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Abstract

We study default and endogenous leverage in the laboratory. To this purpose, we develop a general equilibrium model of collateralized borrowing amenable to laboratory implementation and gather experimental data. In the model, leverage is endogenous: agents choose how much to borrow using a risky asset as collateral, and there are no ad hoc collateral constraints. When the risky asset is financial—namely, its payoff does not depend on ownership (such as a bond)—collateral requirements are high and there is no default. In contrast, when the risky asset is nonfinancial—namely, its payoff depends on ownership (such as a firm)—collateral requirements are lower and default occurs. The experimental outcomes are in line with the theory's main predictions. The type of collateral, whether financial or not, matters. Default rates and loss from default are higher when the risky asset is nonfinancial, stemming from laxer collateral requirements. Default rates and collateral requirements move closer to the theoretical predictions as the experiment progresses.

Key words: collateral, default, double auction, experimental economics, leverage

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1 Introduction

Since the recent financial crisis, there has been a renewed academic interest in collateralized debt markets. One important question is understanding how markets set collateral requirements and whether collateralization is enough to prevent default.

In a recent paper, Fostel and Geanakoplos (2015) (FG) characterize equilibrium leverage and default in binomial economies with collateralized lending, incomplete markets, and financial assets serving as collateral.[1] FG defines a financial asset as an asset that does not provide direct utility to agents, and whose payoffs do not depend on ownership. Examples of financial assets are common stocks and bonds; in contrast, examples of non-financial assets are houses, which provide direct utility, and productive assets such as land and firms, whose payoff depends on the managerial skills of their owners.[2] In the FG economy, collateral is the only enforcement mechanism; as a result, debt contracts are non recourse, that is, they default whenever they promise more than the value of the collateral. FG show that if only one equilibrium exists, there is no default. The only debt contract traded (the "max-min" contract) promises the value of the collateral in the worst state of the world, thus assuring that collateral requirements (the amount of collateral per unit of promise) are enough to guarantee delivery. If there are other equilibria involving default, they are all equivalent, in terms of prices and real allocations, to the no-default equilibrium. Hence, the possibility of default impacts equilibrium (because lenders require collateral to back promises, thereby affecting real allocations), yet actual default does not (because all equilibria are equivalent). Finally, FG also show that, with very realistic frictions (e.g., when sourcing collateral is costly), all default equilibria disappear and the max-min contract is the only debt contract traded.

One key assumption in FG is that all assets serving as collateral are financial. When

[1] For a literature review on collateralized borrowing in general equilibrium models, see Fostel and Geanakoplos (2014).

[2] Note that there are assets that are generally thought of as financial but are not financial according to FG's definition (e.g., a bond taxed at different rates according to country of residency); similarly, "Lucas trees" are financial assets according to this definition.

assets serving as collateral are non financial, theory does not guarantee the existence of a non default equilibrium; moreover, default generally occurs as long as agents' incentives to borrow are strong enough, and it affects prices and real allocations. Indeed, several papers in the collateral general equilibrium literature provide robust examples of default equilibria when such assumptions are violated.[3] As FG write, their results "may explain why there are some markets (like mortgages) in which defaults are to be expected, while in others (like repos) margins are set so strictly that default is almost ruled out."[4]

In this paper, we study collateral requirements and default in a controlled experiment; guided by the theory, we contrast laboratory outcomes when the asset used as collateral is financial and when it is not. In the laboratory, we can address this question by having subjects trade a financial and a non-financial asset, while keeping constant subjects' asset valuations. This obviously cannot be done with field data (for instance, there are several institutional reasons why default rates on repo contracts and land-backed mortgages may differ).

To this purpose, we develop a model that retains the crucial features of FG, but it is simple enough to be implemented in the laboratory. More precisely, we consider a binomial economy where agents can issue debt contracts using a risky asset as collateral. Agents are allowed to borrow as much as they wish using collateral; collateral requirements are endogenously determined in equilibrium. We study two economies: in the "Financial-Asset economy" (from now on, FA-economy), the asset is financial; in the "Non-Financial Asset economy" (from now on, NFA-economy) the asset is not financial. Under both specifications, the equilibrium is unique. As FG predict, in the FA-economy, the only debt contract traded is the max-min debt contract, and there is no default. In contrast, in the NFA-economy, equilibrium collateral requirements are lower and therefore there is default: agents trade promises that exceed the collateral payoff in the low state of world. Importantly, agents' asset valuations are the same across economies, and agents are able to borrow as much as they want; nevertheless, when assets are non financial, equilibrium borrowing, leverage, and asset prices are higher.

We bring the model to the laboratory by having students play in a double auction experiment with collateralized borrowing. We implement the two economies with two different treatments, the "FA-treatment" and the "NFA-treatment." In bring-

[3]See for example Geanakoplos (1997), Fostel and Geanakoplos (2012), Simsek (2013).
[4]See for instance, Baklanova *et al.*, 2019.

ing the model to the laboratory, we face two important challenges. First, in the theoretical model, borrowing and lending occur through several collateralized debt contracts, each traded in a separate market and with its own price. Setting up a double auction with simultaneous trading in several debt markets is hard (see for instance, Asparouhova, 2006); in our experiment, the problem is compounded by the presence of the collateral requirement tying these markets together. Our solution is to link the credit and asset market in the double auction: subjects post orders that determine their simultaneous position in both the asset and the credit market. Second, most of the double-auction experiments on asset markets use non-financial assets in order to generate gains from trade. In the FA-treatment, we create gains from trade through heterogeneous beliefs. Implementing belief heterogeneity in the laboratory is hard, because of the general disfavor toward lying to subjects in experimental economics. Our solution is to allow for the realized state of the world to be different for Buyers and Sellers, while at the same time keeping subjects' incentives aligned with those of the theory.

The experimental outcomes are in line with the theory's main predictions. The type of collateral, whether financial or not, matters. Default rates are higher in the NFA-treatment than in the FA-treatment. Although, in contrast to the theory, default occurs also in the FA-treatment, the losses from default are much lower. Lower default rates and default losses stem from stricter collateral requirements: to issue the same debt contract, subjects need to post twice as much collateral in the FA versus the NFA-treatment. Note that, as theory predicts, default does not prevent trading: indeed, in both treatments gains from trade are fully realized. Default rates and collateral requirements converge to the theoretical prediction as the experiment progresses: subjects learn that whether an asset is financial matters for its collateral capacity even though subjects value financial and non-financial assets the same. Finally, theory predicts that, in both treatments, Buyers should use all their cash as downpayment. In the laboratory, this happens in the FA-treatment but not in the NFA-treatment, where Buyers end up with positive cash balances while at the same time borrowing; we relate this result to the non-recourse nature of the contracts.

This paper belongs to a large literature in experimental finance, starting with Smith (1962), testing asset pricing models in a laboratory financial market where subjects trade in a double auction. For instance, Bossaert *et al.* (2007) find empirical support for the CAPM in a double auction experiment; Crokett *et al.* (2018) use a double auction to study a Lucas-tree model. This literature generally finds that double-auctions converge to the equilibrium of the underlying theoretical model (see, e.g., Asparouhova *et al.*, 2003, Bossaerts and Plott, 2008, Plott, 2008).[5] Recently, Cipriani *et al.* (2012 and 2018) have studied the asset-pricing implication of collateralized borrowing in a laboratory financial market: as predicted by the theoretical literature (see, for instance, Fostel and Geanakoplos, 2008 and Geanakoplos and Zame, 2014), leverage is priced and creates deviations from the Law of One Price. In contrast to our paper, in Cipriani *et al.* (2012 and 2018), leverage is exogenously set by the experimenter, there is only one type of collateral, and, by construction, default never occurs.

The paper is organized as follows. Section 2 develops the theoretical model. Section 3 describes the experimental design and experimental procedures. Section 4 presents the results. Section 5 concludes. All supplementary material is presented in the Appendix.

2 Theory

2.1 The Financial Asset Economy

2.1.1 The Model

There are two periods, $t = 0, 1$. At time 1, there are two states of the world, $s = H$ and $s = L$, (High and Low). In the economy, there is a continuum of risk-neutral agents with unit mass; there are two types of agents, $i = B$ and $i = S$, (Buyers and Sellers). Buyers and Sellers have different beliefs about the probability of state High, q^i for $i \in B, S$.

There are two assets in the economy, cash and a risky asset Y (from now on, "the asset") with payoffs in units of cash. The asset payoff in state $s = H, L$ is given by D_s, with $D_H > D_L$. We denote by p the price of Y in terms of cash (the numeraire) at time 0.

At $t = 0$, agents of type i are endowed with m^i units of cash and a^i units of the asset. An investor's payoff measured in units of cash in each state $s = H, L$ is denoted by ω_s^i. Agent of type $i \in I$ maximizes their expected payoff given by

[5] Convergence is not a feature of the double auction per se; indeed, Crockett *et al.*, 2011, provide an example in which a double auction does not converge to equilibrium because theory predicts it should not.

$$U^i = q^i \omega^i_H + (1 - q^i)\omega^i_L. \quad (1)$$

In addition to trading the asset, agents can borrow and lend through collateralized (non-contingent) debt contracts. Since the only repayment enforcement mechanism is collateral, all borrowing must be collateralized, otherwise agents would have no incentive to repay. Agents can borrow and lend through collateralized debts contracts indexed by $j \in J$, where $J = R_+$ is the set of all available debt contracts. Each debt contract j is a non-contingent promise to pay j at time 1 backed by one unit of asset Y serving as collateral; only the seller (borrower) of the debt contract needs to post collateral, the buyer (borrower) does not.[6] Hence, $\frac{1}{j}$ is the collateral requirement for each dollar the seller of contract j promises to pay at time 1. Note that, in the traditional general equilibrium model with no collateral requirements, a debt contract is fully characterized by the non-contingent promise alone. In a one-period economy, there is only one debt contract; the market for this contract clears at a price (and interest rate) in equilibrium. In contrast, in collateral general equilibrium, each debt contract $j \in J$ is characterized by both its promise and the collateral backing it. Even in a one-period economy, each debt contract j with the associated collateral requirement $\frac{1}{j}$ is a different financial contract. Each debt contract is traded in a different market, with its own equilibrium price and interest rate. In equilibrium, all debt contracts $j \in J$ are priced, although only a subset may be actually traded.[7]

We assume that the debt contract is non-recourse: the maximum borrowers can lose if they do not honor their promise is their collateral.[8] As a result, agents will never choose to repay more than the value of the collateral. In each state $s \in \{H, L\}$, the *actual delivery* of a contract j is given by

$$min\{j, D_s\}. \quad (2)$$

Whenever $j > D_s$, the borrower pays less than the full promise j in state s, and hence defaults on the obligation. In other words, in this economy, a debt contract will default in all states in which the promise j is greater than the value of the

[6] One could think of the debt contract as a zero-coupon bond, where j is the face value of the bond.

[7] In the collateral general equilibrium literature, the terms of a financial contract are summarized by the ordered pair (A_j, C_j). The first component, A_j denotes the promise in each terminal state. The second component, C_j, denotes the assets used as collateral to back the promise.

[8] That is, lenders do not have the right to seize anything beyond the collateral backing a promise.

collateral.

Denote by b_j the price of the debt contract j at time 0: an agent can borrow b_j units of cash today by selling the debt contract j (promising to pay j tomorrow). Similarly, an agent can lend b_j units of cash today by purchasing the debt contract promising to pay j tomorrow. The interest rate associated to a debt contract j is $r_j = \frac{(j-b_j)}{b_j}$. If the promise j is smaller than or equal to D_L, the contract never defaults; in this case, r_j is the riskless interest rate.

Denote by φ^i_j the number of debt contracts j agent i decides to buy or sell; if $\varphi^i_j > 0$, the agent is buying debt contracts j and hence lending cash; if $\varphi^i_j < 0$, the agent is selling debt contracts j and hence borrowing cash. Given the asset and debt contract prices $(p, (b_j)_{j\in J})$, at time 0, each investor i decides cash holdings, $w \geq 0$, asset holdings, $y \geq 0$, and debt contract trades, φ_j, to maximize (1) subject to the budget constraint:

$$py + w \leq pa^i + m^i - \sum_{j\in J}(\varphi_j)b_j, \tag{3}$$

and the collateral constraint:

$$\sum_{j\in J} max(-\varphi_j, 0) \leq y. \tag{4}$$

The budget constraint states that the value of cash and asset holdings cannot exceed the value of initial endowments (of cash and the risky asset) plus the proceeding of any net collateralized borrowing.[9] The collateral constraint states that if an agent borrows, they must hold the required collateral at time 0. In particular, if an agent borrows by selling debt contract j, so that $\varphi_j < 0$, they need to hold one unit of asset Y as collateral per debt contract sold. Hence, the total amount of debt contracts sold, among all potential debt contracts available to be traded, cannot exceed their total asset holdings y.[10]

Agent i's final payoff in state $s \in \{H, L\}$ is equal to the sum of their final cash holdings and the payoff accruing from their asset holdings plus the delivery of their net lending:[11]

[9] If $\sum_{j\in J}(\varphi_j)b_j < 0$, the agent is a net borrower.

[10] If an agent is lending, and hence buying a debt contract, the collateral constraint (4) is trivially satisfied: $\varphi_j > 0$ and $y \geq 0$ (since short sales of the risky assets are not allowed).

[11] If the agent is a net borrower, then $\sum_{j\in J}(\varphi_j)min\{j, D_s\} < 0$, reflecting the repayment at time 1.

$$\omega_s^i = w + yD_s + \sum_{j \in J}(\varphi_j) min\{j, D_s\}.$$

A *Collateral Equilibrium* consists of asset price, debt contract prices, individual cash holdings, asset holdings, and contract trades such that agents maximize their utility (1) subject to their budget (3) and collateral constraint (4), and all markets clear.[12]

In our model, agents face a menu of debt contracts $j \in J$, each promising j and collateralized by one unit of Y. Taking the price of each contract, b_j, as given, they choose which contracts to trade; in other words, collateral requirements are endogenous. Moreover, since collateral is scarce, only a few (or even only one contract as we will see below) will be actively traded in equilibrium.

2.1.2 Parameter Values and Equilibrium Analysis.

Table 1 shows the parameter values we use when implementing the FA-economy in the laboratory.

Table 1: FA-economy Parameterization.

Parameters	D_H	D_L	q^B	q^S	m^B	m^S	a^B	a^S
Values	500	100	0.8	0.2	300	0	0	3

This table shows the parameter values of the FA-economy.

In this economy, the risky asset is a financial asset, since its payoffs do not depend on ownership. As shown in Table 1, the asset payoff is $D_L = 100$ in state Low and $D_H = 500$ in state High for both Buyers and Sellers. Agents have different beliefs about the likelihood of the states of the world. Buyers are more optimistic than Sellers: the probability of the state being High is $q^B = 0.8$ for Buyers and $q^S = 0.2$ for Sellers. Belief heterogeneity generates heterogeneity in agents' asset valuations (420 for Buyers and 180 for Sellers), which is needed for trading to occur. Finally, Buyers are endowed with all the cash, $m^B = 300$, whereas Sellers are endowed with all the risky assets, $a^S = 3$. Accordingly, Buyers are on the demand side and Sellers on the supply side of the asset market.[13]

[12]Our model does not allow for contingent financial contracts (e.g., short-selling). As a result, even if the number of available securities (assets and debt contracts) is larger than the number of states, they may not be fully span the state space (for example, it may not be possible to construct a security that only pays out in state Low). Because of this, the Collateral Equilibrium may not implement the Arrow-Debreu equilibrium, and hence markets are incomplete.

[13]The parameters are chosen so as to make the economy amenable to laboratory implementation.

The unique equilibrium in the FA-economy is described in Tables 2 and 3.[14]

Table 2: Equilibrium Collateral Requirements and Prices in the FA-economy.

Promise j	Asset Price p	Borrowing $b_{j=100}$	Interest rate $r_{j=100}$
100	200	100	0

This table shows the equilibrium promise, asset price, borrowing, and interest rate in the FA-economy.

Table 3: Equilibrium Allocations and Final Payoffs in the FA-economy.

	Buyers	Sellers
y	3	0
$\varphi_{j=100}$	-3	3
w	0	300
ω_H	1200	600
ω_L	0	600

This table shows equilibrium cash, asset holdings, and number of debt contracts traded in the FA-economy.

From FG, we know that there is an equilibrium in which the only debt contract traded is $j = 100$ (and the associated collateral requirement is $1/100$), and hence there is no default; in Appendix I, we show that this equilibrium is unique. Since agents are risk neutral and there is no discounting, the riskless interest rate is zero; therefore, the price of the riskless debt contract promising $j = 100$ (what Buyers actually borrow) is $b_{j=100} = 100$. The equilibrium asset price is 200.

Since Buyers' expected value (420) is greater than the equilibrium price, they buy as many units of the risky asset as they can afford (3 units) on margin: for each unit of the asset that they purchase, they borrow 100, and pay a downpayment of 100 to cover the price of 200. Hence, Buyers sell 3 debt contracts $j = 100$, backed by their total asset holding; this implies, at a zero interest rate, a total borrowing of 300. On the other hand, since Sellers' expected value of the asset, 180, is lower than the price, they sell all their endowment of the asset and lend to Buyers through debt contract $j = 100$ at a zero interest rate.

Buyers' final payoffs are 1200 and 0 in state High and Low respectively. The zero payoff in state Low results from Buyers leveraging the risky asset with a contract that promises the whole value of the collateral in state Low and holding no cash.

The model's predictions regarding leverage and default do not hinge on the extreme heterogeneity in endowments (Buyers hold all the cash and Sellers all the assets supply). Having Sellers and Buyers on only one side of the market simplifies the laboratory implementation considerably (see, for instance, in the double auction literature, Smith, 1962).

[14] See Appendix I for equilibrium analysis and uniqueness proof.

In contrast Sellers' final payoffs are constant across states (600), since Sellers sell all their risky asset endowment, and only hold riskless assets (cash and the $j = 100$ bond).

Finally, the rest of the equilibrium values, omitted from Tables 2 and 3, are $\varphi_j^i = 0$, $i = B, S$, $\forall j \neq 100$, and $b_j = q^S min\{j, 500\} + (1 - q^S) min\{j, 100\}$, $\forall j$. That is, all contracts with promise $j \neq 100$, although priced, are not traded in equilibrium: all contracts with promise $j < 100$ have an equilibrium price of $b_j = j$ and an interest rate of 0; all contracts with promise $100 < j < 500$ have an equilibrium price of $b_j = 0.2j + 0.8(100)$; all contracts with promise $j \geq 500$ have an equilibrium price of $b_j = 0.2(500) + 0.8(100) = 180$, the Seller's valuation of the risky assets. As explained in Appendix I, all contract prices are pinned down by lenders' (Sellers') zero expected profit condition.

2.2 The Non-Financial Asset Economy

In the NFA-economy, the asset is non-financial since its payoffs depend on i, the agent owning the asset: the asset payoff to agent i in state $s = H, L$ is given by D_s^i, with $D_H^i > D_L^i$.

Heterogeneity in asset payoffs introduces a subtlety when defining debt contract deliveries. Note that since the payoff of the risky asset depends on ownership, the delivery of the debt contract will also depend on whether the borrower is a Buyer or a Seller. In particular, the actual delivery of a contract j is given by

$$min\{j, D_s^i\}, \tag{5}$$

where i is the agent selling the debt contract (the borrower).[15] A real-world example is borrowing by entrepreneurs or farmers with different abilities; if they default, their collateral (the firm or the field) is repossessed, but its value will depend on the entrepreneur's (or farmer's) productivity. That is, the value of the collateral depends on the borrower's characteristics, since the repossession happens after the borrower put in their labor.[16,17]

[15] Note that, although the payoff of the contract depends on its seller, this is still a competitive general equilibrium model, albeit with market segmentation. For a discussion, see Appendix I.

[16] Another example is real estate (a house), whose value depends on how its owner maintains it.

[17] In all our analysis, we assume that the collateral is borrower-held. One could also study a model

Table 4 shows the parameter values we use when implementing the NFA-economy in the laboratory.

Table 4: The NFA-economy Parameterization.

Parameters	D_H^B	D_H^S	D_L	q	m^B	m^S	a^B	a^S
Values	500	200	100	0.8	300	0	0	3

This table shows the parameter values of the NFA-economy.

In this economy, the asset is non-financial. Whereas the asset payoff in state Low $D_L = 100$ is the same for both Buyers and Sellers, the asset payoff in state High is higher for Buyers ($D_H^B = 500$) than for Sellers ($D_H^S = 200$). Moreover, Buyers and Sellers attach the same probability $q = 0.8$ to the state High, hence the difference in asset payoff is the only source of asset valuation heterogeneity across agents. Initial endowments are identical across the two economies. Note that the expected value of the risky asset for both Buyers and Sellers is the same in both economies, 420 for Buyers and 180 for Sellers. In other words, in the NFA-economy, the asset valuations do not change for either Buyers and Sellers with respect to the FA-economy; the only change is that the asset is no longer financial. Nevertheless, as we will see, in the NFA-economy, equilibrium borrowing and default are very different.

The unique equilibrium in the NFA-economy is presented in Tables 5 and 6.[18]

Table 5: Equilibrium Collateral Requirements and Prices in the NFA-economy.

Promise j	Asset Price p	Borrowing $b_{j=375}$	Interest rate $r_{j=375}$
375	420	320	0.17

This table shows equilibrium promise, asset price, borrowing, leverage and interest rate in the NFA-economy.

in which the collateral is held by the lender. This would make no difference in the FA-economy (since the asset is financial), but it would make a difference in the NFA-economy. In case of default, the debt contract would pay according to the payoff of the lender; this for instance would be the case if the ability of the holder of the collateral at the time of default determines the risky asset's payoff. From a theoretical standpoint, both modeling choices are justifiable; from an experimental point of view, our choice has the desired effect of increasing the predicted spread in outcomes between the FA and the NFA-economy.

[18]See Appendix I for equilibrium analysis characterization and uniqueness proof.

Table 6: Equilibrium Allocations and Final Payoffs in the NFA-economy.

	Buyers	Sellers
y	3	0
φ	-3	3
w	0	300
ω_H	375	1260
ω_L	0	600

This table shows equilibrium cash, asset holdings, and number of debt contracts traded in the NFA-economy.

Since, in the NFA-economy, the asset is non financial, violating one of the assumptions in FG, the existence of a default-free equilibrium cannot be guaranteed. Indeed, as shown in Appendix I, the unique equilibrium in this economy involves default, since Buyers borrow only through the debt contract promising $j = 375$; the associated collateral requirement (1/375) is lower than in the FA-economy (1/100). The $j = 375$ contract fully delivers $min\{375, 500\} = 375$ in state High but only delivers $min\{375, 100\} = 100$ in state Low. As a result, there is default in state Low. The price of debt contract $j = 375$ is given by Sellers' break-even conditions $b_{j=375} = 0.8(375) + 0.2(100) = 320$, with an associated interest rate of $r_{j=375} = 0.17$.

The equilibrium asset price is 420. Since this is equal to Buyers' expected value, they are willing to buy as many units of the risky asset as they can afford (3 units) on margin. For each unit of the asset that they purchase, Buyers borrow $b_{j=375} = 320$, and pay a downpayment of 100 to cover the unit price of 420. Hence, Buyers sell 3 debt contracts, backed by their total asset holdings.

Sellers sell all their endowment of the asset because their expected value of the asset, 180, is lower than 420, the price. They lend against collateral to Buyers at an interest rate of 17 percent by buying 3 contracts $j = 375$.

Buyers' final payoffs are 375 in state High and 0 in state Low. As in the FA-economy, the zero payoff in state Low stems from Buyers' leveraging with a contract that promises more than the value of the collateral in state Low and holding no cash. Since the Buyers are paying a higher price for the asset than in the FA-economy, their payoff in state High is lower. In contrast to the FA-economy, Sellers' final payoffs are not constant (1260 in state High and 600 in state Low) since now they hold the risky debt-contract $j = 375$.

Finally, the rest of the equilibrium values, omitted from Tables 5 and 6, are $\varphi_j^i = 0$, $i = B, S$, $\forall j \neq 375$, and $b_j = 0.8min\{j, 500\} + 0.2min\{j, 100\}$, $\forall j$.

It is important to note that the presence of default in equilibrium is a robust feature of the NFA-economy, and not a fluke of our parameterization. As discussed in Appendix I, given utility and endowments parameters, there is always a minimum level of asset payoff heterogeneity above which equilibrium always involves default.

2.3 The Equilibria in the FA and NFA-Economies

In both the FA and the NFA-economy, agents can borrow or lend through any debt contract j (collateral requirements and default are endogenous); moreover, agents' asset valuations are the same in both economies (420 for Buyers and 180 for Sellers). So, why do agents choose to borrow through contract $j = 100$ in the FA-economy, whereas in the NFA-economy they choose to borrow through contract $j = 375$? In other words, why are collateral requirements set high enough in the FA-economy so as to prevent default, whereas in the NFA-economy they are set low enough so that default happens in equilibrium?[19]

Under both parameterizations, $p = 180$ (Sellers' valuation) can never be an equilibrium price: competition among Buyers pushes the price of the asset above Sellers' valuations; Buyers finance their purchases by issuing collateralized bonds. In the NFA-economy, Buyers' competition pushes the asset price all the way to their valuation (420); Buyers finance their purchase by selling a bond with promise $j = 375$, which defaults in state Low. In contrast, in the FA-economy, Buyers are willing to increase their borrowing only up to the no-default threshold ($j = 100$), which finances the asset purchase at the equilibrium price of 200.

In the NFA-economy, gains from trade in the asset market arise because the asset payoffs are higher for Buyers. Since Buyers and Sellers have identical preferences, they agree on the pricing of all the debt contracts. Buyers are willing to pay a higher interest rate and competition pushes the price of the risky asset up to Buyers' valuation. In this economy, default always occurs unless Buyers afford to purchase all the asset supply at a price equal to their valuation by borrowing 100 or less.[20]

In the FA-economy, gains from trade in the asset market arise because of differences in preferences (Buyers have more optimistic beliefs). Unlike the NFA-economy, however, this heterogeneity in preferences affects not only the valuation of the risky asset, but those of the bonds as well. In particular, Buyers value the risky asset and all bonds

[19] In what follows, we provide an intuitive argument; for a technical discussion, see Appendix I.

[20] Remember that there is always a minimum level of payoff heterogeneity above default occurs (see Appendix I).

with a face value above 100 (risky bonds) more than Sellers.[21] When Buyers make a leveraged purchase, they go long on the asset and short on the bond. For $j > 100$ differences in preferences affect both legs of the trade in opposite directions: for this reason, one can prove that no leveraged position with $j > 100$ is optimal.[22]

3 The Experiment

3.1 The Experiment Design

The experiment was run at the Interdisciplinary Center for Economic Science (ICES), at George Mason University. We recruited subjects in all disciplines using the ICES online recruiting system.[23] Subjects had no previous experience with the experiment. The experiment was programmed and conducted with the software z-Tree.[24]

The experiment consisted of five sessions. Twelve students participated in each session for a total of 60 students. Each session consisted of two treatments, corresponding to the two economies described in Section 2:

- The Financial Asset Treatment (FA-treatment), where we implemented the FA-economy of Section 2.2.
- The Non Financial Treatment (NFA-treatment), where we implemented the NFA-economy of Section 2.3.

In each session, the same group of students played in both treatments, thus allowing us to study the difference in behavior with one-sample statistical techniques. In order to control for possible order effects in the data, in Sessions 1 and 2, we ran the NFA-treatment first, and in Sessions 3, 4 and 5 we ran the FA-treatment first. Remember that the agents' valuation of the asset is the same in the FA and in the

[21] Because they attach lower probability to state Low and therefore to default.

[22] In an economy where there is both heterogeneity of beliefs and dividends pay according to ownership, default would occur and would affect prices and payoffs; the reason is that although Buyers value both risky bonds and the risky asset more than Sellers, they have an additional gain from trade on the risky asset (higher dividend) that does not affect their valuation of the risky bonds.

[23] When the number of students willing to participate was larger than the number needed, we chose the subjects randomly in order to reduce the chance that the students in the experiment knew each other.

[24] Fischbacher (2007).

NFA-economy, for both Buyers and Sellers. However, the asset is financial in the FA-economy, but non-financial in the NFA-economy.[25]

We ran twelve rounds of the first treatment and ten rounds of the second treatment in each session. The first four rounds of the first treatment and first two rounds of the second treatment were for practice, and did not determine students' payments. Thus, in all sessions, there were eight (non-practice) paid rounds for each treatment.

An important challenge in bringing the theoretical model to the laboratory stems from the fact that, in the theoretical model, many debt contracts j, (in particular any contract such $j \in R_+$), each collateralized by one unit of the risky asset, can be traded. Hence there are many markets in the model: the market for the asset and the markets for each debt contract j, each market with an associated equilibrium price, b_j, and interest rate r_j. In the theoretical model, although all debt contracts j are priced in equilibrium, only one ($j = 100$ in FA and $j = 375$ in NFA) is actively traded. It is very hard for the experimenters to set up a double auction where trading *in any debt contract* j and the risky asset happens contemporaneously while at the same time assuring that the collateral requirement is satisfied. Moreover, the theoretical equilibrium consists of buying on margin, a transaction which simultaneously involves going long on the asset and short on the debt contract; such transaction is hard to implement through two separate double auctions since in continuous time it is hard for subjects to execute two trades contemporaneously. Restricting the set of possible debt contracts to a few markets (that is, a few levels of j) is also not an option since the whole purpose of our exercise is to study how collateral requirements arise endogenously.

Our solution is to allow Buyers (Sellers) to borrow (lend) only as they purchase (sell) the risky asset (and from the same counterparty); they do so by specifying a Downpayment and a Promise in the Buy (Sell) offers. Therefore, in the laboratory, we only observe the Downpayment, the Promise, and whether there is default. We are not able to decompose the Promise into interest and borrowing, which are undetermined because of the portfolio restriction (similarly, we are not able to decompose the total

[25]Note that keeping the asset valuations constant was necessary, otherwise higher borrowing and default in the NFA-treatment could have been the result of higher asset valuations, hardly a surprising finding. Moreover, whereas in the NFA-economy trading can happen only because of payoff differences, in the FA-economy for trading to occur there must be differences in beliefs (or in subjects' preferences). In order to keep valuations constant and have equilibrium trading in both economies, we decrease Sellers' payoff in state High, while increasing their belief on the probability of state Low.

cost of the Buyers' position into price of the risky asset and interest).[26] This indeterminacy does not prevent us from answering the main question of the paper, the interplay between collateral and default.[27]

3.2 The Procedures

We first describe the procedures:

1. At the beginning of the experiment, we gave written instructions for the first treatment to all subjects.[28] After reading the instructions aloud, we gave the subjects time to ask questions, which were answered in private.

2. All payoffs were denominated in an experimental currency called $E\$$. The risky asset was referred to as a "widget."

3. At the beginning of the session, each subject was randomly assigned to be either a Buyer or a Seller. In every round, there were six Buyers and six Sellers. Subjects could see their role in the left corner of their computer. Subjects maintained the same role throughout the experiment.

4. At the beginning of the round, each Buyer was given $E\$300$ and each Seller was given 3 units of the asset.

5. Subjects traded the asset in a double auction by exchanging it among themselves for 200 seconds. They used the trading platform shown in Appendix III.

6. During the 200 seconds of trading activity, Buyers could post Buy Offers and Sellers could post Sell Offers. To post a Sell Offer, a Seller would enter two numbers: i) the Downpayment: the payment they wanted to receive at the time of the trade; and ii) the Promise: the payment they wanted to receive at the end of the round. The offer appeared immediately on everyone's screen in a column labeled "Current Sell Offers" (the identity of the subject making the offer was not revealed). Similarly, to post a Buy Offer, a Buyer would enter two numbers: i) the Downpayment: the payment they were willing to make at the time of the trade and ii) the Promise: the

[26] In the equilibrium of the unrestricted model, Buyers only borrow while buying the asset, and Sellers only lend while selling the asset; for this reason, it is easy to show that our equilibria survive the portfolio restriction imposed in the laboratory.

[27] See Cipriani *et al.* (2012 and 2018) for an experimental analysis of collateralized borrowing and asset pricing.

[28] Instructions are in Appendix III. In the instructions, the first treatment played in the session was referred to as Part A and the second as Part B.

payment they were willing to make at the end of the round.[29] Buyers and Sellers could cancel their offers at any time.

7. A trade took place whenever a Buyer accepted a Sell Offer posted by a Seller or a Seller accepted a Buy Offer posted by a Buyer. At the time of the trade, the Downpayment was debited from the Buyer to the Seller; and an asset was transferred from the Seller to the Buyer.[30] Subjects' screens always displayed their current holdings of cash and assets, the list of past trades in the round, all outstanding Buy and Sell offers, and the time left before the end of the round (see Appendix III).[31]

8. After the 200 seconds elapsed, the state of the world was realized, and subjects' payoffs were computed and appeared on subjects' screens. Each subject's *per-round* payoff was computed by summing the per-trade payoffs of each trade.[32] In order to avoid a zero-payoff, a $E\$1,200$ bonus was added at the end of each round.[33]

9. After round 1 ended, a new round started. The first treatment continued until 12 rounds were played. Each round was independent from the previous one: subjects were not allowed to carry over endowments of cash or assets from one round to the next.

10. After 12 rounds were played, the second treatment was played for 10 rounds. We gave additional written instructions to all subjects. After reading the instructions aloud, we gave the subjects time to ask questions, which were answered in private.

After both treatments ended, we randomly chose 1 round out of the 16 paying rounds (8 per treatment) for payment purposes. The payoff of that round was converted into dollars at the rate of E$35 per $1. Subjects were also paid a show-up fee of $5. We paid subjects in private immediately after the end of the experiment.

[29] A Seller could submit any number of Sell Offers as long as he had assets left to sell. A Buyer could submit any number of Buy Offers as long as the Downpayment of each Buy Offer was smaller than the cash available to the Buyer.

[30] Note that our trading procedure is different from a standard double auction where a trade happens whenever orders cross. The reason is that in our experiment orders cannot be ranked as they consist of two elements (the Downpayment and the Promise).

[31] Subjects' own outstanding offers and trades are highlighted.

[32] That is, the per-round payoff computation does not include the value of the initial endowment.

[33] E$1,200 is the upper-bound in potential losses. This maximum loss is attained when a Seller sells their entire endowment at a price of 100 (the value of the asset in state Low) in the FA-treatment in a round in which the state of the world turns out to be High, that is, 3(100-500).

3.2.1 Heterogeneity of beliefs

In the NFA-economy, beliefs are homogeneous: both Buyers and Sellers believe that the state of the world is High with probability 0.8. In the experiment, the state of world was determined by picking a ball from a bag with 5 balls numbered from 1 to 5; if the ball bore a number higher than one, the state of the world was High.

In contrast, in the FA-economy, Buyers and Sellers disagree about the state probabilities. Implementing heterogeneity of beliefs in the laboratory is hard since all subjects are playing in the same financial economy, and there is a generally accepted prohibition in experimental economics against deceiving subjects.[34]

We solve the problem by having different states of the world for Buyers and Sellers: we compute the state of the world for Buyers *as if* they lived in an economy in which state High has probability 0.8; we compute the state of the world for Sellers *as if* they lived in an economy in which state High has probability 0.2. In particular, the experimenter picked a ball from a bag with five numbered balls. The state of the world was determined according to Table 7. If the ball's number was 2, 3, or 4, the state of world was High for Buyers but Low for Sellers. If the ball's number was either 1 or 5, the state of the world was Low (1) or High (5) for both Buyers and Sellers. We explain this procedure clearly to subjects in the instructions, so they knew that the state of the world was determined differently for Buyers and Sellers.[35]

Table 7: State High and Low in the FA-Treatment

Ball Number	1	2	3	4	5
Buyers	Low	High	High	High	High
Sellers	Low	Low	Low	Low	High

This table shows how the state of the world was determined for Buyers and Sellers in the FA-economy.

Note that, in those rounds when the state of the world was High for Buyers and Low for Sellers, the payoff of each Buyer was computed as if everyone's state of the world was High; similarly, the payoff of each Seller was computed as if the state of the world

[34]See, e.g., Cooper (2014).

[35]An alternative solution could have been to try to influence subjects' assessments on the likelihood of state High through some sort of "framing" (e.g., by trying to affect Buyers' and Sellers' perception of the likelihood of the state of the world through the wording of the Instructions). We decided against it as we would have lost control over subjects' beliefs about the two states of the world. Given that the goal of our experiment is to study how leverage and default differ depending on whether the collateral is financial or not, maintaining control over beliefs in the laboratory (and therefore over asset valuations across treatments) was very important.

was Low. This means that in such rounds, although Buyers are fully delivering on their promises, Sellers are nevertheless facing default.[36]

Our procedure to implement heterogeneous beliefs described in this section is not equivalent to the heterogeneity in valuations in the NFA-economy. In the NFA-economy, when the state is High, the asset is worth 500 to Buyers and 200 to Sellers; each subject's payoff is computed taking this difference into account; in contrast, as explained above, in the FA-economy, when the state of the world is High for Buyers but Low for Sellers, a Buyer's payoff is computed as if the value of the asset were 500 for everyone, whereas a Seller's payoff is computed as if the value of the asset were 200 for everyone.

3.2.2 The Per-Trade Payoff

Given the determination of the state of the world described in the previous subsection, we now define subjects' payoffs. Buyers' *per-trade* payoff is the difference between the asset's payoff to Buyers and how much they paid for the asset. In both treatments, Buyers' per-trade payoff is given by

$$D_s^B - d - min(j, D_s^B)$$

where how much they pay for the asset is given by the sum of i) how much they pay at the moment of the transaction, the Downpayment, and ii) how much they pay at the end of the round, the minimum between the Promise and asset's payoff to Buyers.[37]

Because of how the state of the world is determined, Sellers' per-trade payoff is computed differently across treatments. In the FA-treatment, Sellers' *per-trade* payoff is the difference between how much they receive from selling the asset and the asset's payoff to Sellers. That is,

$$d + min(j, D_s^S) - D_s^S$$

[36]Suppose that a Buyer and a Seller trade a promise $D_L < j < D_H$, and the state of the world is High for Buyers but Low for Sellers. In this case, the Buyer repays his promise but the Seller only receives D_L; the experimenter pockets the difference (something we explained to subjects in the Instructions).

[37]The payment at the end of the round comes from equation (2): a Buyer will never repay the Seller more than the final value of the collateral (that is, they will default whenever the Promise is higher than the final value of the asset).

where how much they are paid for the asset is given by the sum of i) how much they receive at the moment of the transaction, the Downpayment, and ii) how much they receive at the end of the round, the minimum between the Promise and asset's payoff *to Sellers.* As we mentioned in Subsection 3.2.1, when we implement heterogeneous beliefs in the FA-treatment, the realized state of the world may be different for Buyers and Sellers; the delivery of the debt contract (and therefore whether there was default or not on the transactions) was computed for each subject according to *their* realized state of the world.

In contrast, in the NFA-treatment, the delivery of the debt contract is always determined according to the value of the asset to Buyers. As a result, the per-trade payoff for Sellers is given by

$$d + min(j, D_s^B) - D_s^S.$$

Note that in the description of the data, we will use the word "default" whenever the Promise was greater than the final value of the risky asset. In the laboratory, however, we never explicitly used or defined the term. Instead, we explained that a Buyer's payment at the end of the round was the minimum of the Promise and the final value of the asset.

4 Results

4.1 Allocations and Gains from Trade

In the theoretical model described in Sections 2.2 and 2.3, subjects' ability to leverage allows the realization of gains from trade in both the FA and the NFA-economy: the risky asset changes hands from Sellers (who value it less) to Buyers (who value it more). Table 8 shows that experimental outcomes are largely consistent with this prediction. In all sessions of both treatments, across all paid rounds, Sellers end up with only a small amount (0.24 in FA and 0.03 in NFA) of their original endowment of the risky assets (3 units), whereas Buyers hold almost all the risky-asset supply (2.76 in FA and 2.97 in NFA).[38] In other words, through trading and collateralized borrowing subjects (almost) fully realize gains from trade in the laboratory.

[38]As we discuss in Section 3, we paid subjects based on their earnings in one round extracted from the last 10 rounds of both the FA and the NFA-treatment. Therefore, in all the empirical

Since almost the entire supply of the risky asset exchanges hands during trading, the number of trades in each round is close to 18 trades (the total asset supply) per round. Indeed, as Table 9 shows, there are on average 16.55 trades per round in the FA and 17.8 trades per round in the NFA-treatment. Finally, on average, most trading activity occurs in the first 60 seconds of trading (see Figure 1), which suggests that subjects had enough time and trading activity was not cut short arbitrarily.

Table 8: Final Asset Allocations.

	FA		NFA	
Session	Buyers	Sellers	Buyers	Sellers
1	2.63	0.38	2.92	0.08
2	2.54	0.46	2.94	0.06
3	2.90	0.10	3.00	0.00
4	2.90	0.10	2.98	0.02
5	2.83	0.17	3.00	0.00
All	2.76	0.24	2.97	0.03

This table shows average final asset holdings of Buyers and Sellers across all paid rounds of all sessions and by session.

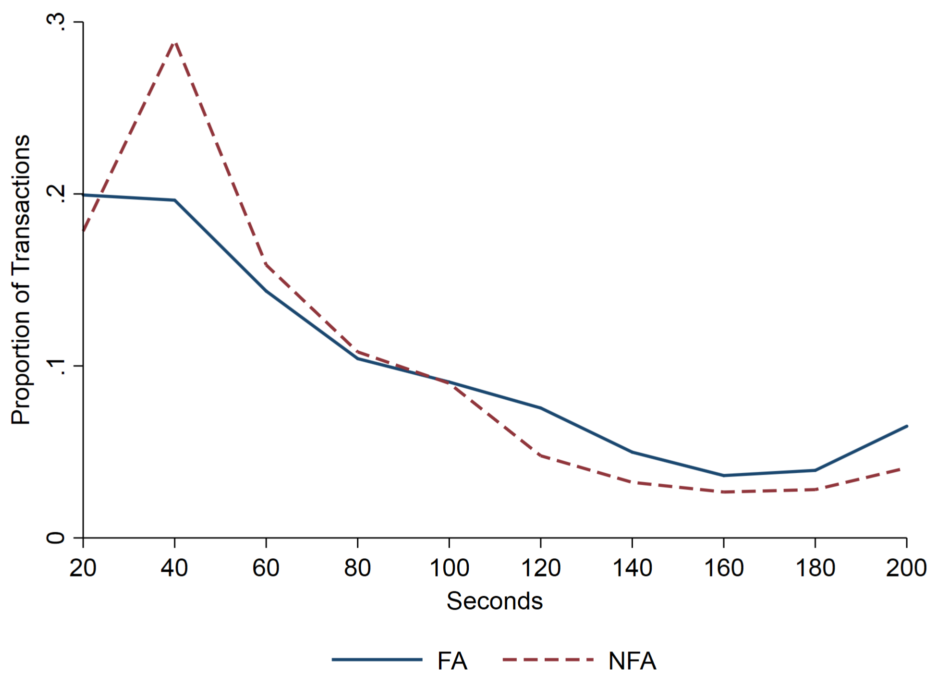
Table 9: Number of Trades per Round

Session	FA	NFA
1	15.75	17.50
2	15.25	17.63
3	17.38	18.00
4	17.38	17.88
5	17.00	18.00
All	16.55	17.80

This table shows the mean number of trades per round across all paid rounds of all sessions and by session.

analysis, unless we explicitly state otherwise, we report results from those rounds only. We report results across all rounds in Appendix II.

Figure 1: Proportion of Transactions within Rounds



This figure displays the proportion of transactions within each 20-second period of the 200-second round relative to the total number of transactions in the round. Each point in the chart shows the average proportion for a given time interval across all paid rounds of all sessions.

4.2 Default

In Table 10, we report, across all paid rounds and sessions, the proportion of transactions that default in the FA and NFA-treatments, separately for rounds in which the state of the world was Low and rounds in which it was High; for the FA-treatment, we consider the state of the world to be Low when it was Low for Buyers, so as to keep the same (ex-ante) proportion of rounds with a Low state of the world as in the NFA-treatment.[39,40] Theory predicts that default should never occur in state High in either treatment. This was indeed the case in the experiment: the proportion of contracts with default was zero in the FA-treatment and very close to zero (only one contract defaulted across all paid rounds of the five treatments) in the

[39] Across the five sessions, in the NFA-treatment, the state of the world was Low in 7 rounds out of 40; in the FA-treatments, Buyers' state of the world was Low in 13 and Sellers' state of the world in 33 rounds out of 40.

[40] In Appendix II, we report the same statistics on the NFA-treatment computed by considering the state of the world to be Low when it was Low for Sellers. The results are similar.

NFA-treatment.

Theory predicts that when the state of the world is Low, default occurs in the NFA-treatment but not in the FA-treatment. In the laboratory, when the state is Low, across all sessions, 86 percent of contracts default in the NFA-treatment, but only 42 percent in the FA-treatment, a statistically significant difference (Wilcoxon signed-rank test: p-value=0.06).[41] In other words, although we observe default in both treatments, the proportion of contracts that default is significantly lower when theory predicts that no default should be observed.

The higher prevalence of defaults in the NFA-treatment is also observed at the round and subject level. Indeed, as Figure 2 shows, the distribution of defaults per Low round in the NFA-treatment is to the right of that in the FA-treatment: as reported in Table 11, the number of defaults in the median Low round decreases from 16 in the NFA-treatment to 6 in the FA-treatment. Similarly, we observe a stark difference between the NFA and the FA-treatment if we look at subjects' median behavior. As Figure 3 shows, the distribution of defaults per Buyer in the NFA-treatment is to the right of that in the FA-treatment; as shown by Table 11, the median Buyer defaults in 3 trades in the NFA-treatment, but only 1 in the FA-treatment.

In the theoretical model, default should occur in the NFA-economy; it should not in the FA-economy. In the experiment, we observe some default in both the FA and the NFA-treatment, albeit with very different frequency. In order to understand the importance of default in the laboratory, it is also useful to study "by how much" subjects default. Indeed, the experimental data show that not only are there fewer defaults in the FA-treatment; defaults also entail lower losses for Sellers. Table 12 reports the average loss from default in the two treatments, measured as the average difference between the promise the actual delivery, for state-Low rounds.[42]Across all sessions, the average default loss was 177 in the NFA-treatment versus 51 in the FA-treatment, a statistically significant difference (Wilcoxon signed-rank test: p-value=0.06). This confirms the theoretical prediction that default is an important

[41]All Wilcoxon signed-rank tests in the paper are run at the session level. For each session, we compute the average of the variable(s) of interest. For each variable, we obtain a sample of five observations. We test for differences across treatments with a paired Wilcoxon signed-rank test; and for equality of a variable to its theoretical counterpart with single-sample Wilcoxon signed-rank tests. We ran the tests on session averages in order to take into account any possible dependency among subjects' behavior within sessions. The p-values of all statistical tests mentioned in the paper are reported both in the tables throughout the paper and, together, in Appendix II.

[42]As we mentioned above, in state High, default almost never occurs in the laboratory, and the loss from default is therefore zero.

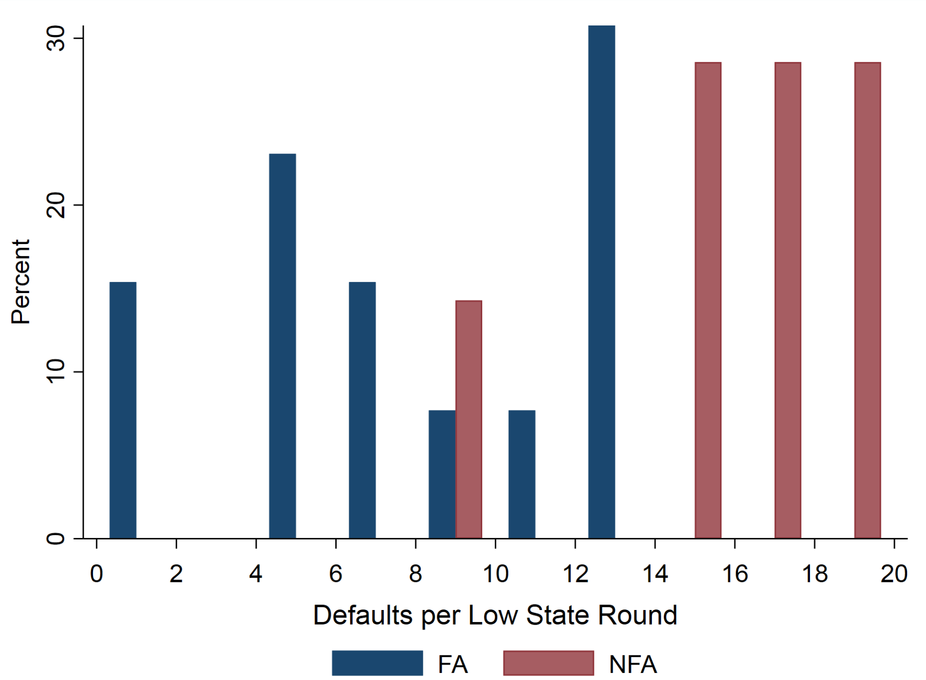
outcome with non-financial assets, but much less so when assets are financial.

Table 10: Proportion of Transactions that Default.

	Low State		High State	
Session	FA	NFA	FA	NFA
1	0.06	0.94	0.00	0.00
2	0.13	0.83	0.00	0.00
3	0.67	1.00	0.00	0.00
4	0.31	0.71	0.00	0.00
5	0.64	1.00	0.00	0.01
All	0.42	0.86	0.00	0.00
Predicted	0	1	0	0
FA vs. NFA	0.06			

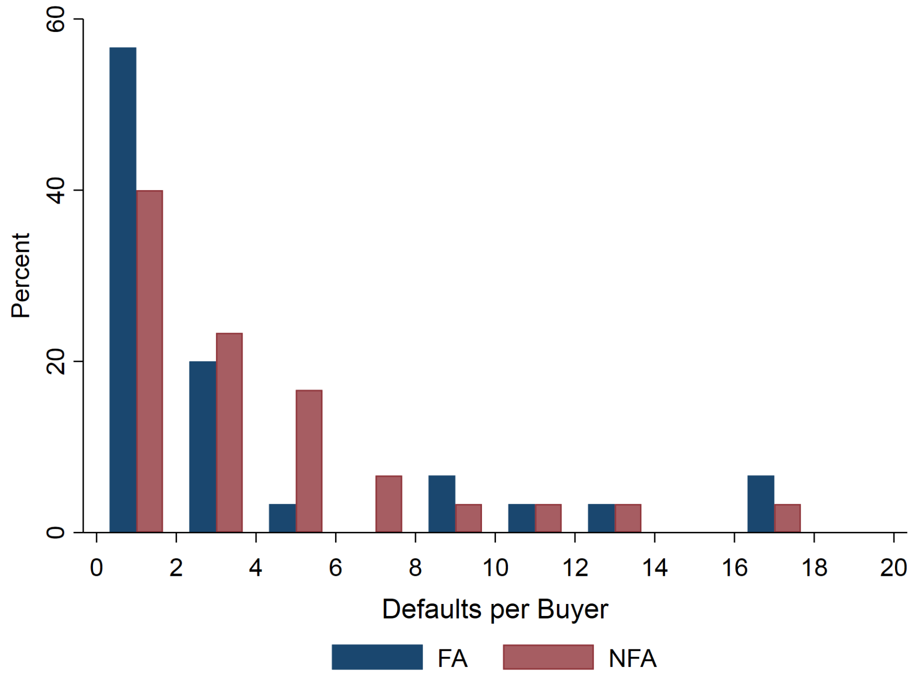
This table shows the proportion of transactions that default in each treatment across all paid Low rounds of all sessions and by session. The last row reports p-values from Wilcoxon signed-rank tests on the nulls that FA proportions equal NFA proportions.

Figure 2: Histogram of the Number of Defaults per Low Round.



This figure displays the histogram of the number of defaults per Low round across all Low paid rounds of all sessions.

Figure 3: Histogram of the Average Number of Defaults per Buyer.



This figure displays the histogram of the average number of defaults per Buyer across all Low paid rounds of all sessions.

Table 11: Default Distribution.

	Round		Buyer	
Statistic	FA	NFA	FA	NFA
P10	1	9	0	1
P25	4	15	0	1
Median	6	16	1	3
P75	12	18	3	5
P90	12	18	11.5	9

This table shows the distribution of defaults per Low round and the distribution of defaults per Buyer across all Low paid rounds of all sessions.

Table 12: Average Default Loss.

	Low State	
Session	FA	NFA
1	21	222
2	17	110
3	76	203
4	22	134
5	87	324
All	51	177
Predicted	0	275
FA vs. NFA	0.06	

This table shows the average loss from default across all Low paid rounds of all sessions and by session. The last rows reports the p-value from a Wilcoxon signed-rank test on the nulls that average losses in the FA-treatment equal those in the NFA-treatment.

4.3 The Promise

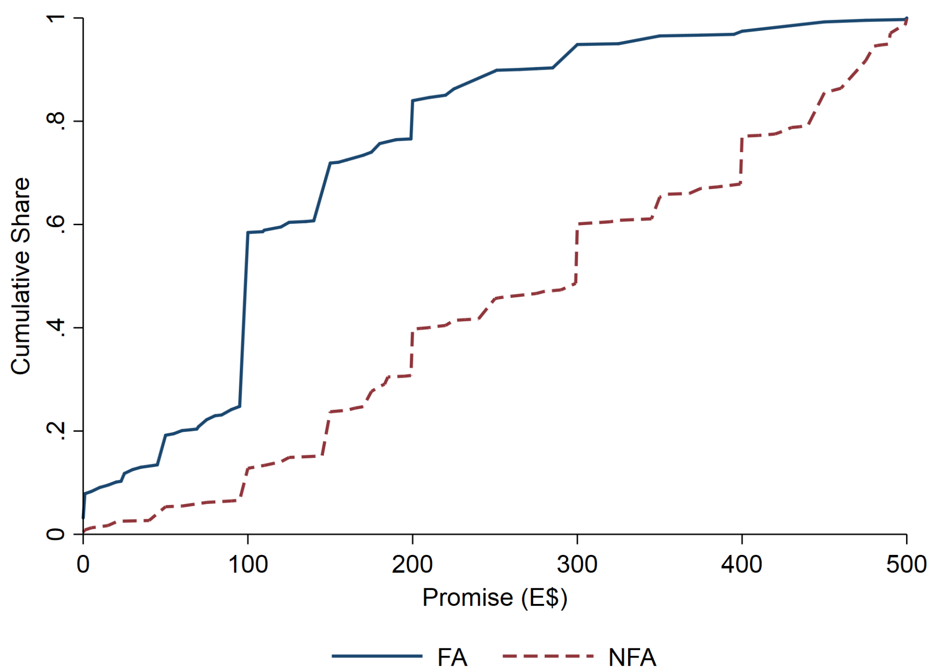
In our experiment, default occurs when the promise exceeds the value of the collateral (the asset payoff at time 1). Therefore, in order to understand why in the laboratory default occurs much more often in the NFA than in the FA-treatment, we analyze Buyers' promises. According to the theoretical model, in the FA-economy, the equilibrium promise is $j = 100$ (the asset payoff in state Low), and default never occurs. In contrast, in the theoretical NFA-economy, the equilibrium promise is $j = 375$, and default occurs in state Low. In other words, in the FA-economy, the collateral requirement per dollar promised at time 1 ($\frac{1}{j}$) is set high enough so as to prevent default, whereas in the NFA-economy the collateral requirement is set so low that default occurs in state Low.

Figure 4 reports the cumulative histogram of promises in the experiment. The mass of the promise distribution in the FA-treatment is to the left of that in the NFA-treatment. Indeed, the empirical cumulative distribution of promises in the NFA-treatment first-order stochastically dominates that of the FA-treatment; consistently with the prediction that in the FA-treatment borrowing becomes too expensive beyond the default threshold, there is a large jump in the cumulative distribution at 100 (across all paid rounds and sessions, 34% of transactions have a promise of 100).

As Table 13 shows, the average promise in the FA-treatment is 135, higher than its theoretical counterpart, 100 (the difference is significant, with a Wilcoxon signed-rank test p-value of 0.06). In contrast, the average promise in the NFA-treatment is 284, lower than its theoretical counterpart of 375 (the difference is not statistically significant, with a Wilcoxon signed-rank test p-value of 0.13). Therefore, we observe that promises are much higher in the NFA-treatment than in the FA-treatment. The difference between the average promise in the two treatments (149) is both quantitatively important and statistically significant (Wilcoxon signed-rank test p-value of 0.06). We obtain similar results if we look at median promises instead of average promises.

Similarly to the frequency of default studied in Section 4.2, the higher level of promises in the NFA-treatment is also observed at the round and subject level. Indeed, as Figure 5 shows, the distribution of the average promise per round in the NFA-treatment is to the right of that of the average promise per round in the FA-treatment; indeed, as Table 14 shows, in the median round the average promise decreases from 264 in the NFA-treatment to 128 in the FA-treatment. Moreover, we observe a stark difference between the NFA and the FA-treatment if we look at subjects' median behavior: as shown in Table 14 and Figure 6, the average promise of the median Buyer is 236 in the NFA-treatment, but only 136 in the FA-treatment.

Figure 4: Cumulative Histogram of the Promise.



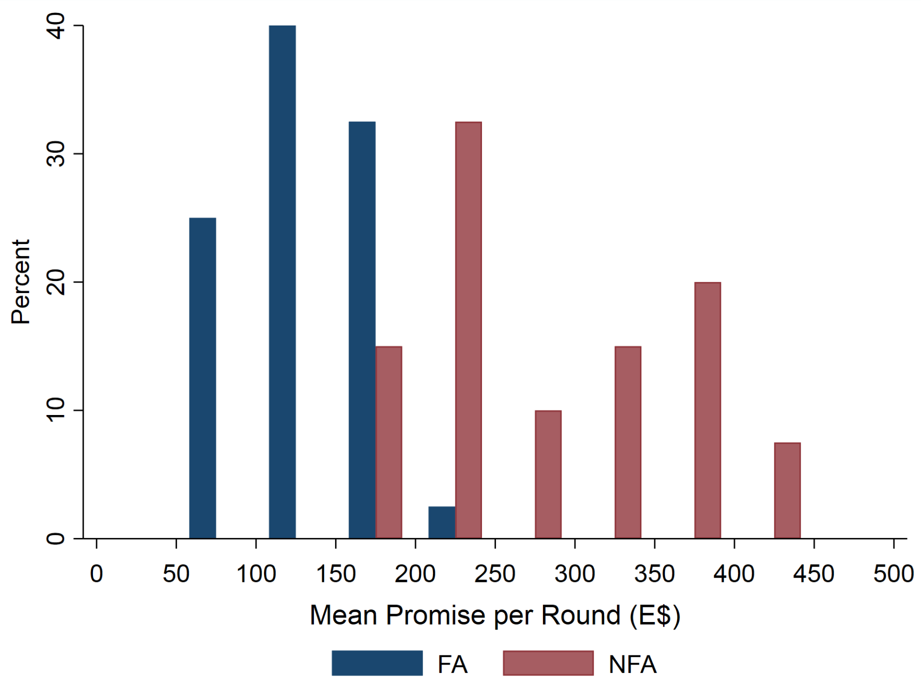
This figure displays the cumulative histogram of the Promise across all paid rounds of all sessions.

Table 13: Mean and Median Promise.

	FA		NFA	
Session	Mean	Median	Mean	Median
1	101	100	310	350
2	138	100	206	185
3	173	175	299	300
4	101	100	222	200
5	161	150	382	405
All	135	100	284	300
Predicted	100	100	375	375
Actual vs. Theory	0.06		0.13	
FA vs. NFA	0.06			

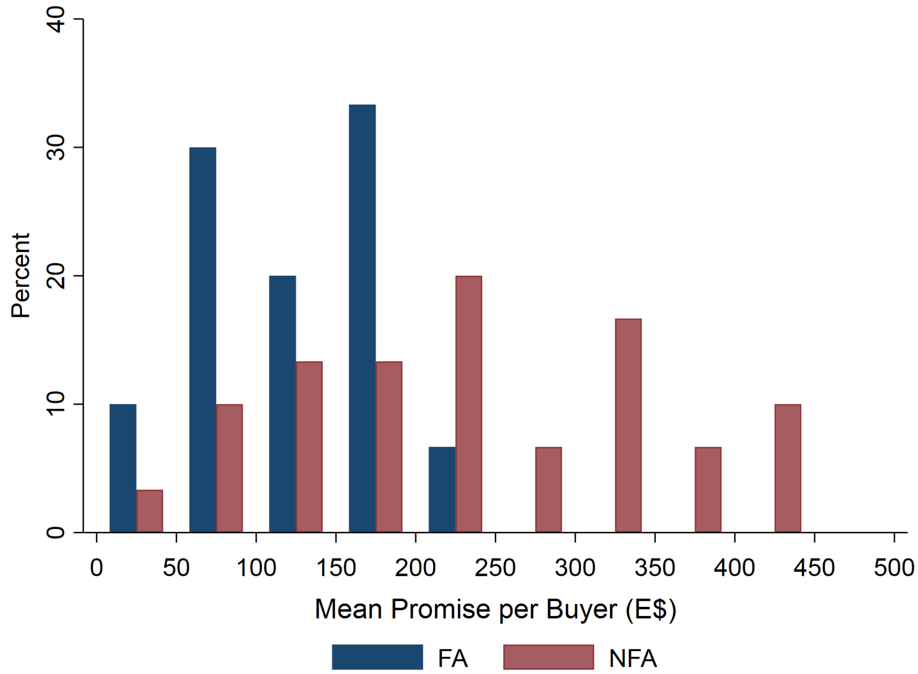
This table shows the mean and median promise across all paid rounds of all sessions and by session. The last two rows report p-values from Wilcoxon signed-rank tests on the nulls that medians equal their theoretical values and that FA median equal NFA median.

Figure 5: Average Promise per Round.



This figure displays the distribution of the average promise per round by treatment across all paid rounds of all sessions.

Figure 6: Average Promise per Buyer.



This figure displays the distribution of the average promise per Buyer by treatment across all paid rounds of all sessions.

Table 14: Distribution of Average Promises.

	Round		Buyer	
Statistic	FA	NFA	FA	NFA
P10	92	188	47	96
P25	101	216	76	144
Median	128	264	136	236
P75	166	358	163	321
P90	178	397	198	396

This table shows the distribution of average promises per round and per Buyer across all paid rounds of all sessions and by session.

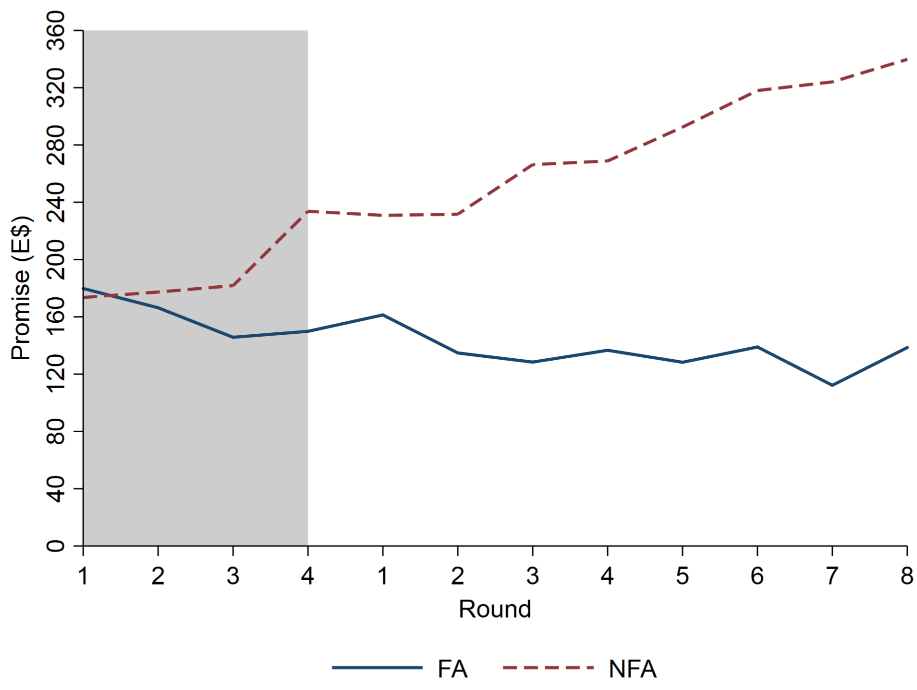
In Section 4.2, we discuss the higher proportion and cost of default in the low rounds of the NFA-treatment. Default in the laboratory happens when subjects' promises are above 100. As Table 15 shows, whereas 41 percent of trades have a promise greater than 100 in the FA-treatment, the number reaches 87 percent in the NFA-treatment, a statistically significant difference (Wilcoxon signed-rank test: p-value=0.06); this is why we observe a higher proportion of default in the NFA-treatment than in the FA-treatment. Moreover, the average promise in all trades in which the promise is greater than 100, $E(j|j > 100)$ (the average promise in a trade that defaults in state Low) is 316 in the NFA-treatment, but only 223 in the FA-treatment (although the difference is not statistically significant, Wilcoxon signed-rank test: p-value=0.19). This explains why as reported in Section 4.2, the loss from default is higher in the NFA than in the FA-treatment.

Table 15: Descriptive Statistics for Promises Greater than 100.

	Pr(j > 100)		Mean | j > 100	
Session	FA	NFA	FA	NFA
1	0.143	0.879	270	345
2	0.238	0.887	301	224
3	0.755	0.979	199	304
4	0.288	0.664	185	295
5	0.610	0.951	235	400
All	0.415	0.872	223	316
FA vs. NFA	0.06		0.19	

This table shows descriptive statistics for promises greater than 100 across all paid rounds of all sessions and by session. The last row reports p-values from Wilcoxon signed-rank tests on the null FA values equal NFA values.

Figure 7: Average Promise over Rounds.



This figure shows the mean promise across all sessions in each round for each treatment with the unpaid (practice) rounds shaded.

Table 16: Promises over the Rounds

	FA Treatment				NFA Treatment			
Session	Practice	1-2	3-6	7-8	Practice	1-2	3-6	7-8
1	179	110	98	98	223	248	319	357
2	206	152	136	127	156	195	198	234
3	152	182	171	167	181	218	299	380
4	123	111	103	86	94	174	222	266
5	186	188	154	150	261	320	392	424
All	163	149	133	126	185	231	287	332
Predicted	100	100	100	100	375	375	375	375
Actual vs. Theory	0.06	0.06	0.13	0.31	0.06	0.06	0.13	0.44
Early vs. 7-8	0.13	0.06	0.06		0.06	0.06	0.06	

This table shows the average promise across all paid and unpaid (practice) rounds of all sessions and by session. The last two rows report p-values from Wilcoxon signed-rank tests on the nulls that means equal their theoretical values and that means from earlier rounds equal means from rounds 7-8.

Finally, we study how the promise evolves over the rounds of trading. In Figure 7 and Table 16, we report the average promise over all rounds, both paid and unpaid (shaded area).[43] In the practice rounds, the average promise in the FA and NFA-treatment are close (163 and 185), respectively above and below their theoretical counterparts. As the experiment continues and subjects become more experienced in trading, the average promise in the FA-treatment converges downward to its theoretical counterpart (100), while the average promise in the NFA-treatment convergences upward towards its theoretical counterpart (375). Indeed, although in the practice rounds and in the first two paid rounds the difference between experimental outcomes and theoretical predictions is significant (as it is in the overall experiment), it ceases to be so from round 3 onward (see the Wilcoxon signed-rank tests at the bottom of Table 20). In other words, as the experiment progresses, in both treatments, the promise converges towards the predictions of the model: subjects learn that borrowing in excess of 100 is too costly in the FA, but worthwhile in the NFA-treatment.

4.4 Cash and Downpayment

In the equilibrium described in Section 2, in both the FA and the NFA-economy, Buyers use all their cash endowment (300 per Buyer) as a downpayment in order to

[43]As discussed in Section 3, we ran 4 unpaid practice rounds in the treatment run first (the NFA-treatment in Sessions 1 and 2 and the FA-treatment in Sessions 3, 4 and 5) and only two in the treatment run second; as a result, in Figure 7 and Table 16, unpaid rounds 1 and 2 in the shaded area, are computed over a smaller number of sessions (2 in the NFA and 3 in the FA-treatment).

buy all the asset supply (3 units per Seller); this implies zero final cash holdings and a downpayment per asset of 100.

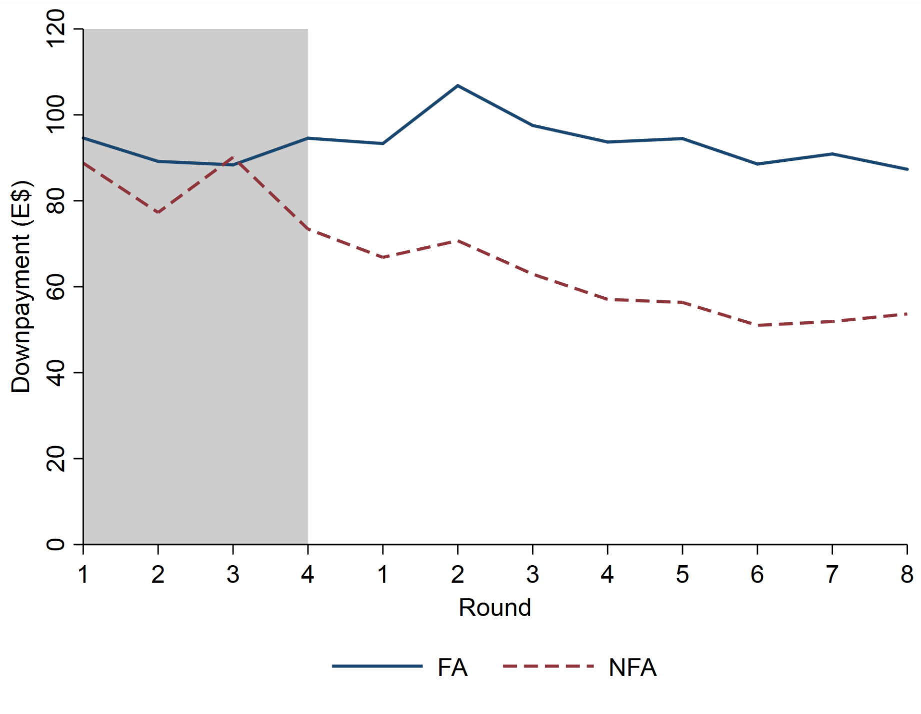
Table 17: Mean and Median Downpayment.

	FA		NFA	
Session	Mean	Median	Mean	Median
1	110	100	70	50
2	99	100	64	50
3	93	95	58	25
4	74	75	64	50
5	95	100	39	35
All	94	100	59	50
Predicted	100	100	100	100
Actual vs. Theory	0.44		0.06	
FA vs. NFA	0.06			

This table shows the mean and median downpayment across all paid rounds of all sessions and by session. The last rows report p-values from Wilcoxon signed-rank tests on the null that medians equal their theoretical values and that FA median equal NFA median.

As Table 17 shows, in the FA-treatment, the experimental outcomes are very close to the prediction of the theoretical model. The average downpayment across sessions is 94, statistically indistinguishable from 100 (Wilcoxon signed-rank test: p-value=0.44). In contrast, in the NFA-treatment the downpayment is roughly half as much of what theory predicts, on average 59 across sessions (significantly different from 100, with a Wilcoxon signed-rank test p-value of 0.06).

Figure 8: Mean Downpayment across Rounds.



This figure shows the downpayment in each round averaged over all sessions with the unpaid (practice) rounds shaded.

Table 18: Downpayment Throughout the Rounds.

	FA				NFA			
Session	Practice	1-2	3-6	7-8	Practice	1-2	3-6	7-8
1	116	126	111	97	91	87	68	56
2	94	100	102	92	88	69	62	62
3	95	96	89	99	86	75	54	48
4	78	79	72	73	76	65	62	66
5	90	105	96	86	59	48	39	32
All	92	100	93	89	82	69	57	53
Predicted	100	100	100	100	375	375	375	375
Actual vs. Theory	0.44	1.00	0.63	0.06	0.06	0.06	0.06	0.06
Early vs. 7-8	0.19	0.13	0.31		0.06	0.13	0.19	

This table shows the mean downpayment across all paid and unpaid (practice) rounds of all sessions and by session. The last two rows report p-values from Wilcoxon signed-rank tests on the nulls that medians equal their theoretical values and that medians from earlier rounds equal medians from rounds 7-8.

Moreover, the evolution of downpayments through the experiment is different from the evolution of promises described in Section 4.3. In particular, as Figure 8 and Table 18 show, in the FA-treatment, the downpayment starts very close to its theoretical counterpart and remains there through the experiment (the average downpayment in the practice rounds is not significantly different from that in the last two rounds, with a Wilcoxon rank-sum test p-value of 0.19). In contrast, in the NFA-treatment, the downpayment starts below 100 and as subjects increase their promises through the rounds, it decreases to an average of 53 in the last two rounds. In other words, in the NFA-treatment, subjects' downpayment does not converge to the theoretical equilibrium as the experiment progresses.

Table 19: Average Final Cash.

	FA		NFA	
Session	Buyers	Sellers	Buyers	Sellers
1	10	290	96	204
2	49	251	112	188
3	30	270	127	173
4	86	214	111	189
5	31	269	182	118
All	41	259	126	174
Buyers vs. Sellers	0.06		0.19	
FA vs. NFA	0.06	0.06		

This table shows the average final cash holdings for Buyers and Sellers across all paid rounds of all sessions and by session. The last two rows report p-values from Wilcoxon signed-rank tests on the nulls that FA means equal NFA means for a subject type and that Buyer means equal Seller means for a treatment.

Of course, since in the FA-treatment the downpayment is close to the theoretical prediction, Buyers end up with almost no cash. Indeed, as Table 18 shows, Buyers' average final cash in the FA-treatment is 41, whereas Sellers end up holding almost the entire cash endowment, with an average final cash of 259 (the difference between Buyers' and Sellers' cash holdings is statistically significant, with a Wilcoxon signed-rank test p-value of 0.06). In contrast, in the NFA-treatment, Buyers hold on to a significant amount of cash, almost half their cash endowment. Buyers' average final cash is 126, whereas Sellers' average final cash is 174, a non-statistically significant difference (Wilcoxon signed-rank test p-value equal 0.19).

The fact that, in both the FA and NFA-treatment, Buyers end up with positive cash holdings does not necessarily imply that they are not cash-constrained: their final cash holdings may not be sufficient to buy another asset since in the laboratory the asset is indivisible. In Table 20, we report the average proportion of Buyers who are cash-constrained at the end of a round taking into account the asset indivisibility. Buyers were cash-constrained when their final cash holdings were less than (or equal to) the average downpayment in the round (which is needed to buy an extra unit of the asset). On average, 82 percent of Buyers were constrained in the FA-treatment;

in contrast, in the NFA-treatment, only 35 percent of Buyers were constrained.[44]

Table 20: Proportion of Cash-constrained Buyers.

Session	FA	NFA
1	0.98	0.46
2	0.79	0.35
3	0.92	0.31
4	0.50	0.46
5	0.92	0.15
All	0.82	0.35
FA vs. NFA	0.06	
Rounds per Median Buyer	5	2
Buyers per Median Round	8	2.5

This table shows the proportion of cash-constrained buyers across all paid rounds of all sessions and by session; it also shows the number of rounds in which the median buyer is constrained, and the number of buyers that are cash-constrained in the median round, across all paid rounds of all sessions. The last row reports p-values from Wilcoxon signed-rank tests on the null that FA statistics equal their NFA counterparts. A buyer is defined to be cash-constrained if at the end of a round, the buyer's final cash holdings are strictly smaller than the average downpayment during the round.

There is a significant difference between Buyers' behavior in the NFA and in the FA-treatment: in the NFA-treatment, surprisingly, not only Buyers borrow more than in the FA-treatment, but they maintain significantly larger cash balances at the end of the round; as a result, as we discussed above, they are often not cash-constrained. This puzzling behavior can be explained by the coexistence of non-recourse debt with Buyers' desire to protect themselves in case state Low is realized. In an economy with uncollateralized borrowing and full recourse, Buyers cannot protect themselves by borrowing while holding positive cash balances (because cash balances can be seized by lenders). In contrast, in our economy, since loan repayment is limited to the value of collateral (no recourse), cash holdings allow Buyers to increase the payoff in state Low, while at the same time financing their purchase of the risky asset through higher borrowing. And that is exactly what Buyers do in the NFA-treatment; indeed, through the round, as their Promise increases, their downpayment decreases (see Figures 7 and 8). Why do we not observe such behavior in the FA-treatment? Because, as explained in Section 2.3, heterogeneity of beliefs makes borrowing in excess of 100 very expensive; as a result, Buyers use all their cash balances to purchase the risky asset.[45]

[44] These proportions are computed considering each Buyer in each round as a different observation.

[45] For the interested reader, we present a formal argument in Appendix I.

4.5 Conclusions

Do markets set collateral requirements high enough to prevent default? We address this question through a laboratory experiment.

To this purpose, we develop a theoretical model of collateralized borrowing that is amenable to laboratory implementation and collect experimental data. Two types of risky assets can be used as collateral: financial assets (whose payoff does not depend on ownership, like a bond) or non-financial assets (whose payoff depends on ownership, like a firm). Theory predicts that when assets used as collateral are financial, collateral requirements are set high enough that default never occurs. In contrast, when assets used as collateral are non financial, collateral requirements are low and default happens.

The laboratory results confirm the theory's main prediction: whether collateral is financial or non financial matters. Default rates and loss from default are higher when assets used as collateral are non financial. Although, in contrast to the theory, default occurs also with non financial assets, the loss from default is much lower. Lower default rates and default losses stem from stricter collateral requirements: to issue the same bond, subjects post twice as much collateral when assets are non financial. Finally, default rates and collateral requirements converge to the theoretical prediction as the experiment progresses: subjects learn that whether an asset is financial matters for its collateral capacity even though subjects value financial and non-financial assets the same.

References

Asparouhova, E., "Competition in Lending: Theory and Experiments," *Review of Finance*, 10, 189-219, 2006.

Asparouhova, E., Bossaert, P., and C. Plott, "Excess Demand and Equilibration in Multi-security Financial Markets: the Empirical Evidence," *Journal of Financial Markets*, 6(1), 1-21, 2003.

Baklanova, V., Caglio, C., Cipriani, M., and A. Copeland, "A New Survey of the U.S. Bilateral Repo Market: A Snapshot of Broker-Dealer Activity," *Review of Economic Dynamics*, 33, 228-249, 2019.

Cipriani, M., Fostel, A., and D. Houser, “Collateral Constraints and the Law of One Price: an Experiment,” *Journal of Finance*, 73(8), 2757-2786, 2018.

Bossaert, P. and C. Plott, “From Market Jaws to the Newton Method: the Geometry of how a Market can Solve System of Equations,” Handbook of Experimental Economics Results, Vol 1 (Elsevier Amsterdam), 2008.

Peter Bossaerts, Charles Plott and William R. Zame, "Prices and Portfolio Choices in Financial Markets: Theory, Econometrics, Experiment," *Econometrica,* 75 (2007), 993-1038.

Cooper, “A Note on Deception in Economic Experiments,” *Journal of Wine Economics*, 9(2), 2014.

Fischbacher, Urs, “z-Tree: Zurich toolbox for ready-made economic experiments,” *Experimental Economics* 10, 171-178, 2007.

Fostel, A. and J. Geanakoplos, “Leverage cycles and the anxious economy,” *American Economic Review,* 98, 1211-1244, 2008.

Fostel, A. and J. Geanakoplos, “Endogenous Collateral Constraints and the Leverage Cycle,” *Annual Review of Economics*, 6, 771-799, 2014.

Fostel, A. and J. Geanakoplos, “Leverage and Default in Binomial Economies: A Complete Characterization,” *Econometrica*, 83(6), 2191-2229, 2015.

Geanakoplos and Zame, 2014: John Geanakoplos and William R. Zame, "Collateral Equilibrium I: A Basic Model," Economic Theory (to appear).

Holt, C. and S. Laury, “Risk aversion and incentive effects,” *American Economic Review* 92, 1644-1655.

Plott, C., “Properties of Disequilibrium Adjustment in the Double-Auction Markets,” *Handbook of Experimental Economics Results*, Vol 1 (Elsevier Amsterdam), 2008.

Smith, V. L., “An Experimental Study of Competitive Market Behavior,” *Journal of Political Economy*, 70, 111-137, 1962.

Default and Endogenous Leverage in the Laboratory. Appendix

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Appendix I: Theory

Equilibrium Analysis in the FA-Economy

Equilibrium

Given the parameterization described in Table 1 of Section 2.1, we solve the equilibrium in the following way. First, we make an educated guess on the "equilibrium regime," that is, we make a guess on which constraints are binding, and hence on the level of some endogenous variables. Then, given this guess, we solve for the remaining endogenous variables using a set of equations derived from the agents' maximization and from market clearing conditions. Third, we show that the solution to the system of equations is a genuine equilibrium by checking that the assumed regime is consistent with agents' maximization and resource feasibility.

In this binomial economy the asset is financial, so by Fostel-Geanakoplos (2015) we can assert the existence of an equilibrium in which the only contract traded in equilibrium is $j = 100$. We further guess that Buyers buy all the assets in the economy ($y^B = 3$); use all their assets holding to sell contracts $j = 100$ ($\varphi^B_{j=100} = -3$) to Sellers; and hold no cash ($w^B = 0$).

Given this guess, the remaining endogenous variables $(p, b_{j=100}, y^S, w^S, \varphi^S_{j=100})$ can be obtained through the following system of equations:

$$-m^B + 3p = 3b_{j=100}, \tag{1}$$

$$b_{j=100} = q^S(100) + (1 - q^S)100, \tag{2}$$

$$y^S = a^B + a^S - 3, \tag{3}$$

$$\varphi^S_{j=100} + 3 = 0 \tag{4}$$

$$w^S = m^B + m^S \tag{5}$$

Equation (1) is the budget constraint for Buyers. Equation (2) is the Sellers' first order condition for lending through contract $j = 100$. Equations (3), (4) and (5) are the market clearing conditions for asset, debt contract $j = 100$, and cash markets. The solution to the system of equations is given by $(p, b_{j=100}, y^S, w^S, \varphi^S_{j=100}) = (200, 100, 0, 300, 3)$.

We need to check that the solution to the system is an equilibrium for the FA-economy (the regime assumed is the correct one). Clearly the Sellers do not want to hold the asset since $p = 200 > 180 = E^S Y$, hence it is optimal for Sellers to sell all their endowment of 3 assets. Buyers want to spend all their cash and borrow all they can through debt contract $j = 100$ to buy all the assets since $p = 200 < 420 = E^B Y$. By FG we don't need to investigate trading in any of the contracts $j \neq 100$. Hence, the solution is an equilibrium.

To complete the characterization of the equilibrium set $\varphi_j = 0, \forall j \neq 100$ and prices for the non traded contracts as $b_j = q^S min\{j, 500\} + (1 - q^S) min\{j, 100\}$, $\forall j \neq 100$. At these prices Buyers will not want to trade in these markets. In the terminology of Fostel-Geanakoplos the contract $j = 100$ is the one with the highest "Liquidity Value" for Buyers. The liquidity value of a debt contract j is the difference between the price of a debt contract (how much the borrower borrows) and the payoff value of the debt contract to borrowers (how much Buyers are expected to pay back at time 1, discounted by the marginal utility of money); it measures the efficiency of a debt contract as liquidity provider. In the equilibrium discussed in Section 2.2, the marginal utility of money (the maximum expected payoff of an extra unit of cash at time zero, given prices) for Buyers is given by $\mu^B = \frac{.8(500-100)}{200-100} = 3.2$. Hence, the payoff value of any debt contract j is given by $\frac{.8min\{500,j\}+.2min\{100,j\}}{3.2}$ (the expected delivery discounted by the marginal utility of money). As we discussed before, the price of all debt contracts are given by the Sellers' valuation, $b_j = .2min\{j, 500\} +$

$.8min\{j,100\}$.[1]

Consider contracts $j \leq 100$. In this case the liquidity value for borrowers is given by $LV_j^B = j - j/3.2$. Clearly this expression is increasing in j and attains its maximum at $j = 100$. Now consider contracts $j > 100$. In this case the liquidity value for borrowers is given by $LV_j^B = .2min\{j,500\} + .8min\{j,100\} - \frac{.8min\{j,500\}+.2min\{j,100\}}{3.2}$. Both expressions are increasing in j, but because of the belief disagreement (Sellers think the state High will happen only with probability .2), the first term increases by less than the second one. Hence the liquidity value decreases as j increases. As a result, no contract with $j > 100$ is actively traded. All contracts have a positive liquidity value, reflecting the fact that Buyers are constrained (their marginal utility of money is bigger than 1). But the liquidity value attains its maximum when $j = 100$, so only this contract is actively traded in equilibrium.[2]

Uniqueness

The non-default equilibrium is unique. We cannot find an equilibrium with the same asset price, bond prices and payoffs for all investors which involves default. By FG, this would imply reshuffling portfolios so that Buyers would hold more risky assets as collateral to issue a higher promise. In this way they would still be buying the same amount of Arrow High securities. In equilibrium, per each leveraged asset, they are buying $500 - 100$ Arrow High securities, through contract $j = 100$. They could still buy the same amount of Arrow High securities by holding $3(\frac{500-100}{500-101})$ of the risky asset to issue $\frac{500-100}{500-101}$ units of contract $j = 101$ per unit of asset. But this is clearly unfeasible since $\frac{500-100}{500-101} > 1$ and there is no more available collateral in the economy, Hence, equilibrium is unique.

Equilibrium Analysis in NFA-Economy

Equilibrium

We solve for the parameter values of Table 4 in Section 2.2. This economy does not satisfy the assumptions in FG, and hence we cannot assert the existence of an

[1] Note that the the marginal utility of money for Sellers at time 0 is given by $\mu^S = 1$, because in equilibrium they only hold riskless assets.

[2] Incidentally, as shown by Fostel and Geanakoplos (2008, 2014) the liquidity value of the active contract in equilibrium equals the collateral value of the asset, $LV_{j=100}^B = CV_Y^B = 68.75$. See Cipriani *et al.* (2018) for a study on the presence of collateral values in the lab.

equilibrium with only $j = 100$ as we did in the FA-economy. In order to calculate the equilibrium we will guess the following equilibrium regime: Buyers buy all the assets in the economy ($y^B = 3$); use all their assets holding to sell only one debt contract j ($\varphi_j^B = -3$); hold no cash ($w^B = 0$); and pay for the asset according to their valuation.

Given this guess, the remaining endogenous variables $(p, b_j, j, y^S, w^S, \varphi_j^S)$ can be obtained through the following system of equations:

$$-m^B + 3p = 3b_j, \tag{6}$$

$$b_j = qj + (1-q)100, \tag{7}$$

$$p = q500 + (1-q)100. \tag{8}$$

$$y^S = a^B + a^S - 3, \tag{9}$$

$$\varphi_j^S + 3 = 0 \tag{10}$$

$$w^S = m^B + m^S \tag{11}$$

Equation (6) is the budget constraint for Buyers. Equation (7) is the Sellers' first order condition for lending through contract j. Equation (8) is the Buyers' first order condition to hold the asset. Equations (9), (10) and (11) are the market clearing conditions for asset, debt contract j and cash market respectively. The solution to the system of equations is given by $(p, b_j, j, y^S, w^S, \varphi_j^S) = (420, 320, 375, 0, 300, 3)$.

We need to check that the solution to the system is an equilibrium for the NFA-economy. Clearly the Sellers do not want to hold the asset since $p = 420 > 180 = E^S Y$, hence it is optimal for Sellers to sell all their endowment of 3 assets. Buyers want to spend all their money and borrow to buy all the asset since $p = 420 = E^B Y$. They are interior (their marginal utility of money is 1) and hence the liquidity value of all contracts is zero. Buyers are indifferent and hence they are optimizing issuing the risky bond $j = 375$, which allows them to pay exactly their asset valuation. To complete the characterization of the equilibrium set $\varphi_j = 0, \forall j \neq 375$ and prices for the non traded contracts as $b_j = q^S min\{j, 500\} + (1-q^S) min\{j, 100\}$, $\forall j \neq 375$.

Uniqueness

This equilibrium is also unique. Let's consider three cases:

1) Any regime in which Buyers hold cash is not going to be optimal given risk-neutrality. It is also obvious that no Buyer would borrow through contracts $j > 375$.

2) Consider all regimes with $j < 375$ and Buyers holding all the assets. For the sake of concreteness, consider the same regime assumed in the FA-economy with $j = 100$. As we saw before in this case $p = 200, b_{j=100} = 100$. But this would not be a genuine equilibrium, since Buyers would like to sell risky debt contracts: $\frac{.8(500-j)}{p-\pi} = 3.2$, for $j = 100$, whereas $\frac{.8(500-j)}{p-\pi} = 3.22$, for $j = 101$. By continuity this argument rules out all regimes with $j < 375$ and Buyers holding all the assets.

3) Consider all the regimes with $j < 375$ and Buyers share assets with the Sellers. Again for concreteness consider $j = 100$. In this case, $p = 180$, for the Sellers to hold it in equilibrium. From the Buyers budget constraint we have that $y^O = 3.75$, which clearly is not an equilibrium for any $j \geq 100$. Next, consider same portfolio regime but for a lower debt contract, say $j = 10$. In this case $y^O = 1.7$, which is a feasible number. But the expected return is given by $\frac{.8(500-10)}{180-10} = 2.3$, whereas a deviation to $j = 11$ would yield a higher return of $\frac{.8(500-11)}{180-11} = 2.31$.

Robustness

Default is a robust feature of the NFA-economy. As explained in Section 2 the parameter values in Tables 1 and 4 were chosen so as to keep agents' asset valuation constant across economies. However, provided that there is enough differences in asset payoffs across agents, default will always occur in equilibrium.

In particular, given the parameters $(D_H^S, D_L, q, m^B, m^S, a^B, a^S)$ there exists $\hat{D}_H^B > D_H^S$ such that for all $D_H^B > \hat{D}_H^B$ there is default in equilibrium, so that $j > 100$. This follows from the following function derived from (6), (7) and (8):

$$F(j, \hat{D}_H^B) = -m^B + (a^B + a^S)(q\hat{D}_H^B + (1-q)D_L) - (a^B + a^S)(qj + (1-q)100) = 0.$$

This expression defines an increasing function $\hat{D}_H^B(j)$. For the parameter values in Table 4, $\hat{D}_H^B = 225$. Hence for differences in payoffs in the state High of less or equal than 25, Buyers would be able to pay their whole valuation of the asset borrowing through debt contracts that do not default. For higher differences, equilibrium will always involve default.

Market Segmentation Model

Note that, although the payoff of the contract depends on its seller, this is still a competitive general equilibrium model, albeit with market segmentation. In particular, we can think of a promise sold by a Buyer as a different contract—and one that only Buyers can sell—than a promise sold by a Seller. In such a model j is a function of the type i, $j(i)$. Given our parameterization in Table 4, only Buyers borrow in equilibrium and therefore only contracts $j(B)$, sold by Buyers and backed by assets held by Buyers, are traded. For this reason, for the sake of keeping the notation simple, we refer to these contracts as contract j (similarly to what we do in Section 2.3). The whole equilibrium would be $(p, b_{j(B)}, j(B), y^S, w^S, \varphi^S_{j(B)}) = (420, 320, 375, 0, 300, 3)$, $\varphi_{j(B)} = 0, \forall j(B) \neq 375$ and prices for the non traded contracts as $b_{j(B)} = q^S min\{j(B), 500\} + (1 - q^S)min\{j(B), 100\}$, $\forall j(B) \neq 375$ and $\varphi_{j(S)} = 0, \forall j(S)$ and prices for the non-traded contracts as $b_{j(S)} = q^S min\{j(S), 500\} + (1 - q^S)min\{j(S), 100\}$, $\forall j(S)$.

Borrowing while holding positive cash under non-recourse contracts

As discussed in Section 4.4 of the paper, in the NFA-treatment, not only Buyers borrow more than in the FA-treatment, but they maintain significantly larger cash balances at the end of the round. This puzzling behavior can be explained by the coexistence of non-recourse debt with Buyers' desire to protect themselves in case state Low is realized. We now present a formal argument to show that this behavior can be optimal.

Consider the FA and NFA economies with the same parameter values as in Tables 1 and 4 of Section 2, but with risk-averse agents. Suppose agents have a CRRA payoff function for state $s = High, Low$ given by:

$$u^i(x_s) = \begin{cases} \frac{x_s^{\beta_i}}{\beta_i}, & \beta_i \neq 0, \\ log(x_s), & \beta_i = 0, \end{cases} \tag{12}$$

We solve for equilibrium for different parameters of risk aversion corresponding to mild levels of risk-aversion a(see Holt and Laury, 2002). Tables 1 and 2 present the equilibrium values in both the FA and the NFA-economy.

Table 1: FA-equilibrium.

β	j	p	b_j	w^B	y^B
0.70	100	200	100	0.3	3
0.6	100	199	100	2	3
0.5	100	197	100	8	3

This table shows the equilibrium in the FA-economy for different parameters of risk aversion.

Table 2: NFA-equilibrium.

β	j	p	b_j	w^B	y^B
0.70	420	397	337	120	3
0.6	418	388	329	123	3
0.5	416	379	321	125	3

This table shows the equilibrium in the NFA-economy for different parameters of risk aversion.

In the FA-economy, Buyers hold (almost) no cash and borrow using the maxmin contract (as in the risk-neutral case). On the other hand, as discussed in Section 4.4, the behavior in the NFA-economy is very different to the one in the risk-neutral equilibrium of Section 2 of the paper. Buyers, while still buying all the asset supply on margin through risky bonds, hold cash in equilibrium. They do so by spending less than their overall cash endowment on downpayment.

Appendix II: Empirical Analysis

Results across Paid and Non-Paid Rounds

Table 3: Final Asset Allocations.

	FA		NFA	
Session	Buyers	Sellers	Buyers	Sellers
1	2.60	0.40	2.85	0.15
2	2.57	0.43	2.78	0.22
3	2.78	0.22	3.00	0.00
4	2.86	0.14	2.93	0.07
5	2.79	0.21	2.95	0.05
All	2.73	0.27	2.90	0.10

This table shows average final asset holdings of Buyers and Sellers in each session across both paid and unpaid rounds of all sessions and by session.

Table 4: Number of Trades per Round.

Session	FA	NFA
1	15.60	17.08
2	15.40	16.67
3	16.67	18.00
4	17.17	17.60
5	16.75	17.70
All	16.38	17.37

This table shows the mean number of trades per round in each session across both paid and unpaid rounds of all sessions and by session.

Table 5: Proportion of Transactions that Default.

	Low State		High State	
Session	FA	NFA	FA	NFA
1	0.06	0.94	0.00	0.00
2	0.13	0.83	0.00	0.00
3	0.65	0.85	0.00	0.00
4	0.35	0.71	0.00	0.00
5	0.68	0.97	0.00	0.01
All	0.46	0.86	0.00	0.00
Predicted	0	1	0	0
FA vs. NFA	0.06			

This table shows the proportion of transactions that default in each treatment across paid and unpaid Low rounds of all sessions and by session. The last rows report p-values from Wilcoxon signed-rank tests on the nulls that FA proportions equal NFA proportions.

Table 6: Default Distributions in the Low State.

	Round		Buyer	
Statistic	FA	NFA	FA	NFA
P10	1	13	0	1
P25	5	14	0	2
Median	8	15	2	5
P75	12	17	5	9
P90	12	18	14	15

This table shows the distribution of defaults per Low round and the distribution of defaults per Buyer for the FA and NFA-treatments across both paid and unpaid rounds of all sessions and by session.

Table 7: Average Default Loss.

	Low State	
Session	FA	NFA
1	21	214
2	17	99
3	79	123
4	29	134
5	87	257
All	54	155
Predicted	0	275
FA vs. NFA	0.06	

This table shows the average loss from default in paid and unpaid Low rounds of all sessions and by session. The last rows reports the p-value from a Wilcoxon signed-rank test on the nulls that average losses in the FA-treatment equal those in the NFA-treatment.

Table 8: Mean and Median Promise.

	FA		NFA	
Session	Mean	Median	Mean	Median
1	116	100	283	250
2	152	100	191	181.5
3	166	170	275	280
4	108	100	198	162.5
5	169	150	360	400
All	143	100	260	236
Predicted	100	100	375	375
Actual vs. Theory	0.06		0.06	
FA vs. NFA	0.06			

This table shows the mean and median promise across paid and unpaid Low rounds of all sessions and by session. The last two rows report p-values from Wilcoxon signed-rank tests on the nulls that means equal their theoretical values and that FA means equal NFA means.

Table 9: Distribution of Average Promises.

	Round		Buyer	
Statistic	FA	NFA	FA	NFA
P10	97	171	51	94
P25	109	186	90	130
Median	142	234	130	223
P75	173	324	176	296
P90	186	388	201	371

This table shows the distribution of average promises per round and per Buyer across paid and unpaid Low rounds of all sessions and by session.

Table 10: Descriptive Statistics for Promises Greater than 100.

	Pr(j > 100)		Mean | j > 100	
Session	FA	NFA	FA	NFA
1	0.212	0.859	279	318
2	0.312	0.830	295	215
3	0.680	0.939	202	288
4	0.330	0.619	189	277
5	0.687	0.938	227	381
All	0.461	0.838	225	297
FA vs. NFA	0.06		0.19	

This table shows descriptive statistics for promises greater than 100 computed across paid and unpaid Low rounds of all sessions and by session. The last row reports p-values from Wilcoxon signed-rank tests on the null FA values equal NFA values.

Table 11: Mean and Median Downpayment.

	FA		NFA	
Session	Mean	Median	Mean	Median
1	112	100	76	50
2	98	100	71	50
3	94	90	63	50
4	75	75	66	50
5	93	100	43	35
All	93	100	64	50
Predicted	100	100	100	100
Actual vs. Theory	0.44		0.06	
FA vs. NFA	0.06			

This table shows the mean and median downpayment in each session across paid and unpaid Low rounds of all sessions and by session. The last rows report p-values from Wilcoxon signed-rank tests on the null that median in the FA and NFA-treatment are the same.

Table 12: Average Final Cash.

	FA		NFA	
Session	Buyers	Sellers	Buyers	Sellers
1	10	290	82	218
2	49	251	103	197
3	39	261	110	190
4	85	215	107	193
5	40	261	174	126
All	46	254	113	187
Buyers vs. Sellers	0.06		0.13	
FA vs. NFA	0.06	0.06		

This table shows the average final cash holdings for Buyers and Sellers in each session, across both paid and unpaid rounds. The last two rows report p-values from Wilcoxon signed-rank tests on the nulls that FA means equal NFA means for a subject type and that buyer means equal seller means for a treatment.

Table 13: Proportion of Cash-constrained Buyers.

	Proportion Constrained	
Session	FA	NFA
1	0.98	0.54
2	0.77	0.43
3	0.86	0.40
4	0.51	0.48
5	0.83	0.22
All	0.79	0.42
FA vs. NFA	0.06	
Rounds per Median Buyer	5	2
Buyers per Median Round	10	4.5

This table shows the proportion of cash-constrained buyers, the number of rounds in which the median buyer is constrained, and the number of buyers that are cash-constrained in the median round computed across paid and unpaid Low rounds of all sessions and by session. The last row reports p-values from Wilcoxon signed-rank tests on the null that FA statistics equal their NFA counterparts. A buyer is defined to be cash-constrained if at the end of a round, the buyer's final cash holdings are strictly smaller than the average downpayment during the round.

Default Results for Sellers' Low State of the World

Table 14: Proportion of Transactions that Default according to Sellers' State of the World.

	Low State		High State	
Session	FA	NFA	FA	NFA
1	0.01	0.94		0.00
2	0.04	0.83	0.00	0.00
3	0.11	1.00	0.00	0.00
4	0.17	0.71	0.00	0.00
5	0.53	1.00	0.00	0.01
All	0.17	0.86	0.00	0.00

This table shows the proportion of transactions that default across all paid Low rounds according to Sellers' state of the world for all sessions and by session.

Non-parametric tests

This table summarizes all significance tests that are referred to in the paper.

	FA vs. NFA	Buyers vs. Sellers	Actual vs. Theory	Early vs. Rounds 7-8	j < 100 vs. j = 100	j ≤ 100 vs. j > 100
Low-Round Default	0.06					
Low-Round Default Loss	0.06					
Constrained Buyer	0.06					
j > 100	0.06					
Cash						
Buyers	0.06					
Sellers	0.06					
FA		0.06				
NFA		0.19				
Promise	0.06					
j > 100	0.19					
FA			0.06			
FA, Practice			0.06	0.13		
FA, Rounds 1-2			0.06	0.06		
FA, Rounds 3-6			0.13	0.06		
FA, Rounds 7-8			0.31			
NFA			0.13			
NFA, Practice			0.06	0.06		
NFA, Rounds 1-2			0.06	0.06		
NFA, Rounds 3-6			0.13	0.06		
NFA, Rounds 7-8			0.44			
Downpayment	0.06					
j < 100	0.13					
j = 100	0.38					
j > 100	0.63					
FA			0.44			
FA, Practice			0.44	0.19		
FA, Rounds 1-2			1.00	0.13		
FA, Rounds 3-6			0.63	0.31		
FA, Rounds 7-8			0.06			
FA, j < 100					0.06	0.06
FA, j = 100						0.06
NFA			0.06			
NFA, Practice			0.06	0.06		
NFA, Rounds 1-2			0.06	0.13		
NFA, Rounds 3-6			0.06	0.19		
NFA, Rounds 7-8			0.06			
NFA, j < 100					0.25	0.06
NFA, j = 100						0.13

Appendix III: Instructions and Screenshots

Instructions

Thank you for participating in today's experiment. You have earned $5 for arriving on time. What you earn in this experiment will be added to this $5. If you read these instructions carefully, you have the potential to earn significantly more.

In the experiment, you will earn Experimental Dollars (E$), which will be converted into cash at the end. For every E$35 you have at the end of the experiment, you will be paid $1 in cash.

You will participate in the experiment along with 11 other students. We will never reveal your identity to other participants, and you will never receive any information about the identity of other participants. During the experiment, you are not allowed to talk to other participants or to use cell phones. If you have any questions, please raise your hand, and an experimenter will assist you.

The experiment consists of two parts: Parts A and B. First, read the instructions for Part A. After reading these instructions, you will answer a brief questionnaire, and then play Part A. After you finish playing Part A, we will distribute the instructions for Part B, and you will play Part B.

Instructions for Part A

This part of the experiment consists of 12 rounds.

- The first 4 rounds are for practice only and will not affect how much you will be paid.
- The following 8 rounds will be used to determine how much you will be paid at the end of the experiment.
- In each round of the experiment, you will buy or sell "widgets" by trading with other participants.

Buyers and Sellers

At the beginning of the experiment

- You are randomly assigned to be a Buyer or a Seller (this information is on the left corner of your computer screen).
- 6 of you will be Buyers, 6 of you will be Sellers.
- You keep the same role throughout the experiment.

<u>Description of each round</u>

In each round, Buyers can buy widgets from Sellers and Sellers can sell widgets to Buyers.

At the beginning of each round, Buyers are given an endowment of E$300 and Sellers are given an endowment of 3 widgets. You can find this information in the left column of the screen, where your ***Widgets*** and ***Cash*** are indicated.

<u>Widgets</u>

At the end of each round, the value of the widgets will be either

High: E$**500.**

Low: E$**100.**

At the end of each round, after trading has ended, we will pick a ball from a bag with five numbered balls, from 1 to 5:

- <u>For Buyers:</u> if the number of the ball is 1, the final value of all widgets is Low (E$100). If the number is 2 or higher, the final value of all widgets is High (E$500). Hence, the chance of the final value being High is 80% for Buyers.
- <u>For Sellers:</u> if the number on the ball is 4 or lower, the final value of all widgets is Low (E$100). If the number is 5, the final value of all widgets is High (E$500). Hence, the chance of the final value being High is 20% for Sellers.

This is summarized in the following table:

Ball Number	**1**	**2**	**3**	**4**	**5**
Buyers	Low (100)	High (500)	High (500)	High (500)	High (500)
Sellers	Low (100)	Low (100)	Low (100)	Low (100)	High (500)

Note that if the number on the ball is 1, the final value of the widgets is Low (E$100) for both Buyers and Sellers. If the number on the ball is 5, the final value of the widgets is High (E$500) for both Buyers and Sellers. <u>If the number on the ball is between 2 and 4, the final value of each widget is High (E$500) for Buyers, but Low (E$100) for Sellers.</u>

In each round, we pick the ball from a new bag. This means that the chance of the value being High or Low <u>does not depend</u> on the value in previous rounds.

<u>Trading</u>

In each round, trading takes place for <u>200 seconds</u>. During trading, Buyers submit *Buy Offers* and Sellers submit *Sell Offers*. A Buy or Sell Offer is for 1 widget. A Buyer can accept any Sell Offer and a Seller can accept any Buy Offer. Both buyers and sellers can also cancel their own offers.

When a Buyer and a Seller make a trade, they agree on a **Downpayment** and a **Promise.**

- The **Downpayment** is what the Buyer pays immediately at the time of the trade.
- The **Promise** is what the Buyer promises to pay at the end of the round.

Buying and selling happen in two ways: either a Seller accepts a Buy Offer or a Buyer accepts a Sell Offer.

Only Buyers can make Buy offers and only Sellers can make Sell Offers. Once a Buyer has a widget, (s)he cannot sell it, and once a Seller has cash, (s)he cannot use it to buy widgets.

<u>Buy Offers</u>

In a Buy Offer, a Buyer indicates the Downpayment that (s)he is willing to pay immediately and a Promise of payment at the end of the round. For example, a buyer may post a Buy Offer with a Downpayment of E$50, and a Promise of E$200 to be paid at the end.

If you are a Buyer, you can post a Buy Offer by filling in:

1) The Downpayment.
2) The Promise.

After reviewing the information, you can complete the offer by clicking ***Place Offer.***

You can submit as many Buy Offers as you like. However, you will not be able to post Buy Offers with Downpayment greater than the cash available to you. For example, if you have E$100 in cash, you can post as many Buy Offers as you want as long as the Downpayment of each Buy Offer is no more than E$100.

On the top left corner of the screen, you can see the ***Open Buy Offers***, where your outstanding Buy Offers are displayed along with those of the other Buyers (you can see all the offers by scrolling through them; your own offers are indicated by an asterisk in the left column). For each offer, you can see the Downpayment and the Promise. By clicking ***Cancel***, you can cancel any offer you posted that has not been executed.

Sell Offers

Similarly, in a Sell Offer a Seller indicates the Downpayment (s)he wants to receive at the time of the trade and the Promise for future payment (s)he is willing to accept. For example, a Seller may ask a Downpayment of E$50, and a Promise of future payment of E$300.

If you are a Seller, you can post a Sell Offer by indicating:

1) The Downpayment
2) The Promise

After reviewing the information, you can complete the offer by clicking ***Place Offer.*** On the top right of the screen, you can see the ***Open Sell Offers,*** where your outstanding Sell Offers are displayed along with those of the other Sellers (you can see all the offers by scrolling through them; your own offers are indicated by an asterisk in the left column). For each offer, you can see the Downpayment and the Promise. By clicking ***Cancel,*** you can cancel any offer you posted that has not been executed.

As a Seller, you can submit as many Sell Offers as you want as long as you have widgets left to sell (otherwise you will receive a warning message).

Exchange

A trade takes place whenever a Buyer accepts a Sell Offer, or a Seller accepts a Buy Offer. If you want to accept a Sell Offer, you can click on the offer you like and then click ***Buy***. If you want to accept a Buy Offer, you can click on the offer you like and then click ***Sell***.

When the trade takes place, the widget is transferred from the Seller to the Buyer, and the Downpayment is transferred from the Buyer to the Seller.

If you are a Buyer, when you buy a widget, your Cash is reduced by the amount of the Downpayment, and your Widget account is increased by one. If you are a Seller, when you sell a widget, your Cash is increased by the amount of the Downpayment, and your Widget account is decreased by one. This information is reflected in ***Cash*** and ***Number of Widgets*** in the left column. You can see all the information about past trades on the bottom of the screen under ***Past Trades*** (your own trades are market with an asterisk).

Finally, after a trade takes place the computer automatically deletes your outstanding Buy Offers that you can no longer afford with the remaining cash. And it deletes all your outstanding Sell Offers if you have no widgets left to sell.

The Final Payment

- At the end of the round, the Buyer must pay the Promise to the Seller.
- **BUT:** the Buyer will never pay more than the final value of the widget to Buyers and the Seller will never receive more than the final value of the widget to Sellers.

Example: Suppose a Buyer and a Seller trade a widget with a Downpayment of E$100 at the time of the trade, and a Promise of E$300.

How much does the Buyer pay? When the trade takes place, the Buyer pays the Downpayment of E$100. Remember that the Promise is E$300. However, depending on the widget's value at the end of the round, the Buyer might not need to pay the entire Promise to the Seller. If, at the end of the round, the widget is worth E$500 to the Buyer (High Value), (s)he pays the entire Promise (E$300) to the Seller. If, however, the widget is only worth E$100 to the Buyer (Low value), (s)he only pay E$100.

Hence, Buyers may not have to pay the full agreed-upon Promise if the value of the widget to Buyers is Low.

How much does the Seller gets paid? The Seller receives the Downpayment of E$100 at the time of the trade. If, at the end of the round, the widget is worth E$500 to him/her, (s)he receives the entire Promise E$300. If, at the end of the round, the widget is only worth E$100 to him/her, (s)he only receives E$100.

Hence, Sellers may not receive the full agreed-upon Promise, when the value of the widget to Sellers is Low.

Note that in some rounds the value of the widget may be High (E$500) for Buyers, but Low (E$100) for Sellers. In this case, it is possible that a Buyer pays the entire Promise (because it is less than E$500), but a Seller only receives E$100 (in which case, the experimenter pockets the difference).

To summarize, for Buyers, the final payment is the minimum of the value of the widget to Buyers and the Promise. For Sellers, the final payment received is the minimum of the value of the widget to Sellers and the Promise.

The Profit from each Trade

For a Buyer, the Per-Trade Profit from buying one widget is:

Per-Trade Profit = Final Value to Buyer – Downpayment – Final Payment =

Final Value to Buyer – Downpayment – Minimum of Promise and Final Value to Buyer

For a Seller, the Per-Trade Profit from selling a widget is:

Per-Trade Profit = (Downpayment + Final Payment) – Final Value to Seller =

(Downpayment + Minimum of Promise and Final Value to Sellers) – Final Value to Seller

So, a Buyer's Per-Trade Profit is the difference between the value of the widget to him/her and the total amount (s)he paid for the widget (Downpayment + Final Payment). A Seller's Per-Trade Profit is the difference between the total amount (s)he was paid for the widget (Downpayment + Final Payment) and the final value of the widget to him/her.

<u>Example:</u> Suppose a Buyer and a Seller trade a widget with a Downpayment of E$50 and a Promise of E$300.

The Buyer pays the Seller E$50 at the time of the trade. At the end of the round, (s)he pays the minimum of the Promise (E$300) and the value of the widget to Buyers:

- If the widget is worth E$500 to Buyers, (s)he repays the entire Promise (E$300), and the overall cost of the widget to the Buyer is E$50 + E$300 = E$350. The Buyer's Per-Trade Profit is E$500 - E$50 - E$300 = E$150.

- If the widget is worth only E$100 to Buyers, (s)he only pays E$100 at the end of the round, and the overall cost of the widget is E$50 + E$100 = E$150, which is less than the sum of Downpayment and Promise. In this case, his/her Per-Trade Profit is E$100 – E$150 = - E$50 (negative E$50). Note that, as in this example, the Per-Trade Profit can be negative (that is, it can be a Per-Trade Loss).

The Seller receives the Downpayment of E$50 from the Buyer at the time of the trade. At the end of the round, (s)he gets back the minimum of the Promise (E$300) and the value of the widget to Sellers:

- If the widget is worth E$500 to Sellers, (s)he receives the entire promise (E$300) and the overall amount the Seller receives from selling the widget is E$50 + E$300 = E$350, which equals the sum of Downpayment and Promise. The Per-Trade Profit to the Seller is E$350 minus the final value of the widget to the Seller, that is, E$350 – E$500 = -E$150 (negative 150), a Per-Trade Loss.

- But if the widget is worth only E$100 to Sellers, (s)he receives only E$100 at the end of the round and the overall amount the Seller receives from selling the widget is only E$50 + E$100 = E$150, which is less than the agreed-upon sum of Dowpayment and Promise. The Per-Trade Profit to the Seller is E$150 minus the final value of the widget to the Seller, that is, E$150 – E$100 = E$50.

The Per-Round Profit

As we said, in each round we give Buyers an initial endowment of E$300, and Sellers an initial endowment of 3 widgets, so that Sellers can sell the widgets and Buyers can buy them. At the end of the round, we will take these initial endowments back, so that the Per-Round Profit only depends on the profits or losses made while trading and not on the initial endowment.

As a result, your Per-Round Profit is ***the sum of the Per-Trade Profits from each of your trades.***

At the end of the round, your screen will show the Final Value of the widget, the Per-Trade Profits of each trade, and the Per-Round Profit for that round. Note that the Per-Round Profit can be positive or negative depending on whether you made or lost money in the round.

Other Rounds

After the first round ends, you will move to the next round, until round 12. At the beginning of each round, you will be given cash (if you are a Buyer) or widgets (if you are a Seller) to be able to trade in the round. Each round is separate: **you will not be able to use the widgets or cash from previous rounds**.

Part B of the Experiment

After Part A ends, you will read the Instructions for Part B and then play Part B, which only consists of 10 rounds. When Part B ends, we will discard the first 2 rounds, which are for practice only.

Final Payoff

At the end of the experiment, we will randomly select ONE round in order to calculate your final payoff. This round is chosen out of 16 rounds: the last 8 rounds of Part A, and the last 8 rounds of Part B.

Your Final Payoff will be

The Chosen Per-Round Profit +1,200

We add E$1,200 to the chosen Per-Round Profit to ensure that you never end up with a negative Final Payoff.

Finally, we will convert your Final Payoff from E$ into US Dollars at the exchange rate of E$35 per $1. To this amount we will add the $5 participation fee, and pay you.

This is the end of the instructions for Part A. If you have any questions, please raise your hand and an experimenter will assist you privately.

Instructions for Part B

The experiment in Part B is like the experiment in Part A except for four differences:

1) The value of the widget when it is High.

2) How the value of the widget is determined.

3) How the profit from each trade is computed.

4) Number of rounds

1) The Final Value of the Widget.

In Part B, when the final value of the widget is High, it is worth E$500 for Buyers but only E$200 for Sellers (in contrast, in Part A the widget was worth E$500 for both Buyers and Sellers when it was High). So, at the end of each round, the final value of the widgets will be either

High: E$**500** for Buyers and E$**200** for Sellers
or
Low: E$**100** for both Buyers and Sellers

Note that when the final value of the widget is High, it is worth E$500 for Buyers but only E$200 for Sellers.

2) How we determine the Final Value of the Widget.

In Part B, the widget will either be High for everyone or Low for everyone (in contrast, in Part A the widget final value could be High for Buyers but Low for Sellers).

As in Part A, at the end of each round, we pick a ball from a bag with five numbered balls, from 1 to 5. If the number of the ball is 1, the final value of all widgets is Low (E$100). If the number is 2 or higher, the final value of all widgets is High (E$500 for Buyers and E$200 for Sellers).

The following table summarizes this information:

Ball Number	**1**	**2**	**3**	**4**	**5**
Value of the Widgets	Low	High	High	High	High
Value for Buyers	100	500	500	500	500
Value for Sellers	100	200	200	200	200

To summarize: in Part B: 1) the final value of the widget is either High for both Buyers and Sellers, or Low for both Buyers and Sellers and 2) when the final value of the widget is High, it is worth E$500 to Buyers but only E$200 to sellers.

3) The Final Payment and the Profit from each Round

Similarly to Part A, at the end of the round, the Buyer must pay the Promise to the Seller. However, the Buyer will never pay more and the Seller will never receive more than the final value of the widget to Buyers. That is, in order to determine how much Buyers pay Sellers only the value of the widget to Buyers is what matters.

Note that this is different to what happened in Part A. In Part A, the Seller never received more than the final value of the widget to Sellers. As a result, in Part A, it was possible that a Buyer paid the entire Promise (e.g., when the Buyer's final value was 500 and the promise was smaller), but a Seller only received E$100 (because the Seller's final value was 100). This never happens in Part B. If the Promise is lower than the Buyer's final value, the Buyer pays it in its entirety, and the Seller receives the amount that the Buyer pays (even if the payment is higher than the value of the widget to Sellers).

As a result, for Buyers the Per-Trade Profit from buying one widget is:

Per-Trade Profit = Final Value to Buyer – Downpayment – Final Payment =

Final Value to Buyer – Downpayment – Minimum of Promise and Final Value to Buyers

For a Seller, the Per-Trade Profit from selling a widget is:

Per-Trade Profit = (Downpayment + Final Payment) – Final Value to Seller =

(Downpayment + Minimum of Promise and Final Value **to Buyers**) – Final Value to Sellers

Example: Suppose a Buyer and a Seller trade a widget with a Downpayment of E$50 and a Promise of E$300.

The Buyer pays the Seller E$50 at the time of the trade. At the end of the round, (s)he pays the Seller the minimum of the Promise (E$300) and the value of the widget to Buyers:

- If the state is High, *the widget is worth E$500 to Buyers and E$200 to Sellers*.
    - The Buyer repays the entire Promise (E$300). The overall cost of the widget to the Buyer is E$300 + E$50 = E$350. The Buyer's Per-Trade Profit is E$500 - E$300 - E$50 = E$150.
    - The Seller receives the entire Promise (E$300). The overall amount the Seller receives from selling the widget is E$300 + E$50 = E$350, which equals the sum of Downpayment and Promise. The Per-Trade Profit to the Seller is E$350 minus the final value of the widget to the Seller, that is, E$350 – E$200 = E$150.

- If the state is Low, *the widget is worth only E$100 to Buyers and Sellers*.
    - The Buyer only pays E$100 at the end of the round. The overall cost of the widget is E$50 + E$100 = E$150, which is less than the sum of Downpayment and Promise. In this case, his/her Per-Trade Profit is E$100 – E$150 = - E$50 (negative E$50). Note that, as in this example, the Per-Trade Profit can be negative (that is, can be a Per-Trade Loss).
    - The Seller receives only E$100 at the end of the round. The overall amount the Seller receives from selling the widget is only E$50 + E$100 = E$150, which is less than the agreed-upon sum of Dowpayment and Promise. The Per-Trade Profit to the Seller is E$150 minus the final value of the widget to the Seller, that is, E$150 – E$100 = E$50.

The Rounds of the Experiment

Unlike Part A, you will only play for 10 rounds. In particular, you will only have two practice rounds. The profit for these first 2 rounds will not be considered to calculate your Final Payoff, since they are just for practice.

At the end of the experiment, we will randomly select ONE round in order to calculate your Final Payoff. This round is chosen from the last 8 rounds of Part A, and the last 8 rounds of Part B.

Your Final Payoff will be:

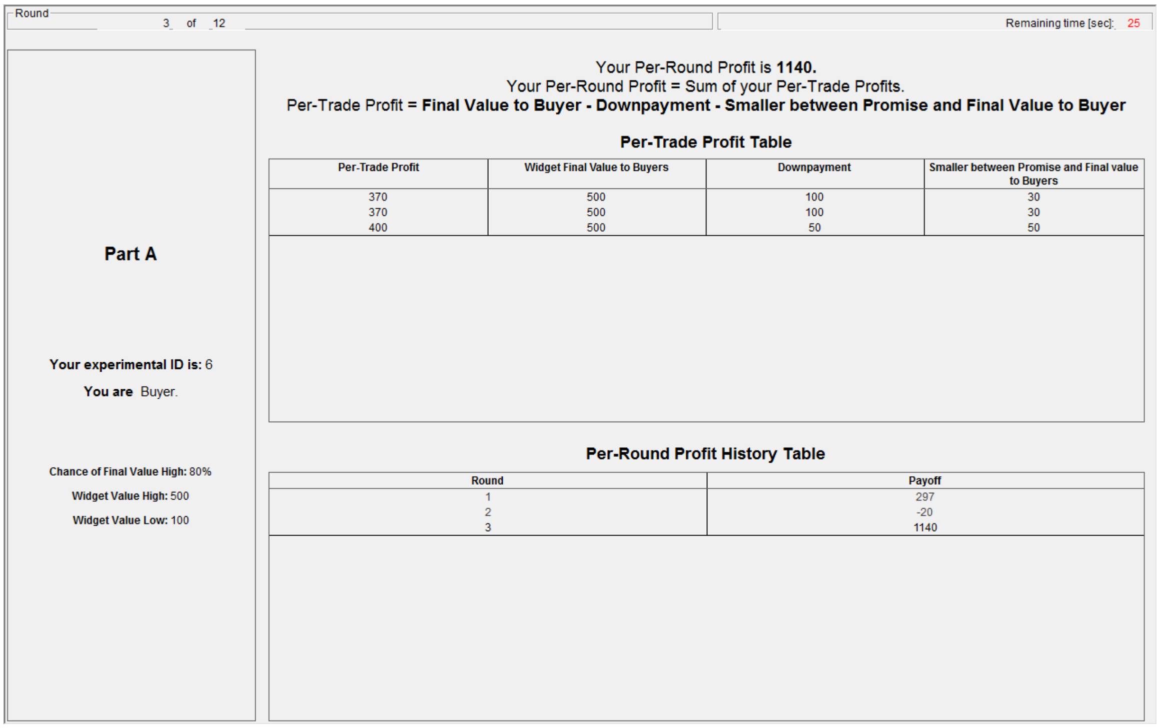
The Chosen Per-Round Profit +1,200

We add E$1,200 to the chosen Per-Round Profit to ensure that you never end up with a negative Final Payoff.

Finally, we will convert your Final Payoff from E$ into US Dollars at the exchange rate of E$35 per $1. To this amount we will add the $5 participation fee, and pay you.

This is the end of the Instructions for Part B. If you have any questions, please raise your hand and an experimenter will assist you privately.

Screenshots


Round
3 of 12
Remaining time [sec]: 25

Part A

Your experimental ID is: 6
You are Buyer.

Chance of Final Value High: 80%
Widget Value High: 500
Widget Value Low: 100

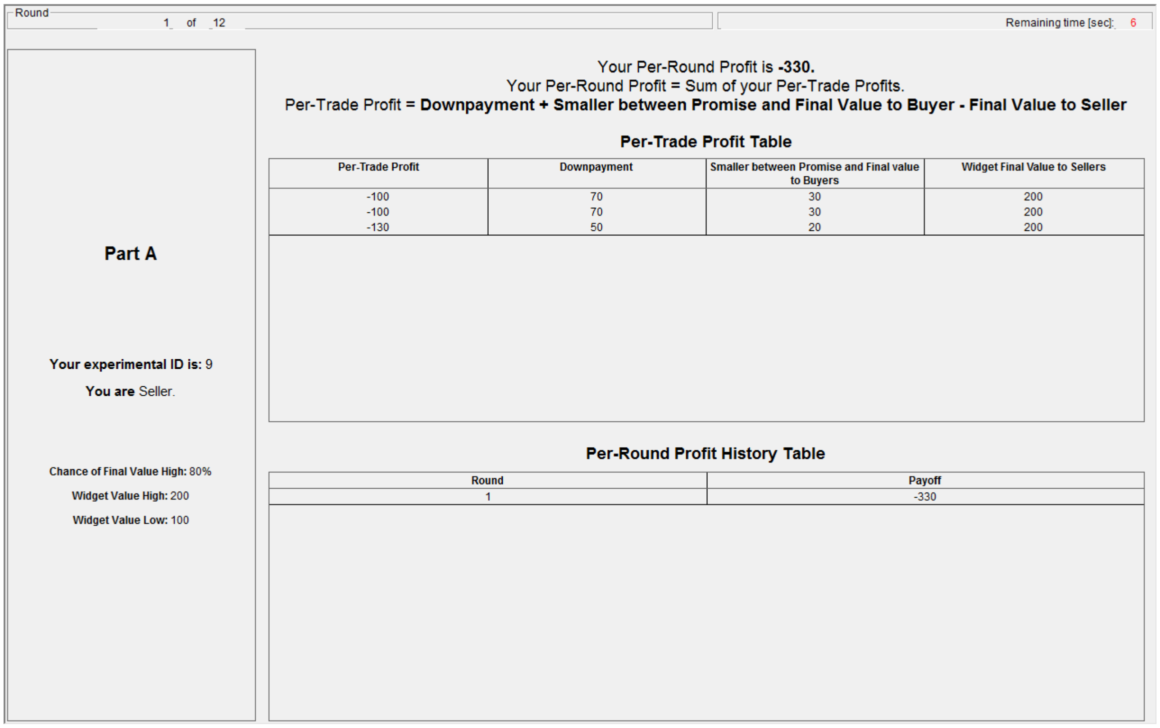
Your Per-Round Profit is **1140.**
Your Per-Round Profit = Sum of your Per-Trade Profits.
Per-Trade Profit = **Final Value to Buyer - Downpayment - Smaller between Promise and Final Value to Buyer**

Per-Trade Profit Table

Per-Trade Profit	Widget Final Value to Buyers	Downpayment	Smaller between Promise and Final value to Buyers
370	500	100	30
370	500	100	30
400	500	50	50

Per-Round Profit History Table

Round	Payoff
1	297
2	-20
3	1140



Per-Trade Profit	Downpayment	Smaller between Promise and Final value to Buyers	Widget Final Value to Sellers
-100	70	30	200
-100	70	30	200
-130	50	20	200

Round	Payoff
1	-330