and the other traders will receive a number of units of the fictitious good. The number of units you receive will be shown in the top center of the screen labeled as "Initial number of units." On this example screen, you have been initally allocated three units.

You and other traders are free to buy or sell units in the market.

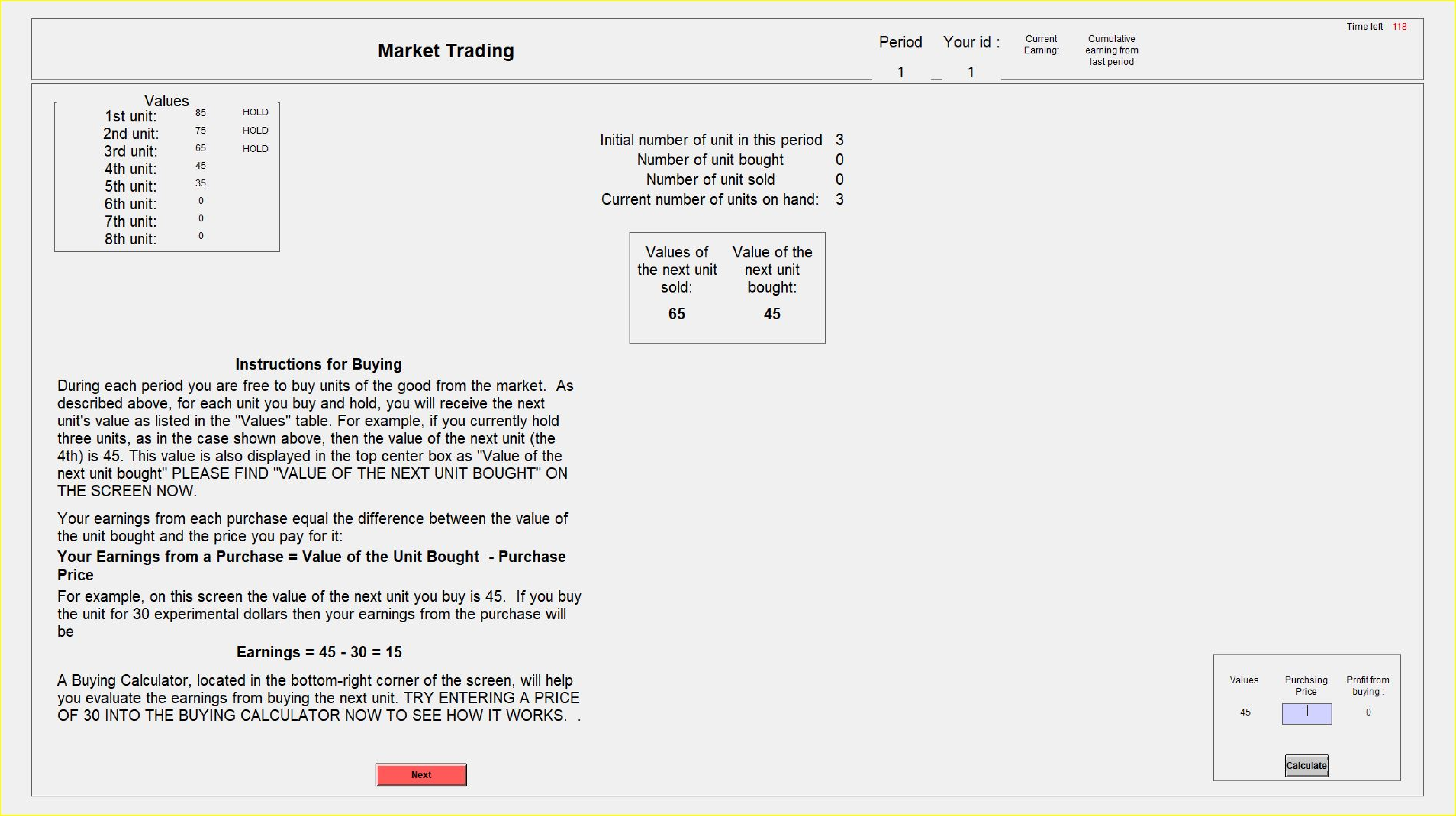
In the top left corner of your trading screen you will find a box called "Values" which shows the value of each unit. PLEASE FIND "VALUES" BOX ON THE SCREEN NOW.

The units that you currently hold and may sell will be marked with "HOLD." To make money by selling, you will have to sell a good for a price that exceeds its value. .

You can also buy extra units. To make money from buying, you must buy at a price that is less than the unit's value. The box shows the value of additional units - the more you hold, the lower the value of each additional unit. Note that the number of units allocated at the beginning of a period may differ across traders, and across periods. .

For example, this screen indicates that you currently hold three units. The first unit has a value of 85; the second unit has a value of 75; and the third unit has a value of 65. These values are what you give up if you decide to sell. If you were to buy additional units, the next (4th) unit would be worth 45 and the fifth would be worth 35. Any units above the fifth have no value.

Your Earnings in a period will equal the sum of earnings you make from buying and selling. You can ONLY make money from buying and selling, not from simply holding the units that you have been allocated, as we explain on the next screen. .



Time left 118

Market Trading

Period	Your id :	Current Earning:	Cumulative earning from last period
1	1		

Values		
1st unit:	85	HOLD
2nd unit:	75	HOLD
3rd unit:	65	HOLD
4th unit:	45	
5th unit:	35	
6th unit:	0	
7th unit:	0	
8th unit:	0	

Initial number of unit in this period	3
Number of unit bought	0
Number of unit sold	0
Current number of units on hand:	3

Values of the next unit sold:	Value of the next unit bought:
65	45

Instructions for Buying

During each period you are free to buy units of the good from the market. As described above, for each unit you buy and hold, you will receive the next unit's value as listed in the "Values" table. For example, if you currently hold three units, as in the case shown above, then the value of the next unit (the 4th) is 45. This value is also displayed in the top center box as "Value of the next unit bought" PLEASE FIND "VALUE OF THE NEXT UNIT BOUGHT" ON THE SCREEN NOW.

Your earnings from each purchase equal the difference between the value of the unit bought and the price you pay for it:

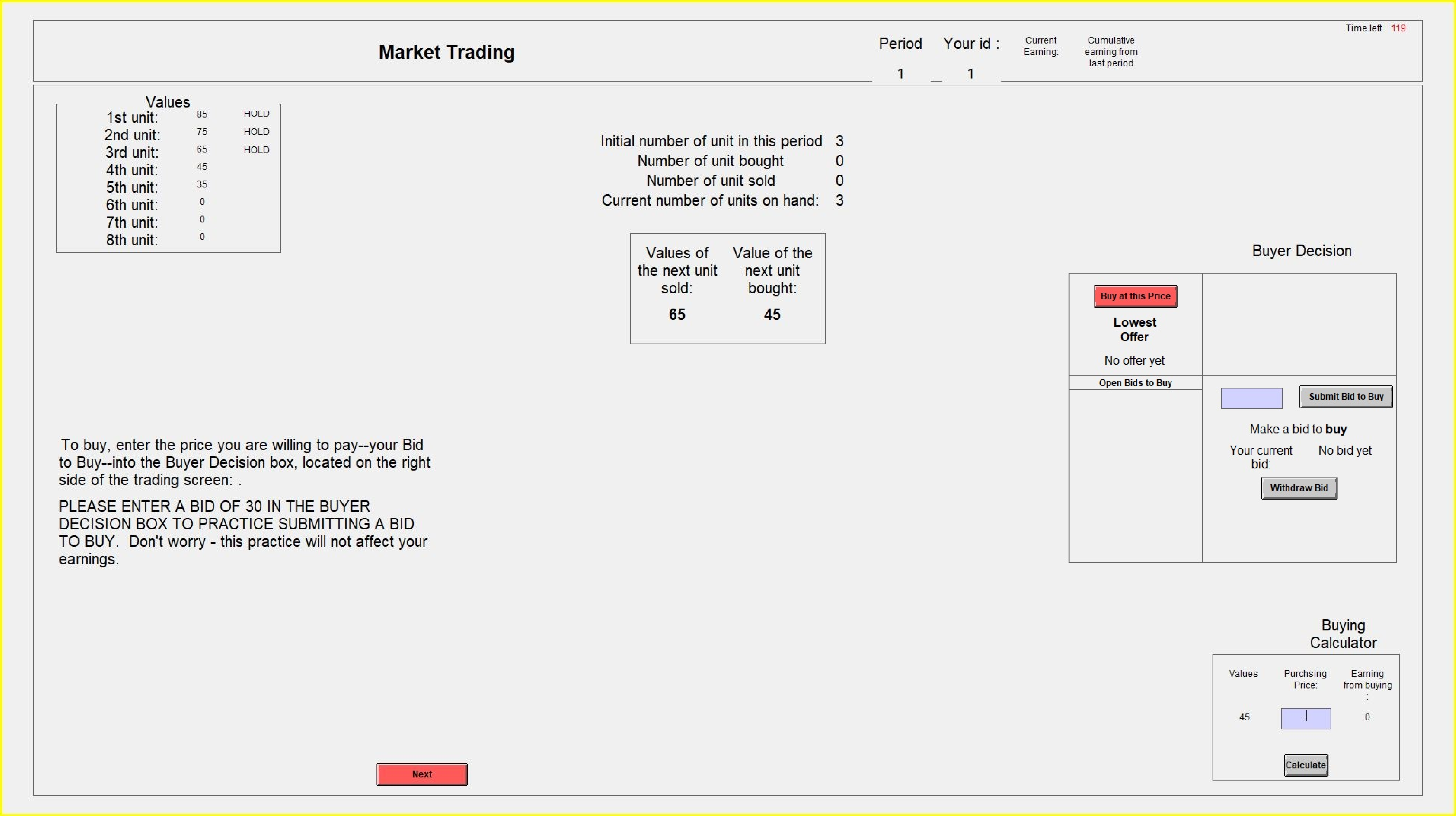
Your Earnings from a Purchase = Value of the Unit Bought - Purchase Price

For example, on this screen the value of the next unit you buy is 45. If you buy the unit for 30 experimental dollars then your earnings from the purchase will be

Earnings = 45 - 30 = 15

A Buying Calculator, located in the bottom-right corner of the screen, will help you evaluate the earnings from buying the next unit. TRY ENTERING A PRICE OF 30 INTO THE BUYING CALCULATOR NOW TO SEE HOW IT WORKS. .

Values	Purchsing Price	Profit from buying :
45		0



Market Trading

Period 1
Your id : 1
Current Earning:
Cumulative earning from last period
Time left 119

Values		
1st unit:	85	HOLD
2nd unit:	75	HOLD
3rd unit:	65	HOLD
4th unit:	45	
5th unit:	35	
6th unit:	0	
7th unit:	0	
8th unit:	0	

Initial number of unit in this period	3
Number of unit bought	0
Number of unit sold	0
Current number of units on hand:	3

Values of the next unit sold:	Value of the next unit bought:
65	45

Buyer Decision

Lowest Offer

No offer yet

Make a bid to **buy**

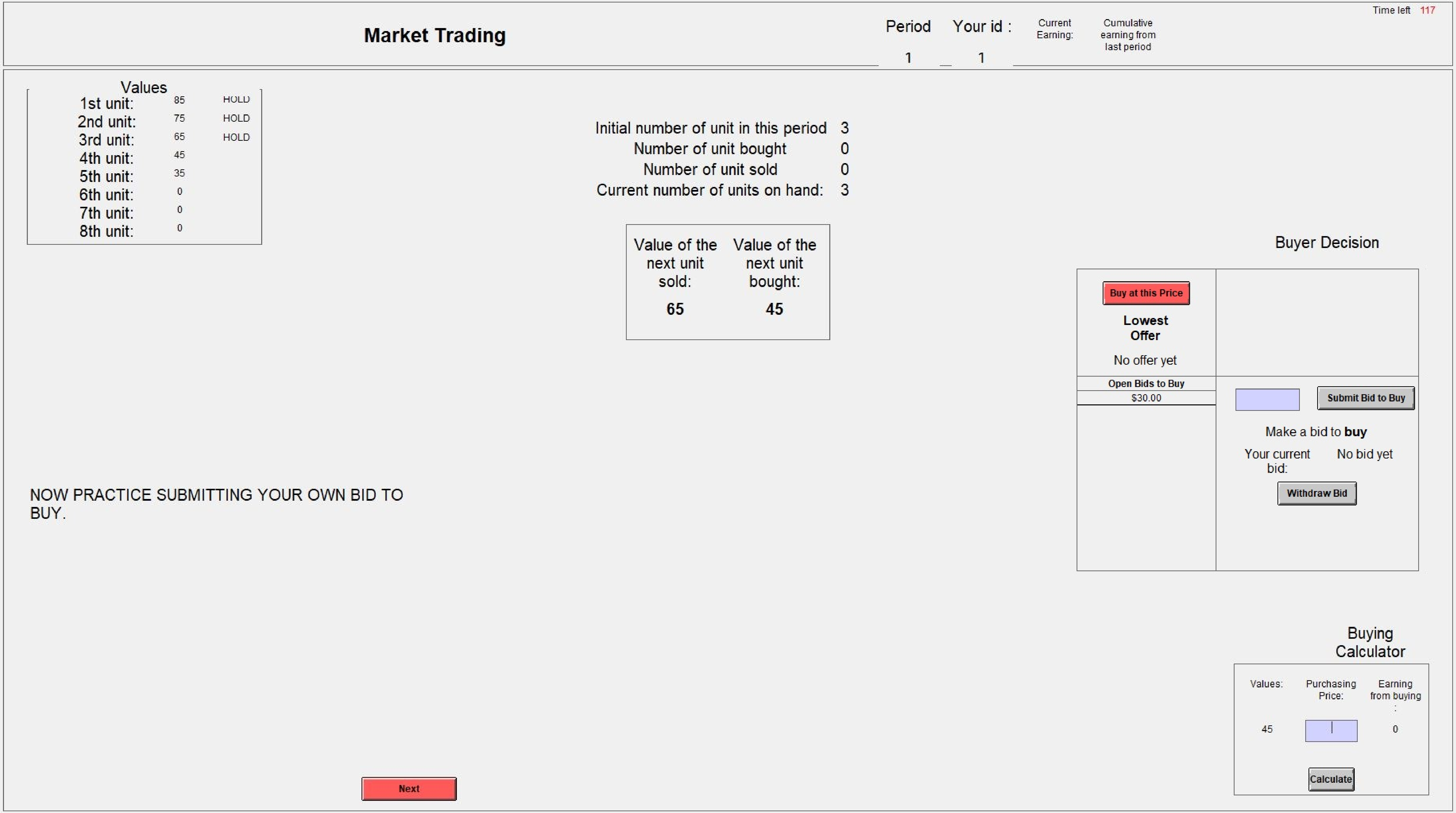
Your current bid: No bid yet

To buy, enter the price you are willing to pay--your Bid to Buy--into the Buyer Decision box, located on the right side of the trading screen: .

PLEASE ENTER A BID OF 30 IN THE BUYER DECISION BOX TO PRACTICE SUBMITTING A BID TO BUY. Don't worry - this practice will not affect your earnings.

Buying Calculator

Values	Purchsing Price:	Earning from buying :
45		0



Market Trading

Time left 117

Period: 1

Your id : 1

Current Earning:

Cumulative earning from last period

Values

1st unit:	85	HOLD
2nd unit:	75	HOLD
3rd unit:	65	HOLD
4th unit:	45	
5th unit:	35	
6th unit:	0	
7th unit:	0	
8th unit:	0	

Initial number of unit in this period 3
Number of unit bought 0
Number of unit sold 0
Current number of units on hand: 3

Value of the next unit sold:	Value of the next unit bought:
65	45

Buyer Decision

Lowest Offer
No offer yet

Open Bids to Buy
$30.00

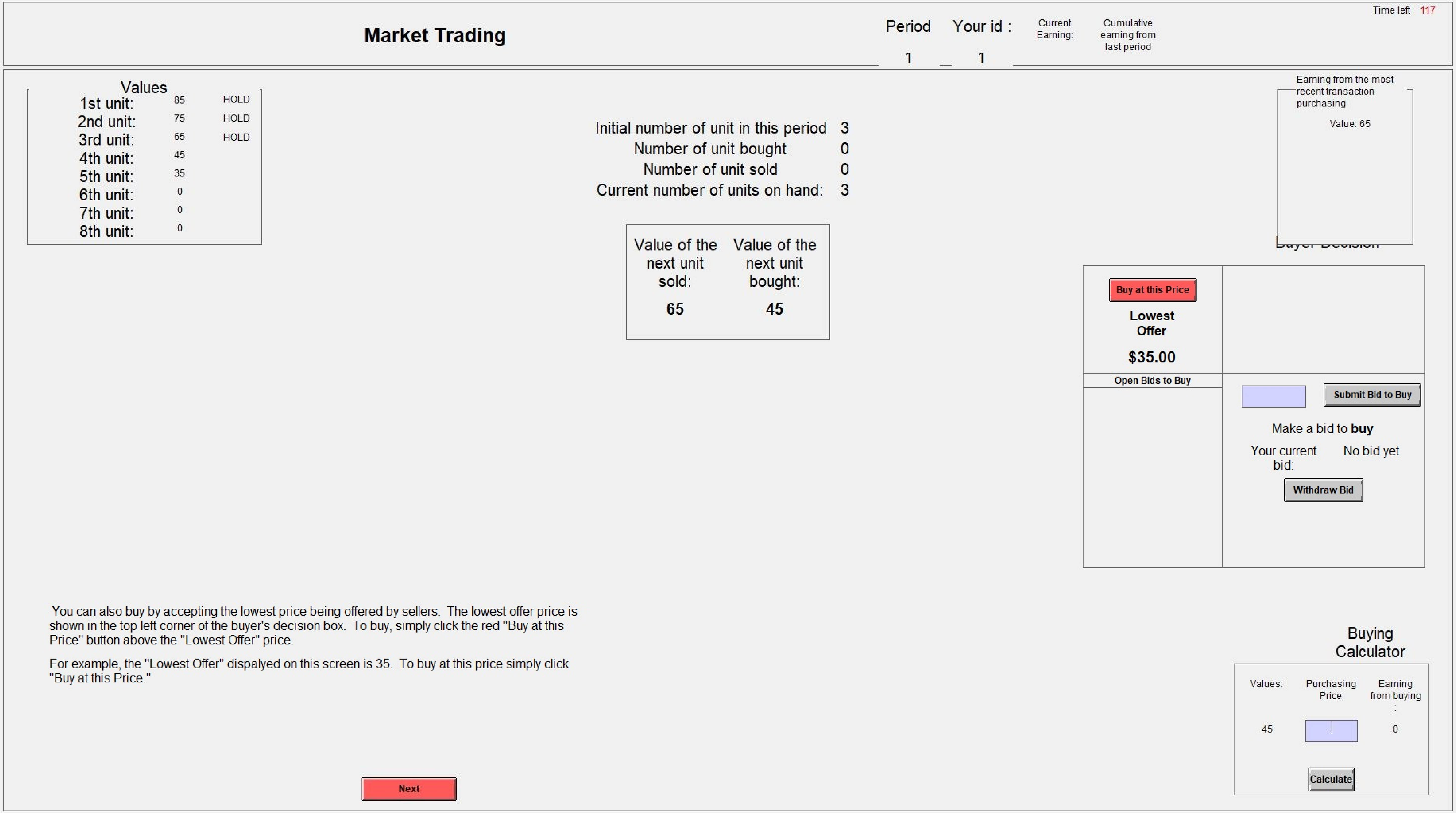
Make a bid to **buy**

Your current bid: No bid yet

NOW PRACTICE SUBMITTING YOUR OWN BID TO BUY.

Buying Calculator

Values:	Purchasing Price:	Earning from buying :
45		0



Market Trading

Period 1

Your id : 1

Current Earning:

Cumulative earning from last period

Time left 117

Values

1st unit:	85	HOLD
2nd unit:	75	HOLD
3rd unit:	65	HOLD
4th unit:	45	
5th unit:	35	
6th unit:	0	
7th unit:	0	
8th unit:	0	

Initial number of unit in this period 3
Number of unit bought 0
Number of unit sold 0
Current number of units on hand: 3

Value of the next unit sold:	Value of the next unit bought:
65	45

Earning from the most recent transaction purchasing

Value: 65

Lowest Offer

$35.00

Make a bid to **buy**

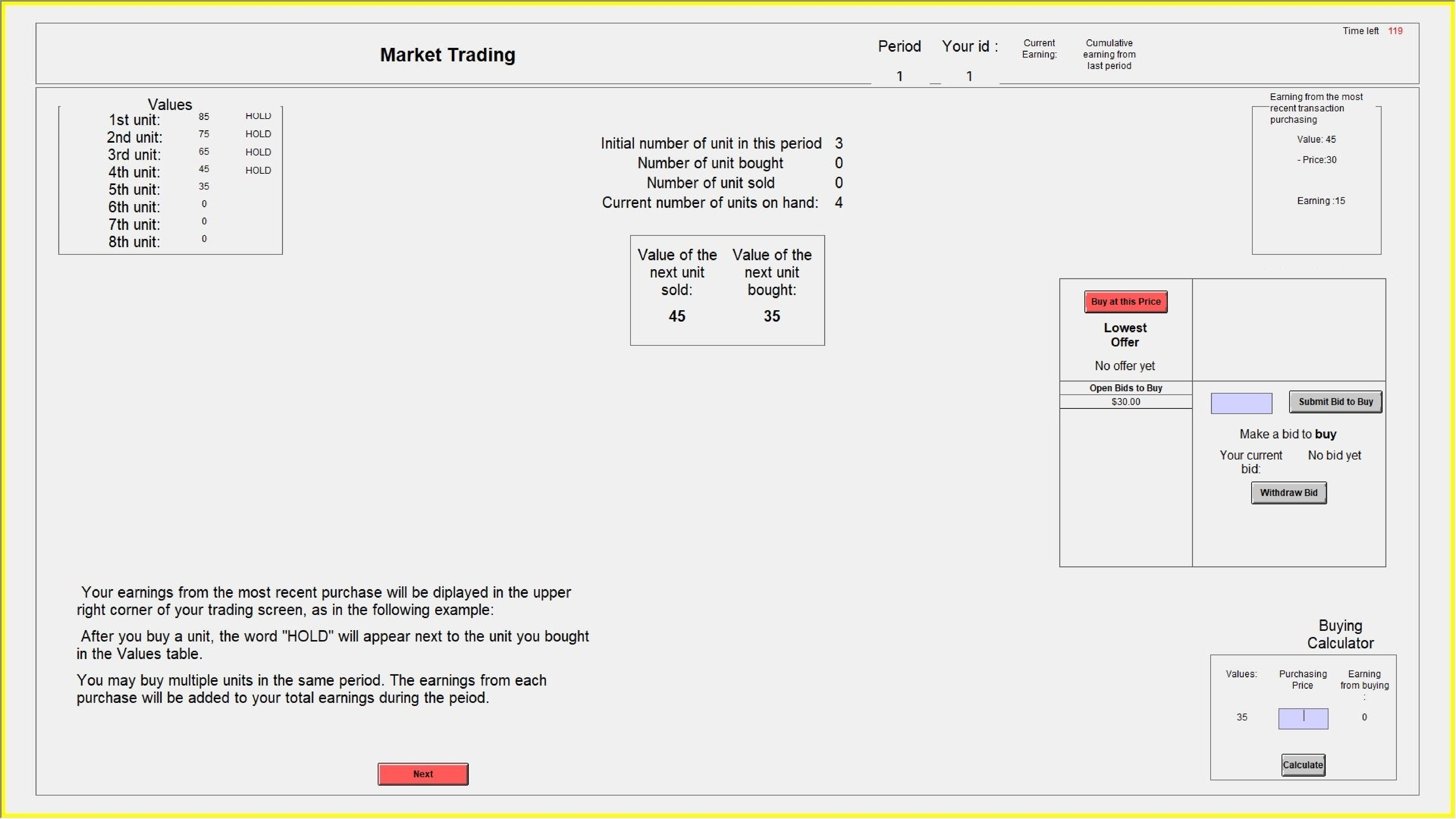
Your current bid: No bid yet

Buying Calculator

Values:	Purchasing Price	Earning from buying :
45		0

You can also buy by accepting the lowest price being offered by sellers. The lowest offer price is shown in the top left corner of the buyer's decision box. To buy, simply click the red "Buy at this Price" button above the "Lowest Offer" price.

For example, the "Lowest Offer" dispalyed on this screen is 35. To buy at this price simply click "Buy at this Price."



Market Trading

Period: 1

Your id : 1

Current Earning:

Cumulative earning from last period

Time left 119

Values

1st unit:	85	HOLD
2nd unit:	75	HOLD
3rd unit:	65	HOLD
4th unit:	45	HOLD
5th unit:	35	
6th unit:	0	
7th unit:	0	
8th unit:	0	

Initial number of unit in this period 3
Number of unit bought 0
Number of unit sold 0
Current number of units on hand: 4

Value of the next unit sold:	Value of the next unit bought:
45	35

Earning from the most recent transaction purchasing

Value: 45
- Price:30
Earning :15

Lowest Offer

No offer yet

Open Bids to Buy

$30.00

Make a bid to **buy**

Your current bid: No bid yet

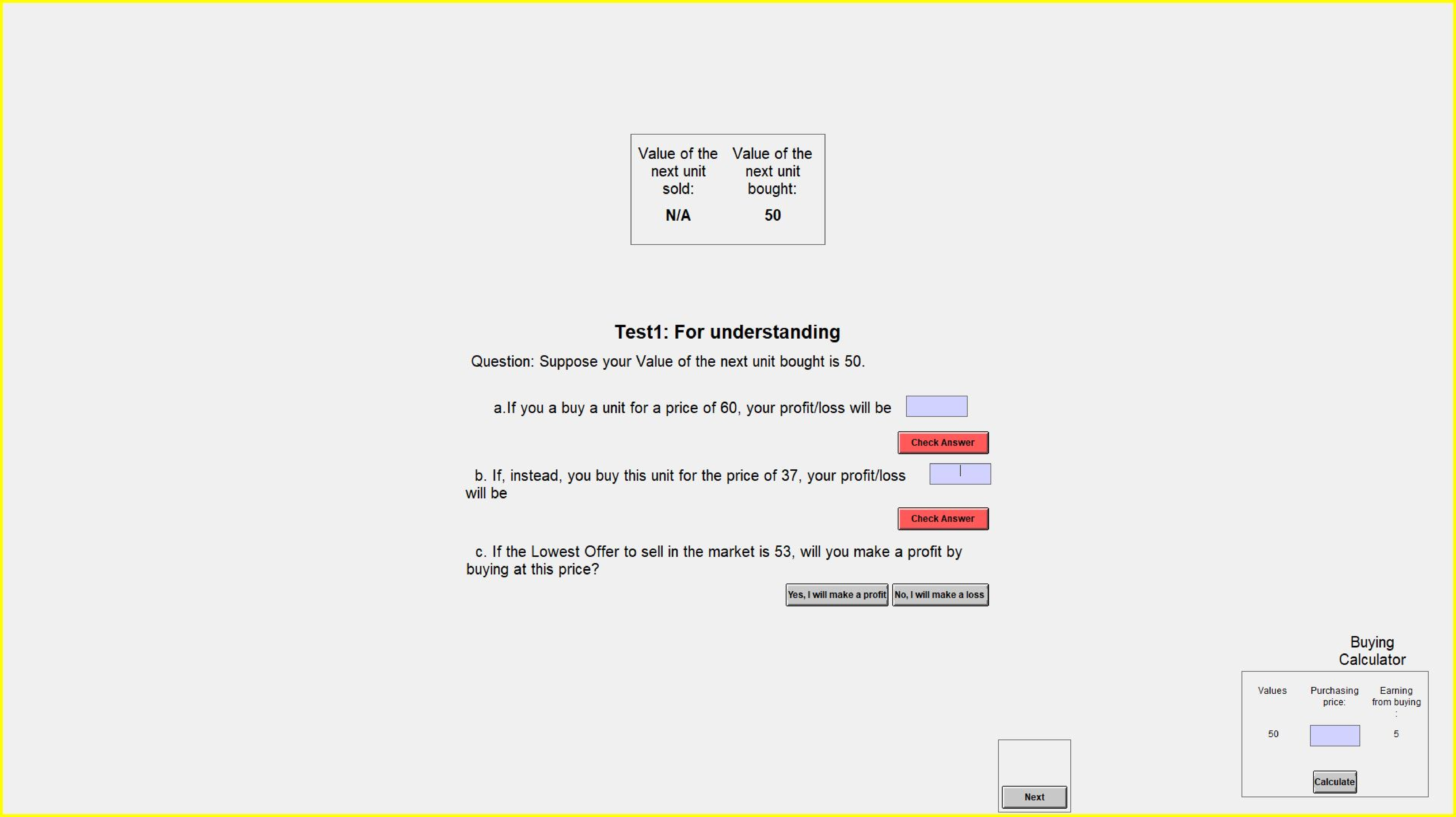
Your earnings from the most recent purchase will be diplayed in the upper right corner of your trading screen, as in the following example:

After you buy a unit, the word "HOLD" will appear next to the unit you bought in the Values table.

You may buy multiple units in the same period. The earnings from each purchase will be added to your total earnings during the peiod.

Buying Calculator

Values:	Purchasing Price	Earning from buying :
35		0



Value of the next unit sold:	Value of the next unit bought:
N/A	**50**

Test1: For understanding

Question: Suppose your Value of the next unit bought is 50.

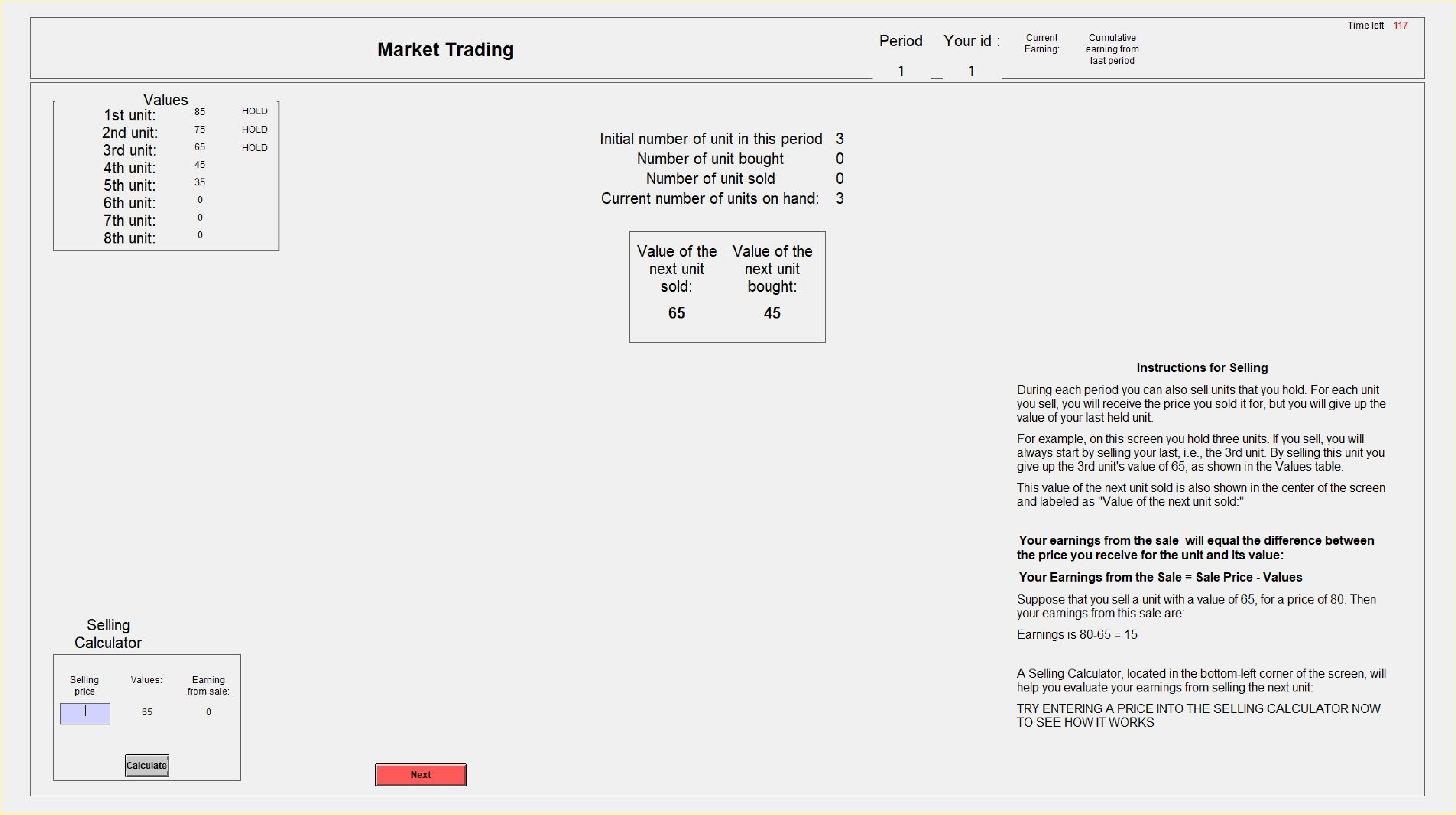
a.If you a buy a unit for a price of 60, your profit/loss will be

b. If, instead, you buy this unit for the price of 37, your profit/loss will be

c. If the Lowest Offer to sell in the market is 53, will you make a profit by buying at this price?

Buying Calculator

Values	Purchasing price:	Earning from buying :
50		5



Time left 117

Market Trading

Period	Your id :	Current Earning:	Cumulative earning from last period
1	1		

Values

1st unit:	85	HOLD
2nd unit:	75	HOLD
3rd unit:	65	HOLD
4th unit:	45	
5th unit:	35	
6th unit:	0	
7th unit:	0	
8th unit:	0	

Initial number of unit in this period	3
Number of unit bought	0
Number of unit sold	0
Current number of units on hand:	3

Value of the next unit sold:	Value of the next unit bought:
65	**45**

Instructions for Selling

During each period you can also sell units that you hold. For each unit you sell, you will receive the price you sold it for, but you will give up the value of your last held unit.

For example, on this screen you hold three units. If you sell, you will always start by selling your last, i.e., the 3rd unit. By selling this unit you give up the 3rd unit's value of 65, as shown in the Values table.

This value of the next unit sold is also shown in the center of the screen and labeled as "Value of the next unit sold:"

Your earnings from the sale will equal the difference between the price you receive for the unit and its value:

Your Earnings from the Sale = Sale Price - Values

Suppose that you sell a unit with a value of 65, for a price of 80. Then your earnings from this sale are:

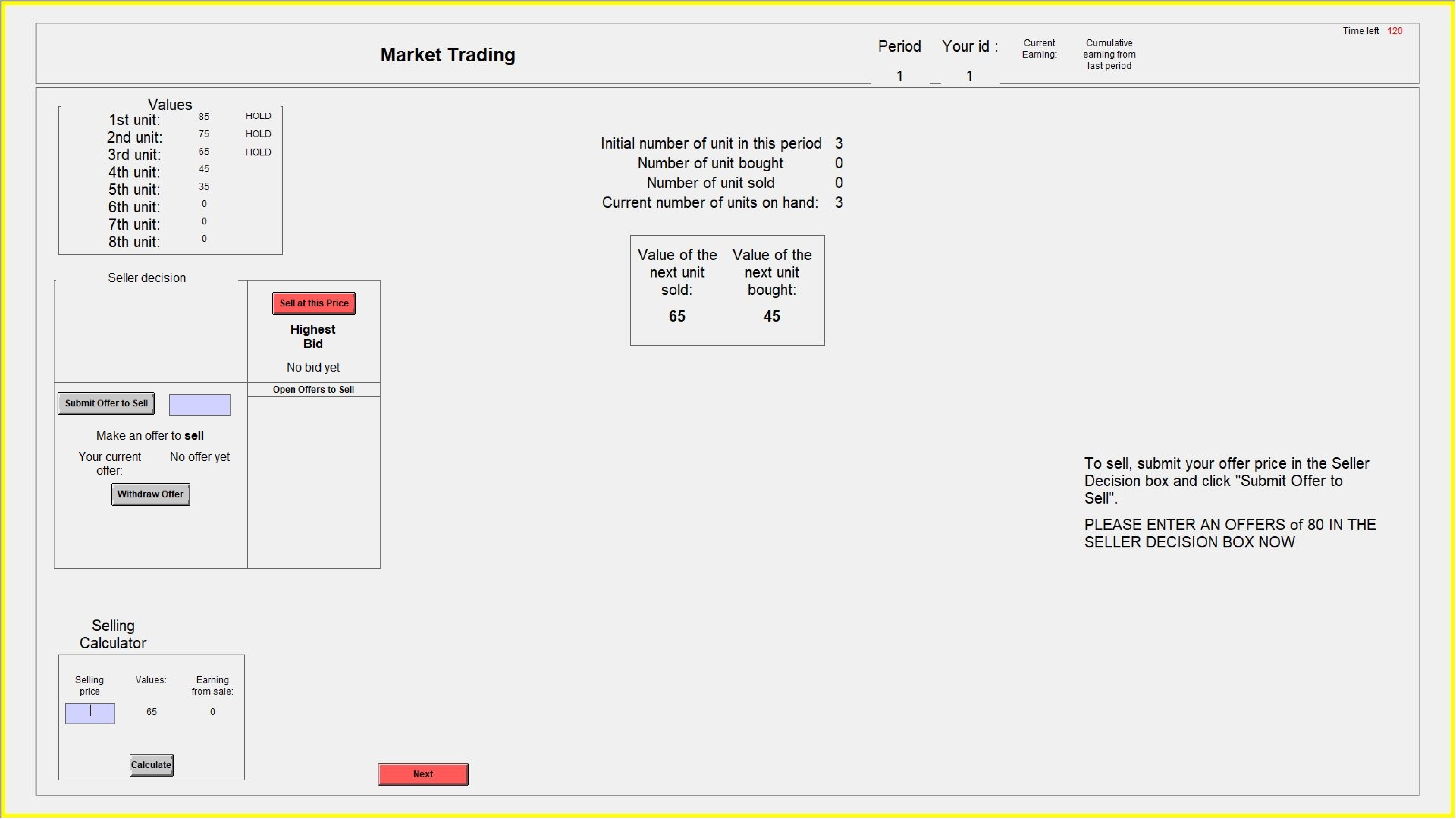
Earnings is 80-65 = 15

A Selling Calculator, located in the bottom-left corner of the screen, will help you evaluate your earnings from selling the next unit:

TRY ENTERING A PRICE INTO THE SELLING CALCULATOR NOW TO SEE HOW IT WORKS

Selling Calculator

Selling price	Values:	Earning from sale:
	65	0



Market Trading

Period 1
Your id : 1
Current Earning:
Cumulative earning from last period

Time left 120

Values

1st unit:	85	HOLD
2nd unit:	75	HOLD
3rd unit:	65	HOLD
4th unit:	45	
5th unit:	35	
6th unit:	0	
7th unit:	0	
8th unit:	0	

Initial number of unit in this period 3
Number of unit bought 0
Number of unit sold 0
Current number of units on hand: 3

Value of the next unit sold:	Value of the next unit bought:
65	45

Seller decision

Highest Bid

No bid yet

Open Offers to Sell

Make an offer to **sell**

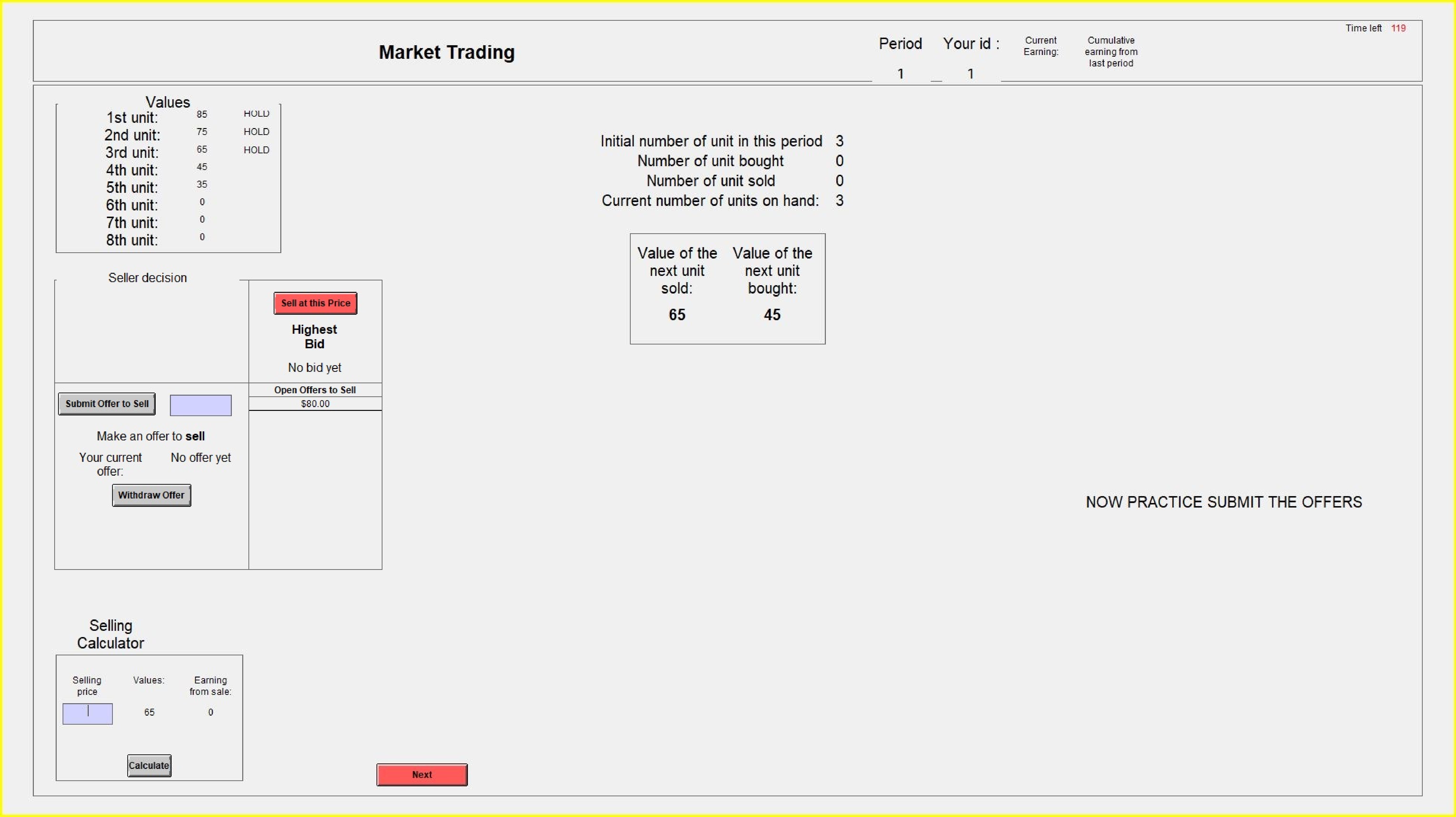
Your current offer: No offer yet

Selling Calculator

Selling price	Values:	Earning from sale:
	65	0

To sell, submit your offer price in the Seller Decision box and click "Submit Offer to Sell".

PLEASE ENTER AN OFFERS of 80 IN THE SELLER DECISION BOX NOW



Time left 119

Market Trading

Period 1

Your id : 1

Current Earning:

Cumulative earning from last period

Values

1st unit:	85	HOLD
2nd unit:	75	HOLD
3rd unit:	65	HOLD
4th unit:	45	
5th unit:	35	
6th unit:	0	
7th unit:	0	
8th unit:	0	

Initial number of unit in this period 3
Number of unit bought 0
Number of unit sold 0
Current number of units on hand: 3

Value of the next unit sold:	Value of the next unit bought:
65	45

Seller decision

Highest Bid

No bid yet

Open Offers to Sell

$80.00

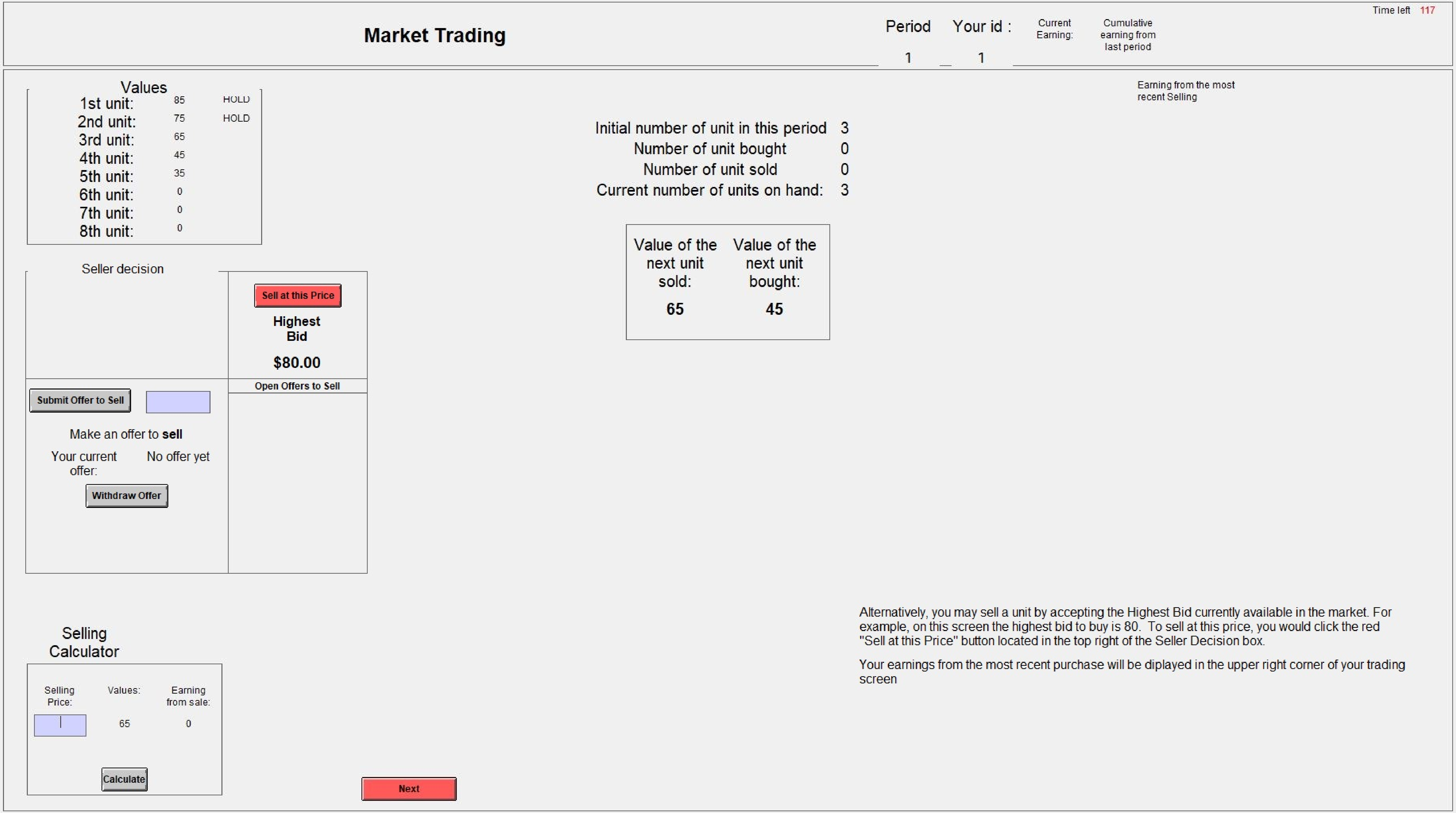
Make an offer to **sell**

Your current offer: No offer yet

NOW PRACTICE SUBMIT THE OFFERS

Selling Calculator

Selling price	Values:	Earning from sale:
	65	0



Market Trading

Time left 117

Period	Your id :	Current Earning:	Cumulative earning from last period
1	1		

Earning from the most recent Selling

Values

1st unit:	85	HOLD
2nd unit:	75	HOLD
3rd unit:	65	
4th unit:	45	
5th unit:	35	
6th unit:	0	
7th unit:	0	
8th unit:	0	

Initial number of unit in this period 3
Number of unit bought 0
Number of unit sold 0
Current number of units on hand: 3

Value of the next unit sold:	Value of the next unit bought:
65	45

Seller decision

Highest Bid

$80.00

Make an offer to **sell**

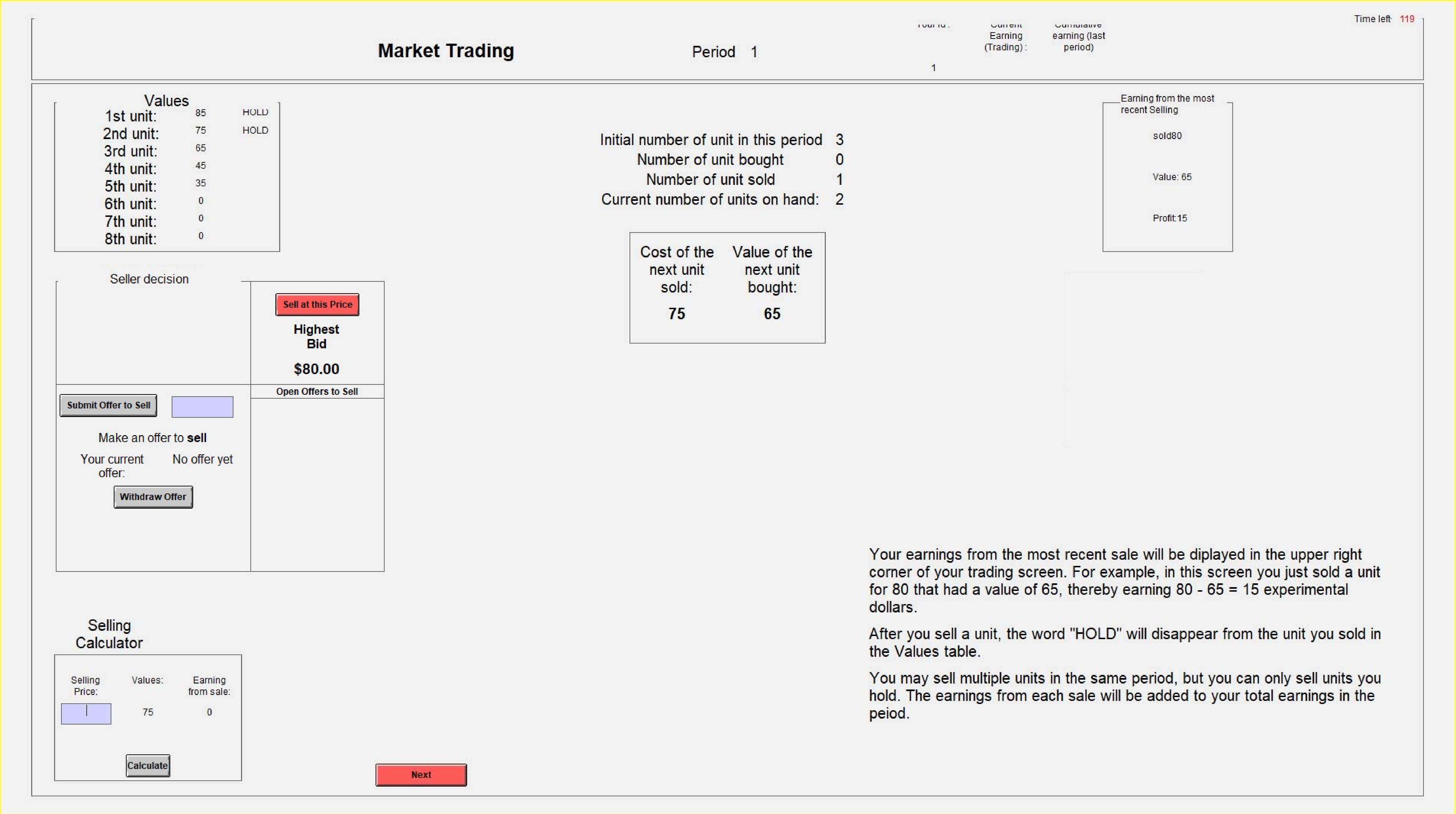
Your current offer: No offer yet

Selling Calculator

Selling Price:	Values:	Earning from sale:
	65	0

Alternatively, you may sell a unit by accepting the Highest Bid currently available in the market. For example, on this screen the highest bid to buy is 80. To sell at this price, you would click the red "Sell at this Price" button located in the top right of the Seller Decision box.

Your earnings from the most recent purchase will be diplayed in the upper right corner of your trading screen



Your id : 1

Values

1st unit:	85	HOLD
2nd unit:	75	HOLD
3rd unit:	65	
4th unit:	45	
5th unit:	35	
6th unit:	0	
7th unit:	0	
8th unit:	0	

Initial number of unit in this period 3
Number of unit bought 0
Number of unit sold 1
Current number of units on hand: 2

Cost of the next unit sold:	Value of the next unit bought:
75	65

Earning from the most recent Selling
sold80
Value: 65
Profit:15

Highest Bid $80.00

Make an offer to **sell**

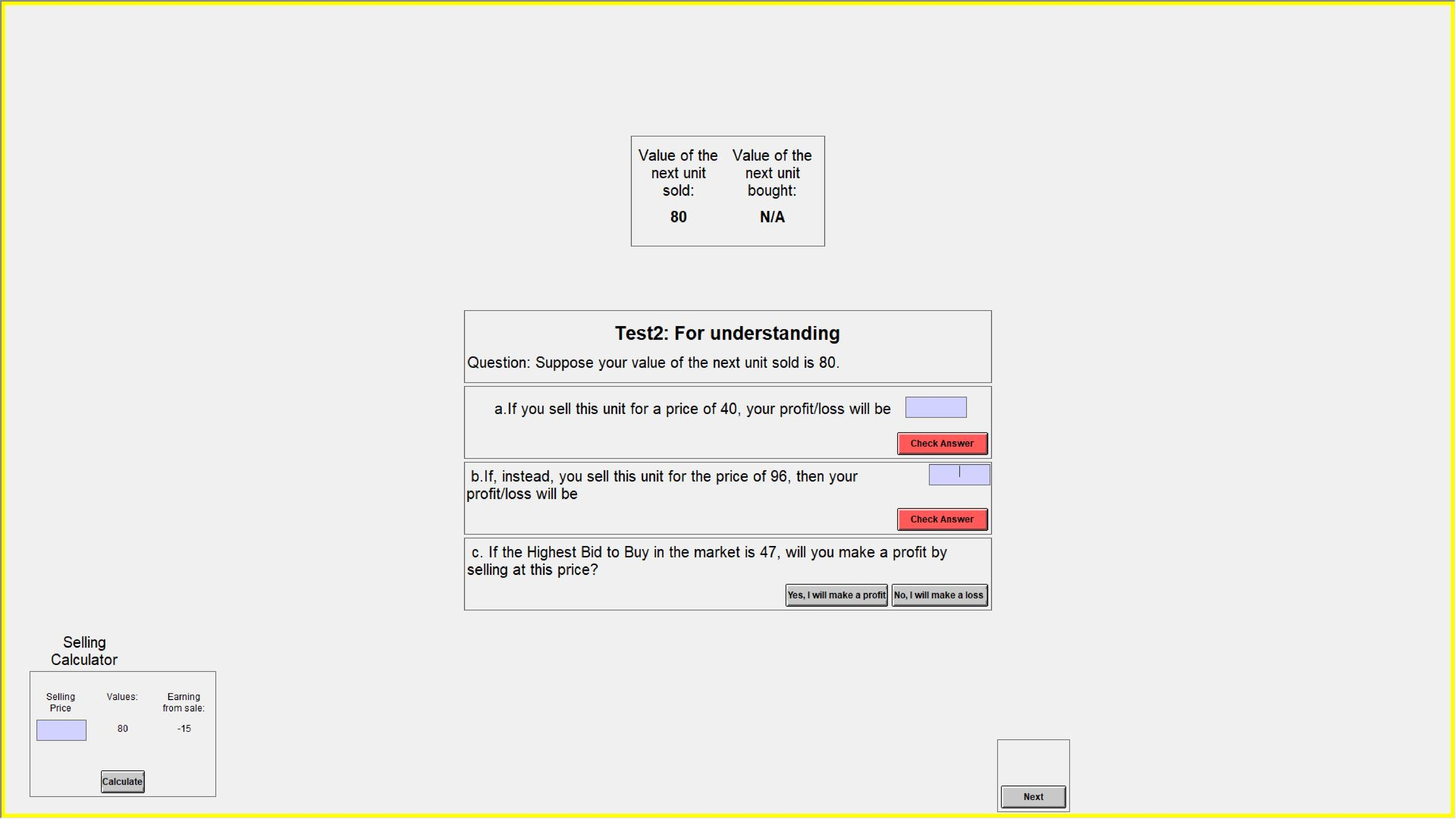
Your current offer: No offer yet

Selling Price:	Values:	Earning from sale:
	75	0

Your earnings from the most recent sale will be diplayed in the upper right corner of your trading screen. For example, in this screen you just sold a unit for 80 that had a value of 65, thereby earning 80 - 65 = 15 experimental dollars.

After you sell a unit, the word "HOLD" will disappear from the unit you sold in the Values table.

You may sell multiple units in the same period, but you can only sell units you hold. The earnings from each sale will be added to your total earnings in the peiod.



Value of the next unit sold:	Value of the next unit bought:
80	**N/A**

Test2: For understanding

Question: Suppose your value of the next unit sold is 80.

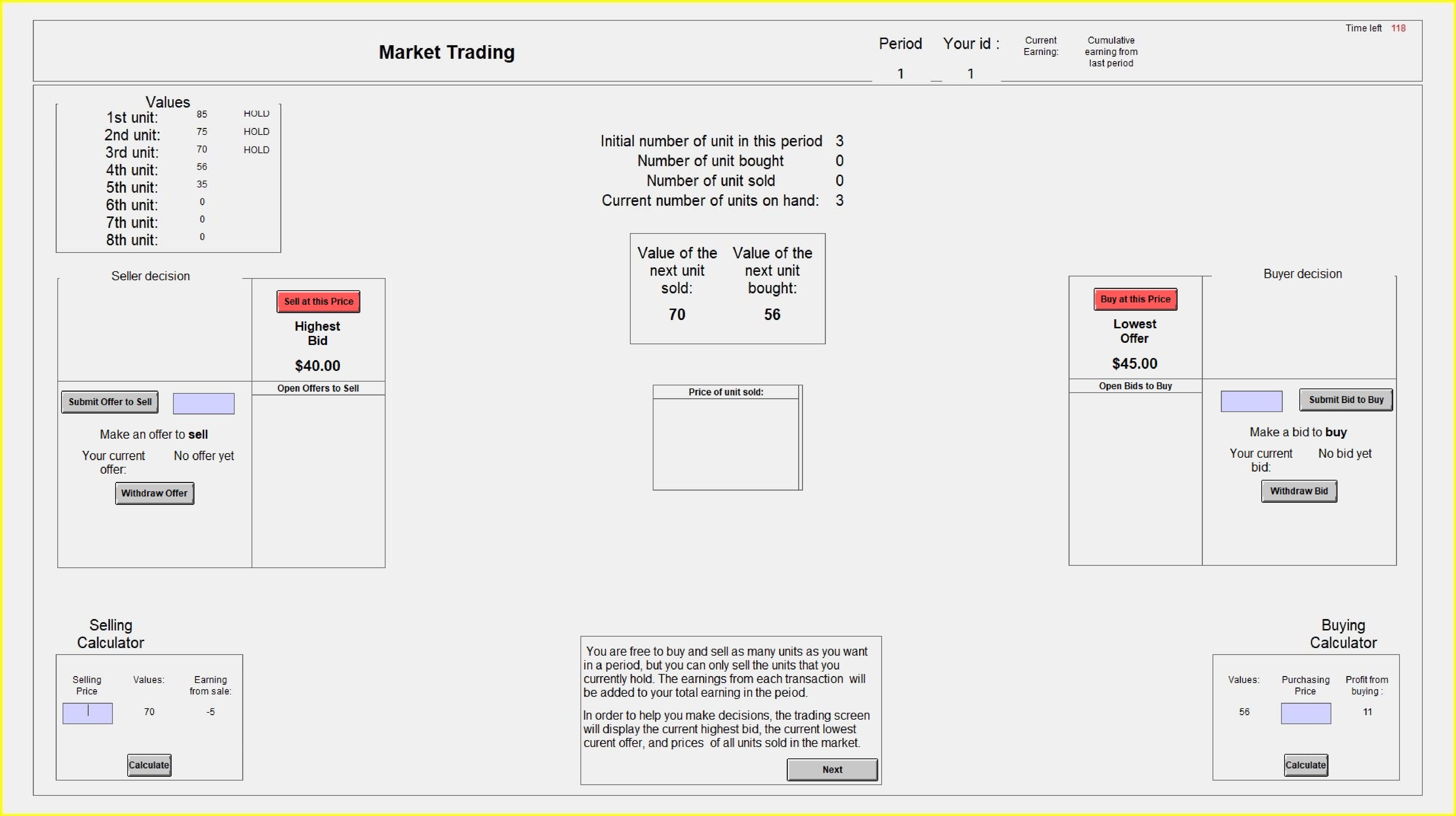
a.If you sell this unit for a price of 40, your profit/loss will be

b.If, instead, you sell this unit for the price of 96, then your profit/loss will be

c. If the Highest Bid to Buy in the market is 47, will you make a profit by selling at this price?

Selling Calculator

Selling Price	Values:	Earning from sale:
	80	-15



Market Trading

Period 1

Your id : 1

Current Earning:

Cumulative earning from last period

Time left 118

Values

1st unit:	85	HOLD
2nd unit:	75	HOLD
3rd unit:	70	HOLD
4th unit:	56	
5th unit:	35	
6th unit:	0	
7th unit:	0	
8th unit:	0	

Initial number of unit in this period	3
Number of unit bought	0
Number of unit sold	0
Current number of units on hand:	3

Value of the next unit sold:	Value of the next unit bought:
70	56

Highest Bid

$40.00

Your current offer: No offer yet

Lowest Offer

$45.00

Your current bid: No bid yet

Selling Calculator

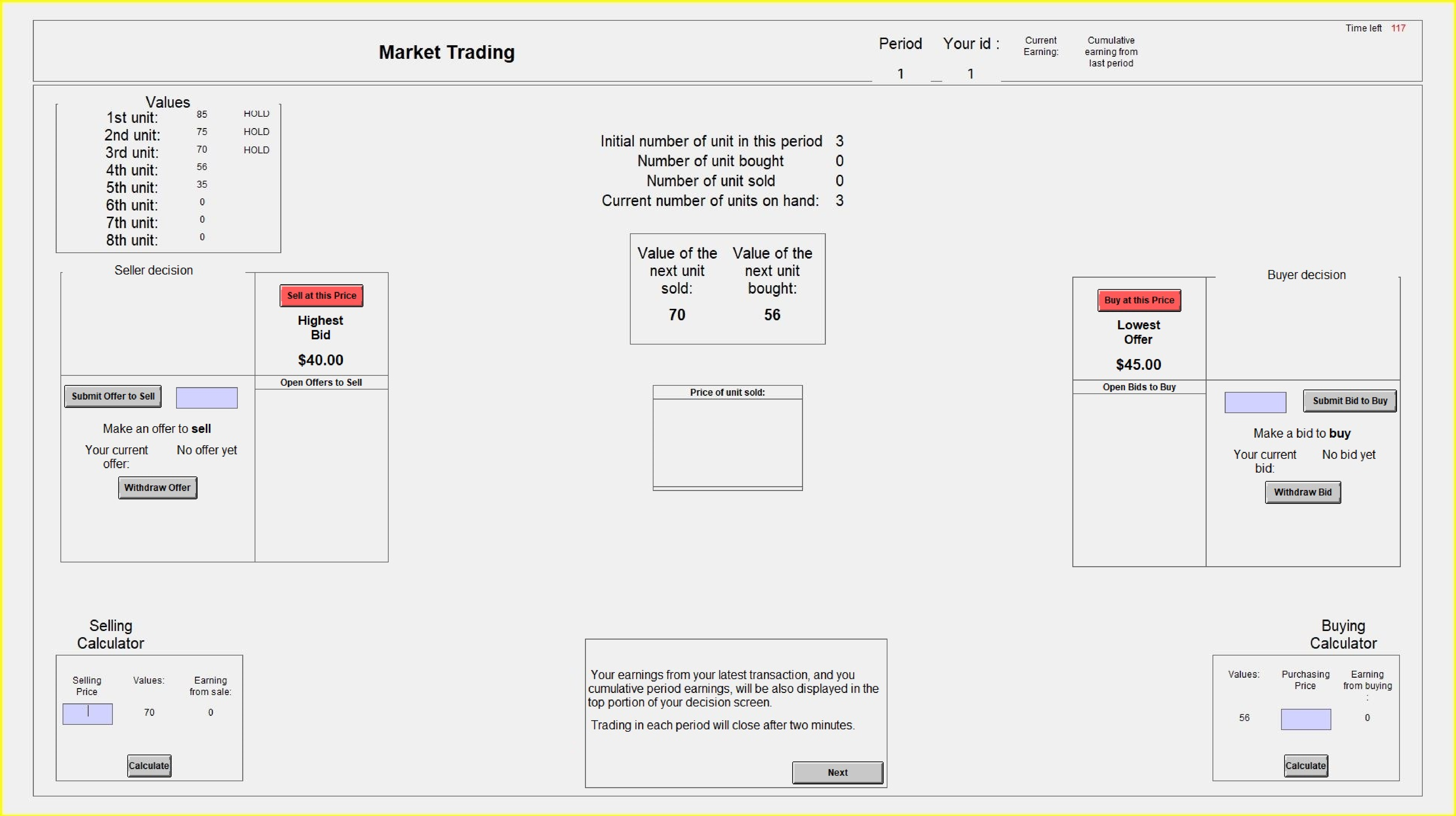
Selling Price	Values:	Earning from sale:
	70	-5

Buying Calculator

Values:	Purchasing Price	Profit from buying :
56		11

You are free to buy and sell as many units as you want in a period, but you can only sell the units that you currently hold. The earnings from each transaction will be added to your total earning in the peiod.

In order to help you make decisions, the trading screen will display the current highest bid, the current lowest curent offer, and prices of all units sold in the market.



Market Trading

Period: 1

Your id : 1

Current Earning:

Cumulative earning from last period

Time left 117

Values

1st unit:	85	HOLD
2nd unit:	75	HOLD
3rd unit:	70	HOLD
4th unit:	56	
5th unit:	35	
6th unit:	0	
7th unit:	0	
8th unit:	0	

Initial number of unit in this period 3

Number of unit bought 0

Number of unit sold 0

Current number of units on hand: 3

Value of the next unit sold:	Value of the next unit bought:
70	56

Seller decision

Highest Bid

$40.00

Make an offer to **sell**

Your current offer: No offer yet

Buyer decision

Lowest Offer

$45.00

Make a bid to **buy**

Your current bid: No bid yet

Price of unit sold:

Selling Calculator

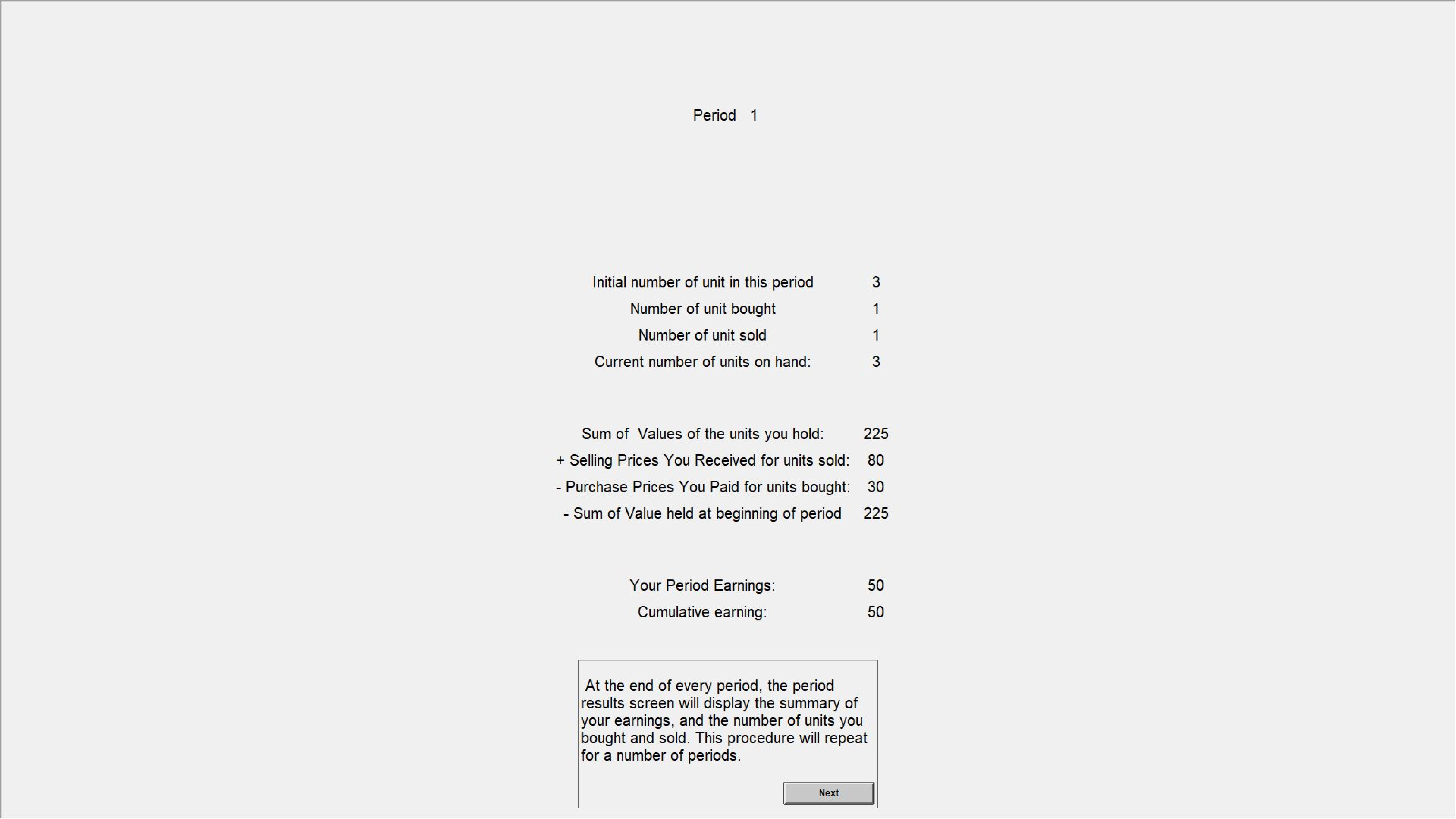
Selling Price	Values:	Earning from sale:
	70	0

Buying Calculator

Values:	Purchasing Price	Earning from buying :
56		0

Your earnings from your latest transaction, and you cumulative period earnings, will be also displayed in the top portion of your decision screen.

Trading in each period will close after two minutes.



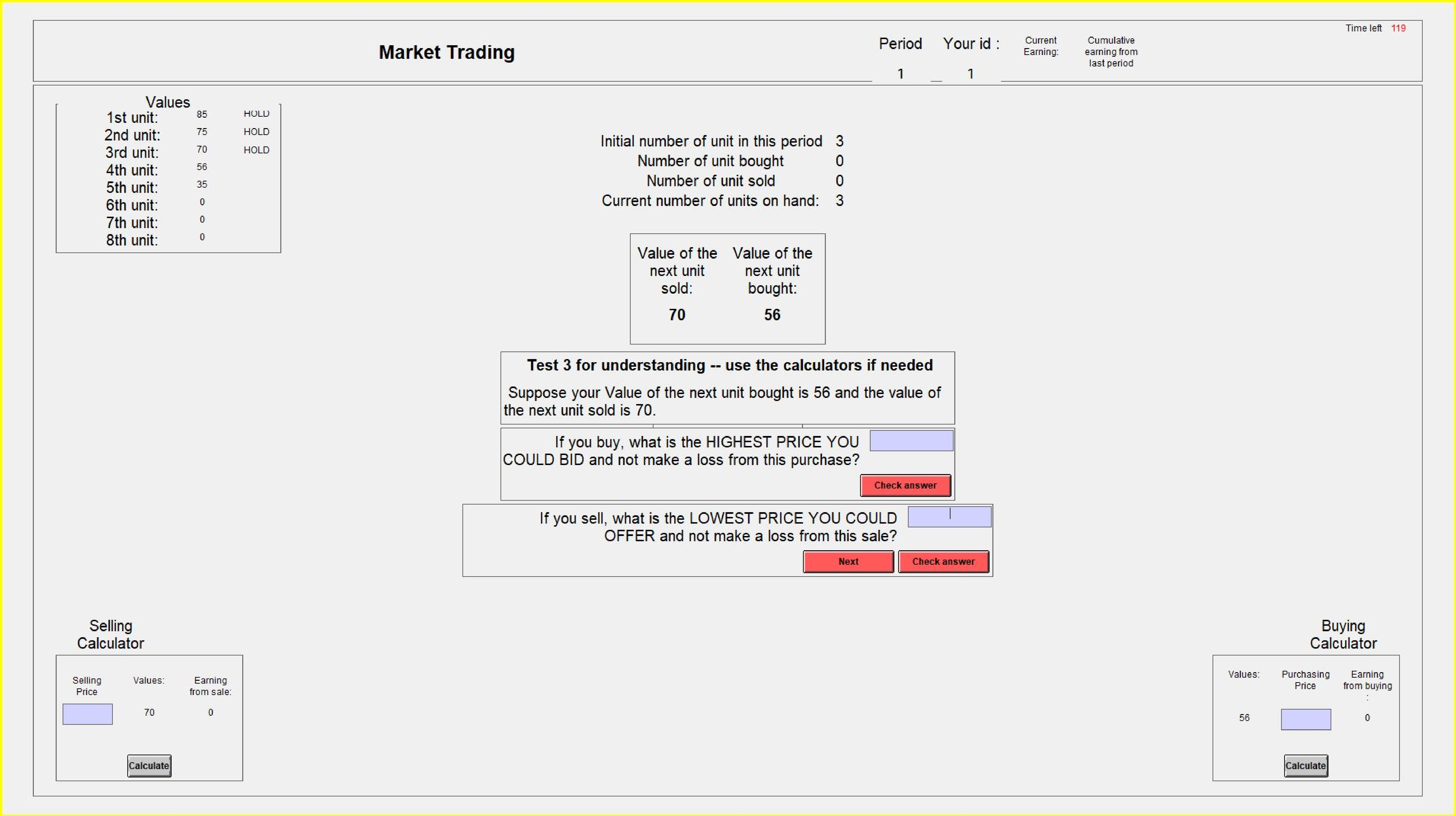
Period 1

Initial number of unit in this period	3
Number of unit bought	1
Number of unit sold	1
Current number of units on hand:	3

Sum of Values of the units you hold:	225
+ Selling Prices You Received for units sold:	80
- Purchase Prices You Paid for units bought:	30
- Sum of Value held at beginning of period	225

Your Period Earnings:	50
Cumulative earning:	50

At the end of every period, the period results screen will display the summary of your earnings, and the number of units you bought and sold. This procedure will repeat for a number of periods.



Market Trading

Period 1

Your id : 1

Current Earning:

Cumulative earning from last period

Values

1st unit:	85	HOLD
2nd unit:	75	HOLD
3rd unit:	70	HOLD
4th unit:	56	
5th unit:	35	
6th unit:	0	
7th unit:	0	
8th unit:	0	

Initial number of unit in this period	3
Number of unit bought	0
Number of unit sold	0
Current number of units on hand:	3

Value of the next unit sold:	Value of the next unit bought:
70	**56**

Test 3 for understanding -- use the calculators if needed

Suppose your Value of the next unit bought is 56 and the value of the next unit sold is 70.

If you buy, what is the HIGHEST PRICE YOU COULD BID and not make a loss from this purchase?

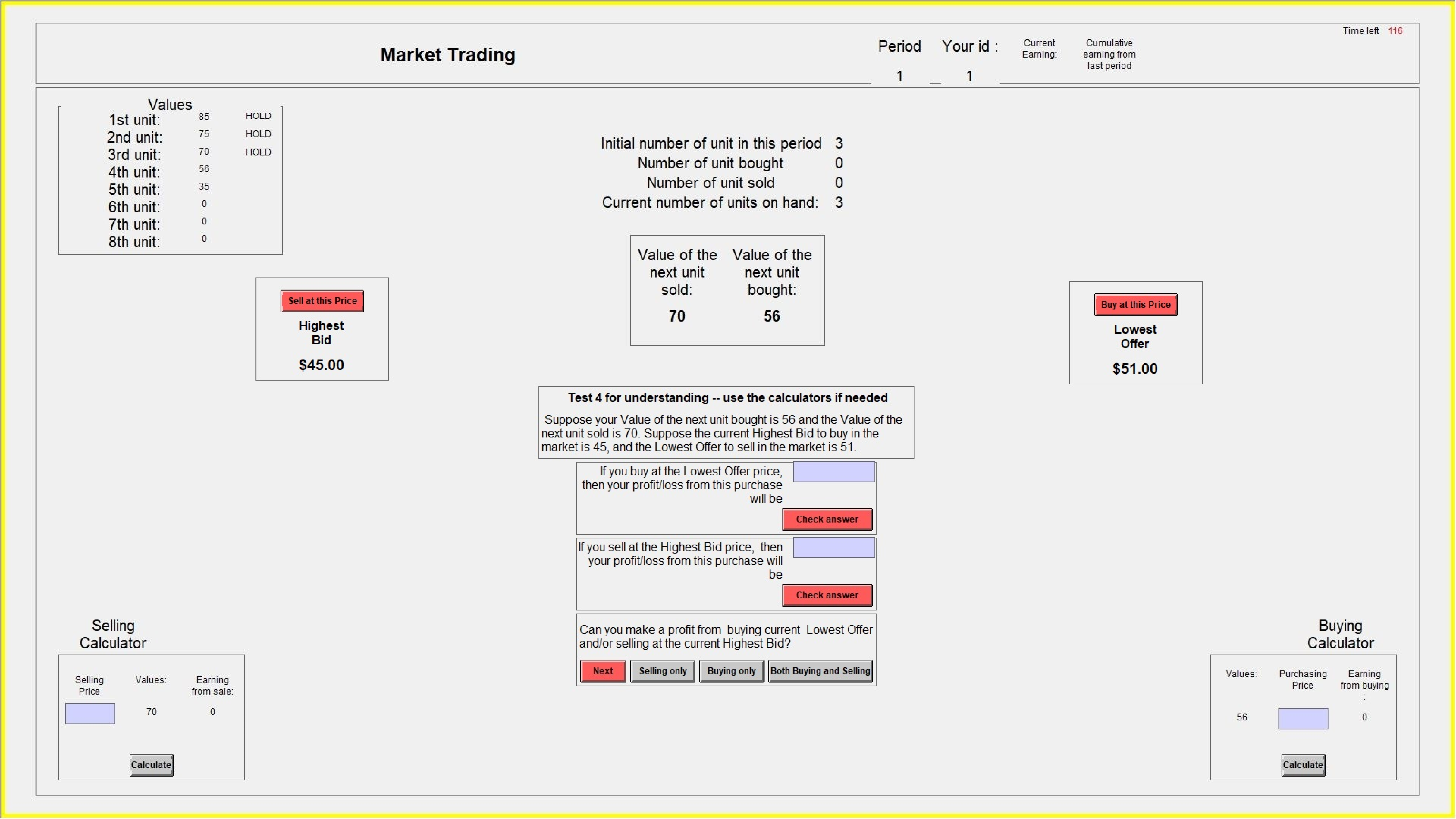
If you sell, what is the LOWEST PRICE YOU COULD OFFER and not make a loss from this sale?

Selling Calculator

Selling Price	Values:	Earning from sale:
	70	0

Buying Calculator

Values:	Purchasing Price	Earning from buying :
56		0



Market Trading

Period 1

Your id : 1

Current Earning:

Cumulative earning from last period

Time left 116

Values

1st unit:	85	HOLD
2nd unit:	75	HOLD
3rd unit:	70	HOLD
4th unit:	56	
5th unit:	35	
6th unit:	0	
7th unit:	0	
8th unit:	0	

Initial number of unit in this period	3
Number of unit bought	0
Number of unit sold	0
Current number of units on hand:	3

Value of the next unit sold:	Value of the next unit bought:
70	56

Highest Bid

$45.00

Lowest Offer

$51.00

Test 4 for understanding -- use the calculators if needed

Suppose your Value of the next unit bought is 56 and the Value of the next unit sold is 70. Suppose the current Highest Bid to buy in the market is 45, and the Lowest Offer to sell in the market is 51.

If you buy at the Lowest Offer price, then your profit/loss from this purchase will be

If you sell at the Highest Bid price, then your profit/loss from this purchase will be

Can you make a profit from buying current Lowest Offer and/or selling at the current Highest Bid?

Selling Calculator

Selling Price	Values:	Earning from sale:
	70	0

Buying Calculator

Values:	Purchasing Price	Earning from buying :
56		0

ARE THERE ANY QUESTIONS?

Next