Leverage and Asset Prices: An Experiment.

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Abstract

This is the first paper to test the asset pricing implication of leverage in the laboratory. We show that as theory predicts, leverage increases asset prices: when an asset can be used as collateral, its price goes up. This increase is significant, and quantitatively close to what theory predicts. However, important deviations from theory arise in the laboratory. First, allowing agents to buy on margin shifts the aggregate demand for the asset, even though agents do not exhaust their purchasing power when collateralized borrowing is not allowed. Second, the spread between collateralizable and non-collateralizable assets does not increase during crises.

Keywords: Leverage, Asset Pricing, Experimental Economics.

JEL Codes: A10, C90, G12

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The recent financial crisis highlighted the impact that leverage has on financial system stability. The crisis was preceded by a sharp increase of leverage in the financial system, both at the institution and at the asset level. The crisis poster-children, AIG and Lehman, as well as the systemic banking troubles in the US and Europe clearly illustrate the risks margin calls pose for the financial system’s liquidity and solvency. Because of this, recent academic work has focused on the effect of leverage in a financial economy.\footnote{See for instance, Acharya and Viswanathan (2011), Adrian and Shin (2010), Araujo et al. (Forthcoming), Brunnermeier and Pedersen (2009), Cao (2010), Fostel and Geanakoplos (2008, 2011 and forthcoming), Garleanu and Pedersen (2011), Geanakoplos (2010), Gromb and Vayanos (Forthcoming) and Simsek (2010).}

An important strand of this literature has studied the asset pricing implication of leverage. Two papers develop a formal theory of asset pricing: Fostel and Geanakoplos (2008) in a general equilibrium model with incomplete markets, and Garleanu and Pedersen (2011) in a CAPM model.\footnote{Hindi (1994) studied the pricing implication of leverage in a partial-equilibrium setup with exogenous leverage.} These papers show that, in a world where agents are heterogeneous and markets incomplete, using an asset as a collateral (i.e., buying on margin) increases its price in equilibrium.

This happens because when assets can be used as collateral to borrow money, their prices not only reflect future cash flows, but also their efficiency as liquidity providers. Fostel and Geanakoplos (2008) show that the price of any asset can be decomposed into two parts: its payoff value and its collateral value. The payoff value reflects the asset owner’s valuation of the future stream of payments, i.e., it is the value attached to the asset due to its investment role. The collateral value reflects the asset owner’s valuation of being able to use the asset as collateral to borrow. The asset collateral role is priced in equilibrium and, as a result, creates deviations from the Law of One Price: two assets with
identical payoffs are priced differently if they have different collateral values. An example of such deviation is the so-called “CDS-basis,” which became more severe during the recent crisis. An investor buying a corporate bond and its CDS creates a synthetic risk-free position. However, the price of this synthetic instrument is usually below that of a treasury, an apparent arbitrage opportunity that can be explained by the fact that treasuries can be used more easily as collateral than the synthetic instrument.

Theory also predicts that leverage allows gains from trade to be realized: when leverage is possible the asset is held in equilibrium by those agents who value it the most. Moreover, as a result of bad news, the spread between assets that can be bought on margin and those that cannot should increase in equilibrium. Fostel and Geanakoplos (2008) called this phenomenon “Flight to Collateral:” when the crisis hits, assets that can be used as collateral see their prices drop by less than assets that cannot.

Our paper is the first to test the asset pricing implications of leverage in a controlled laboratory environment. To this purpose, we build a model of a financial economy with incomplete markets and heterogeneous agents that is amenable to experimental implementation. We compare two economies, which are identical except that in one, the asset can be used as collateral and in the other, it cannot. When the asset can be used as collateral, its collateral value is positive, and, in equilibrium, its price is higher than when it cannot.

The laboratory results confirm the theory’s main predictions. When the asset can be used as collateral, its price increases. This increase is significant and quantitatively close to what theory predicts. That is, subjects are willing to pay more when the asset can be used as collateral despite the fact that payoffs in all states of the world are the same. Moreover, as theory suggests, leverage allows gains from trade to be realized in the laboratory.
age is possible, agents who value the asset the most end up holding more of it.

However, important deviations from theory arise in the laboratory. First, allowing agents to buy on margin shifts the aggregate demand for the asset, even though agents do not exhaust their purchasing power when collateralized borrowing is not allowed. We show that this is the result of subjects’ heterogeneous behavior: borrowing primarily stems from those subjects who were close to their budget constraint when the asset could not be bought on margin. Second, Flight to Collateral does not arise in the laboratory. We show that this happens because the empirical aggregate supply function was a smooth version of the theoretical one.

Section 1 develops the theoretical model. Section 2 describes the experiment design and the experimental procedures. Section 3 presents the results.

1 Theory

1.1 The Model

We develop a model of leverage and asset prices that is amenable to laboratory implementation. The model retains the main features of the standard models in the literature (Geanakoplos 2003, and Fostel and Geanakoplos 2008): market incompleteness and agent heterogeneity. As in these earlier models, a spread between collateralizable and non-collateralized asset prices arises in equilibrium, and there is flight to collateral when bad news are more likely. Our model is novel because it contains three features that make it implementable in the laboratory, and which are not present together in the previous literature: there are only two types (as opposed to a continuum) of agents,
agents are risk neutral, and there is no consumption at time zero.

**Time and Assets**

We consider a two-period economy, with time $t = 0, 1$. At time 1, there are two states of the nature, $s = High$ and $s = Low$, which occur with probability $q$ and $1 - q$ respectively. In the economy, there is a continuum of risk-neutral agents, of two different types—which we will characterize later—indexed by $i = O, P$.

There are two assets in the economy, cash and a risky asset $Y$ (from now on “the asset”) with payoffs in units of cash. In state $Low$, the risky asset pays $D_{Low}$, which is the same for all agents’ types, whereas in state $High$ it pays $D_{High}^i$, which differs across types. Nevertheless, for each type $i$, it is always true that $D_{Low} < D_{High}^i$, that is, the payoff in the high state of the world is always higher than the payoff in the low state of the world.

**Agents**

At $t = 0$, agents of type $i$ have an endowment of $m^i$ units of cash and of $a^i$ units of the asset. Agents’ payoff in each state $s = High, Low$ is given by a linear payoff function:

$$u^i_s = w + D^i_s y - \varphi.$$

In equation (1), $w$ denotes final cash holdings, $y$ refers to final asset holdings, $D^i_s y$ represents the asset payoffs in state $s$, and $\varphi$ is debt repayment. The expected payoff to agent of type $i$ is given by

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3We introduce the debt repayment $\varphi$ in the payoff function to mimic the way payoffs are explained to the subjects in the laboratory. One could re-write the model having $\varphi$ in the budget constraint, and having only final cash holdings net of repayment in the payoff function.
\[ U^i = qu_{High}^i + (1 - q)u_{Low}^i. \]  

(2)

As we mention above, in this model, agents are heterogeneous as they disagree on what the asset pays in the high state. Following Fostel and Geanakoplos (2008), we consider two types of agents: Optimists and Pessimists, denoted by \( i = O, P \). Each type of agent has mass 1. Optimists believe that the asset pays more in state High than do Pessimists, that is, \( D^O_{High} > D^P_{High} \).\(^4\) The difference in payoffs may be interpreted as Optimists and Pessimists owning different technologies that affect the asset’s productivity. What is crucial for our results is to have some sort of heterogeneity. In Fostel and Geanakoplos (2008) heterogeneity is modeled as differences in subjective probabilities over the states of the world. In contrast, here, in order to make the experiment easier to implement in the laboratory, heterogeneity is modeled as differences in the asset payoff in the high state of the world.\(^5\)

The purpose of this paper is to study the asset pricing implications of collateralized borrowing in a laboratory financial market. In order to do so, we study two different economies: first, the No-Leverage economy, from now on the \( NL \)-economy, where agents cannot borrow. Second, the Leverage economy, from now on the \( L \)-economy, where agents are allowed to borrow using the asset as collateral.

We will now present the theoretical models of the \( NL \) and \( L \)-economy that we bring to the laboratory.\(^4\)This is similar to how gains from trade arise in the double auction literature, see, e.g., Smith (1962), Plott and Sunder (1982), and subsequent papers.\(^5\)Our model could be re-written as a model with heterogeneous priors and three states of nature, where the assets pays \( D_{Low} \), \( D^P_{High} \), and \( D^0_{High} \). Optimists would give probability \( q \) to the state paying \( D^O_{High} \) and 0 to the state paying \( D^P_{High} \), whereas Pessimists would do the opposite.
The **NL-economy**

In the **NL**-economy agents cannot borrow, and therefore $\varphi = 0$. Taking as given the asset price, agents choose asset holdings $y$ and cash holdings $w$ in order to maximize the payoff function (2) subject to their budget constraint:

$$w + py \leq mi + pa^i.$$  

(3)

An equilibrium in the **NL**-economy is given by asset price $p$, cash holdings $w$, and asset holdings $y$ such that asset market clears and that agents maximize their payoff function (2) subject to the budget constraint (3).

The **L-economy**

In the **L**-economy agents can borrow from a bank using the asset $Y$ as collateral. Agents cannot borrow unless they post the asset as collateral. We assume that the maximum amount agents can borrow per unit of the asset is $D_{Low}$, that is, the asset payoff in the low state. In other words, the minimum downpayment to purchase one unit of the asset is $p - D_{Low}$. This condition guarantees that there can never be default in equilibrium, as the loan is equal to the asset payoff in state Low. This borrowing constraint is sometimes referred to as Value at Risk equal to zero ($VaR = 0$) and is widely used in the literature.7

Agents take the asset price $p$ as given and choose asset holdings $y$, cash holdings $w$, and borrowing $\varphi$ in order to maximize (2) subject to the borrowing constraint (4) and budget constraint (5):

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6Since we are not modeling the credit market, we will assume that the interest rate set by the bank is zero. That is, the amount borrowed at time 0, $\varphi$, is also the amount to be repaid at time 1.

\[ \varphi \leq D_{Low}y, \quad (4) \]

\[ w + py \leq m^i + pa^i + \varphi. \quad (5) \]

An equilibrium in the \( L \)-economy is given by asset price \( p \), cash holdings \( w \), asset holdings \( y \), and borrowing \( \varphi \) at \( t = 0 \) such that the asset market clears and that agents maximize their payoff function (2) subject to constraints (4) and (5).

The degree of leverage at the security level is measured by the Loan-to-Value ratio, defined as \( LTV = \frac{\varphi}{py} \), which measures how much an agent can borrow using one unit of asset as collateral as a proportion of the asset price. The Loan-to-Value ratio can be interpreted as a measure of how effective the asset is as collateral. We will show in the remainder of the section that this role as collateral has profound asset pricing implications.

### 1.2 Equilibrium Analysis

#### Parameter Choice: The Bullish Market

In order to study the asset pricing implications of collateralized borrowing, we calculate the equilibrium in both the \( L \) and \( NL \)-economy. Note that even for this simple model of collateral economy, one cannot solve for the equilibrium price and quantities analytically. For this reason, we solved the model numerically for the set of parameters presented in Table 1. These parameter values were chosen so that the economy is amenable to laboratory implementation. We further discuss this choice in Section 1.3 below.
Table 1: Parameter Values in the Bullish Market

<table>
<thead>
<tr>
<th>Parameters</th>
<th>$D_{Low}$</th>
<th>$D_{High}^O$</th>
<th>$D_{High}^P$</th>
<th>$q$</th>
<th>$m^O$</th>
<th>$m^P$</th>
<th>$a^O$</th>
<th>$a^P$</th>
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</thead>
<tbody>
<tr>
<td>Values</td>
<td>100</td>
<td>750</td>
<td>250</td>
<td>0.6</td>
<td>15,000</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

Under this parametrization, the asset’s payoff in state Low is $D_{Low} = 100$; in state High is $D_{High}^O = 750$ for the Optimists and $D_{High}^P = 250$ for the Pessimists. The probability of the state of the world being High is $q = 0.6$. Optimists have initial cash endowments $m^O = 15,000$, whereas Pessimists have no cash. In contrast, Pessimists have initial asset endowments, $a^P = 100$, whereas Optimists have no asset endowment. Note that since Optimists have all the cash endowment and Pessimists have all the asset endowment, Optimists are on the demand side of the market, and Pessimists on the supply side. In the remainder of the paper, we refer to this combination of parameters as the Bullish market, since under this parametrization, the High state is more likely than the Low state.

**NL-economy**

The equilibrium values are presented in the left column of Table 2. The equilibrium asset price is 190.

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8The reason why we parametrized the model with large cash and asset endowments is to generate differences in behavior across treatments that can be detectable in the laboratory. For instance, with our parameter values, if subjects had only 10 units of the asset and 1,500 in cash, Optimists’ equilibrium holdings in the L and NL-economies would have been 9 and 10 units respectively. As a result, even a small amount of noise would have masked the effect of leverage in the laboratory.

9Dividing subjects into sellers and buyers simplifies the laboratory implementation considerably (see, for instance, in the double auction literature, Smith, 1962).

10Note that, as a convention, we will use the world “market” to refer to the parametrization (Bullish vs. Bearish) and the word “economy” to refer to whether agents are allowed to leverage on the asset or not (L and NL-economy).
Individual decisions are described in the lower part of the table. In equilibrium, the Optimists use all their cash to buy all the assets they can afford; this happens because their expected value of the asset \( (0.4(100) + 0.6(750) = 490) \) is higher than the price, and the solution to their optimization problem is a corner solution. As a result, they invest their wealth of 15,000 in buying 78.95 units at the price of 190, and their final cash holdings are zero.

In contrast, the solution to the Pessimists’s optimization problem is not a corner solution: at a price of 190 they are indifferent between holding cash and holding the asset (as their expected value, \( 0.4(100) + 0.6(250) \), equals the price). In equilibrium, they end up with 21.05 units of \( Y \) and 15,000 of cash.\(^{11}\)

Figure 1 shows the Pessimists’ supply and the Optimists’ demand. The supply (gray line) is a step function that becomes horizontal at the Pessimists’ expected value (190). The demand (black line) is a decreasing function of the price, determined by the Optimists’ budget constraints.\(^{12}\) Demand intersects

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\(^{11}\)In the experiment, we will not assume that the asset is perfectly divisible, hence we will use as a theoretical benchmark the closest integer approximation.

\(^{12}\)The demand drops to zero when the price reaches the Optimists’ expected value (490). In our parametrization, however, this region of the demand curve is irrelevant for the deter-
Figure 1: Supply (grey) and Demand (black) in the Bullish NL-economy.

supply in the horizontal segment of the supply schedule. As a result, in equilibrium, Pessimists’ expected value determines the price, whereas Optimists’ budget constraint pins down the quantity traded.

In equilibrium, assets change hands from Pessimists (who value the asset less) to Optimists (who value the asset more), thereby realizing gains from trade in the economy. However, due to the Optimists’ inability to borrow, gains from trade are not fully exploited. Indeed, in equilibrium Pessimists hold a strictly positive quantity of the asset and share it with Optimists.

Finally, the payoff resulting from the equilibrium allocation are 59,212 in state High and 7,895 in state Low for Optimists; 20,262 in state High and
17, 105 in state Low for Pessimists.

**L-economy**

The equilibrium values are presented in the right column of Table 2. The equilibrium asset price is 250.

Individual decisions are described in the lower part of the table. Since Optimists' expected value (490) is greater than the equilibrium price, they buy as many units of the risky asset as they can afford (100 units) on margin. That is, for each unit of the asset that they purchase, they borrow the maximum amount allowed, 100 per unit of the asset, and pay a downpayment of 150 to cover the unit price of 250. Hence, Optimists borrow 10,000 using the assets as collateral and use their initial wealth to cover the total downpayment, i.e., $100(250 - 100) = 15,000$. They do not save any of their initial cash endowment and leverage to the maximum extent. As a result, the equilibrium asset loan-to-value is $LTV = \frac{\phi}{\rho_y} = \frac{10,000}{250(100)} = 0.4$. By borrowing 100 per asset, Optimists can afford to buy 100 units and, as a result, end up holding all the assets in the economy.

The solution to Pessimists' optimization problem is also a corner solution, since their expected value of the asset (190) is now lower than the price. As a result, they sell all their endowment of the risky asset at a price of 250 and receive $100(250) = 25,000$ in cash.

In this equilibrium, unlike in the previous one, Optimists determine the price through their budget and borrowing constraints. This happens because collateralized borrowing reduces the downpayment to be paid at time 0, from $p$ to $p - \varphi$, thereby shifting demand upward with respect the NL-economy. The supply side of the market is not affected by the change in credit conditions since, in this economy, the supply of credit is exogenous and perfectly elastic. As a result, as Figure 2 shows, demand (black line) now intersects supply (gray
line) on the vertical segment of the supply curve and, in equilibrium, the price is solely determined by demand.

In contrast to the NL-economy, gains from trade are fully realized in equilibrium: all the assets change hands from the Pessimists to the Optimists. In equilibrium the payoff are 65,000 in state High and 0 in state Low for Optimists; 25,000 in both states for Pessimists.

1.3 Leverage and Asset Prices

The Spread in Prices

The important feature of our model is that the equilibrium price is higher in the L-economy than in the NL-economy. As we have seen in Section 1.2,
\[ p_L = 250 > p_{NL} = 190, \] generating a spread of \( s = 60. \) That is, two assets with identical payoffs (i.e., the risky asset in the \( L \)-economy and the risky asset in the \( NL \)-economy) have different prices in equilibrium.

In the economy without leverage, even if the Optimists value the asset more than the Pessimists do, they cannot afford to buy all the assets in the economy; as a result, some assets end up in the hands of the less enthusiastic investors (the Pessimists), lowering the asset price in equilibrium. In contrast when leverage is possible, Optimists can afford to buy all the assets in the economy. The asset price is determined only by the Optimists (i.e., by their budget and borrowing constraints). Since the asset price does not reflect Pessimists’ expectations, it will be higher.

![Figure 3: Supply (grey) and Demand (\( NL \)-economy: dotted black; \( L \)-economy: solid black) in the Bullish Market.](image)
The effect of leverage on the equilibrium price can be seen in Figure 3, which combines Figures 1 and 2, that is, the supply and demand in the $L$ and $NL$-economy. The gray line is the supply function, which, as we already mentioned, is the same for both economies.

The ability to borrow against the asset, however, does affect the demand: the demand in the $L$-economy (solid black) is always higher than in the $NL$-economy (dotted black). This can be seen from equations (3), (4) and (5). In both $L$ and $NL$ economies, Optimists chose zero cash holdings provided that the price is less than 490 (their expected value). From their budget constraint (equation 3), we have that the demand in the $NL$-economy is given by $p_i = \frac{m^i}{y}$; whereas from equations (4) and (5) the demand in the $L$-economy is given by $(p - D_{Low}) = \frac{m^i}{y}$, that is, there is a shift in demand. The shift happens because as mentioned before, the downpayment in the $L$-economy is reduced by the amount borrowed per unit of asset.

Note that the wedge between demands is the only factor generating the spread between prices in the two economies. Because of this gap, demand intersects supply in two different segments of the supply function. In the $NL$-economy, the intersection occurs when supply is flat, and as a result Optimists and Pessimists share the asset, and Pessimists’ expectations determine its price. In the $L$-economy, the curves intersect when supply is vertical at 100; as a result, only Optimists hold the assets and their budget and borrowing constraints determine the price.\(^\text{13}\)

Notice, that the effect of collateralized borrowing is different from the effect of an increase in the cash endowment $m^i$. This is so because the loan repayment

\(^{13}\text{In the NL-economy the price needs to be equal to Pessimists’ expected value for them to be willing to hold (some units of) it; in the L–economy, the price needs to be greater than Pessimists’ valuation for them to be willing to sell all of it.}\)
affects the asset payoffs in the final period. Because of buying on margin, the
net asset payoff is \( D_{High} - D_{Low} \) in state High and 0 in state Low. To put it
differently, Optimists when buying one unit of asset on margin are effectively
buying the Arrow security that pays 1 in state High.

The spread between the equilibrium prices in the \( L \) and \( NL \)-economy is
positive when the set of agents determining the price is different across the two
economies. As explained before, in the \( NL \)-economy the Pessimists determine
the price, whereas in the \( L \)-economy the price is determined by the Optimists.
A spread would not have been generated in equilibrium if the set of agents
determining the price in the two economies were the same. This can happen
under two circumstances: i) when Optimists have a large cash endowment \( m^0 \)
so that they afford to buy all the assets even in the \( NL \)-economy, and ii) if the
borrowing constraint is very tight (i.e., \( D_{Low} \), the maximum agents can borrow
per asset, is small), so that even if the Optimists borrow as much as they can,
they are still not able to afford all the assets in the economy. The choice of
parameters described in Table 1 ensures that the set of agents determining the
price is different across economies.\(^{14} \)

**Payoff Value and Collateral Value**

How can we interpret the spread between the \( L \) and the \( NL \)-economy?
In the \( NL \)-economy, Pessimists determine the price in equilibrium. Since
they are risk neutral, the price equals the asset’s expected value according
to Pessimists, 190. In the \( L \)-economy, Optimists price the asset. Its price in
equilibrium, however, is lower than the Optimists’ expected value (490).

Fostel and Geanakoplos (2008) first showed that in an economy with col-

\(^{14}\)Note that the set of parameter choices for which this occurs is an open set with positive
measure, that is, small perturbations in the parameter values do not destroy the properties
of the equilibriums that we describe. For a discussion of the robustness of the pricing effect
of leverage see Fostel and Geanakoplos (2008).
lateralized borrowing, assets have a dual role: they are not only investment opportunities (i.e., they give a right to a future cash flow), but also allow investors to borrow money (i.e., they provide a technology to transfer wealth across time). That is, their price can be decomposed into two parts: the Payoff Value, which reflects the asset future cash flow, and the Collateral Value, which reflects the premium agents are willing to pay to hold an asset that can be used as a collateral.

Let us first define the Payoff Value. As we saw, Optimists use all their cash to buy the asset on margin, thereby synthetically creating a new security, the Arrow security that pays 1 in state High. As a result, the payoff of a unit of cash today is given by the payoff of the Arrow security High \(0.6(750 - 100)\) divided by the downpayment \(250 - 100\). Denote by \(\eta_O\) the payoff to an Optimist of a unit of cash at time 0. Then, \(\eta_O = \frac{0.6(750-100)}{250-100} = 2.6\), which is greater than one. Hence, the appropriate discount factor for the cash flow at time 1 for the Optimist is not 1, but \(\frac{1}{\eta_O} = 0.38\). The asset’s Payoff Value for an Optimist is therefore given by \(PV = \frac{E_O(Y)}{\eta_O} = \frac{490}{2.6} = 188.5\).

The second role of the asset is that of a provider of liquidity, which defines the asset’s Collateral Value. For each asset, an Optimist can borrow 100 units of cash. As we saw before, Optimists invest cash in the Arrow security High, whose expected return is \(\frac{0.6(750-100)}{250-100} - 1\) = \(\eta_O - 1 = 1.6\). The resulting expected cash flow from borrowing 100, that is, \(100(1.6)\), is to be discounted as before by \(\frac{1}{\eta_O} = 0.38\). Hence, the asset’s Collateral Value for an Optimist is given by \(CV = \frac{100\times(\eta_O-1)}{\eta_O} = \frac{100\times1.6}{2.6} = 61.5\).

Hence the price of the asset in the \(L\)-economy is given by \(p = PV + CV = 188.5 + 61.6 = 250\), which equals the asset’s price in equilibrium (see Table 1). Note that the Payoff Value in the \(L\)-economy is lower than that in the
Nevertheless, because of the presence of the Collateral Value, there is a positive spread between the two economies.

In the Appendix, we present a model identical to the model presented in Section 1, except that two assets with the same payoffs in all states of the world are traded; one that cannot be used as collateral, and one that can. We show that for the same parameter choices as in the Bullish market, the price of the asset that can be used as a collateral is higher. Indeed, in this two-asset economy, the price of the asset that cannot be used as collateral is the same as the asset price in the NL-economy, and the price of the asset that can be used as collateral is the same as the asset price in the L-economy. This result is a deviation from the Law of One Price, since two assets with the same payoffs in all states of the world have different prices in equilibrium in the same economy.

Unfortunately, the two-asset model would be very difficult to implement in the laboratory. For this reason, in the experiment, we implemented the NL and L-economy sequentially. As a result, we do not observe a spread between the prices of the two assets in equilibrium in the same economy. Nevertheless, since the two economies are identical in everything except the collateral capacity of the asset, the spread between the prices in the two economies is akin to a deviation from the Law of One Price.

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15In the NL-economy, since Pessimists are not constrained, their marginal payoff of money is one, $\eta_P = 1$. Hence, the Payoff Value coincides with the Pessimists' expected value, 190.

16As we describe in the Procedures (Section 2) and in the Instructions (see Appendix), the game implemented in the laboratory is already very complex, especially the explanation of how buying on margin works. An extension to a two-asset case, in which only one asset can be bought on margin, would have been extremely difficult to explain to the subjects.
1.4 The Bearish Market

In this section, we consider a parametrization identical to the Bullish market, except that $q$ is lowered to 0.4. We refer to this as the *Bearish Market*, as the probability of state High is now lower than that of state Low.

Table 3 shows the equilibrium outcomes when $q = 0.4$ for both the $NL$ and $L$-economy.

<table>
<thead>
<tr>
<th></th>
<th>$NL$-economy</th>
<th>$L$-economy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>160</td>
<td>250</td>
</tr>
<tr>
<td>Spread: 90</td>
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<td></td>
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<tr>
<td>Optimists</td>
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<td>Pessimists</td>
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<td>$u_U$</td>
<td>16,562</td>
<td>25,000</td>
</tr>
<tr>
<td>$u_D$</td>
<td>15,625</td>
<td>0</td>
</tr>
</tbody>
</table>

Note that the equilibrium price of the $NL$-economy drops from 190 in the Bullish market to 160 in the Bearish market. In contrast, in the $L$-economy, the equilibrium price stays put at 250. As a result, the spread between the $NL$ and $L$-economy increases from 60 in the Bullish market to 90 in the Bearish market. The increase in spread after bad news is what Fostel and Geanakoplos (2008) interpreted as *Flight to Collateral*: during a crisis, assets that can be used as a collateral become relatively more valuable.

In the Bearish market, the equilibrium regime is the same as the one described before: that is, in the $NL$-economy the price is determined by Pessimists, whereas in the $L$-economy it is determined by the Optimists. The
supply and demand curves for both the \( L \) and \( NL \)-economies are shown in Figure 4. In both \( L \) and \( NL \)-economies, the Optimists’ demand function does not shift with respect to the Bullish Market, as Optimists’ behavior is determined by their budget and borrowing constraints (which are not affected by the decrease in probability of the high state of the world).\(^{17} \) In contrast, the Pessimists’ supply function shifts downward, as their expected value of the asset decreases. Because of this downshift in supply, the price in the \( NL \)-economy decreases.

The question is why the downward shift in price does not occur in the \( L \)-economy. In the \( L \)-economy the price is only determined by the Optimists, for demand intersects the vertical segment of the supply schedule. Since demand does not change as \( q \) changes, the price does not change either. Because the decrease in \( q \) lowers the price only in the \( NL \)-economy, the spread between the \( L \) and \( NL \)-case increases when we move from the Bullish to the Bearish market.

\section{The Experiment}

\subsection{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 at George Mason University using the ICES online recruiting system. 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

\(^{17}\text{Strictly speaking, this is true only for the region of prices below the Optimists’ new expected value (360), which, however, is the relevant region for price determination given the Pessimists’ supply function.}\)
in the experiment knew each other. Subjects had no previous experience with the experiment. The experiment was programmed and conducted with the software z-Tree\textsuperscript{18}.

The experiment consisted of five sessions. Twelve students participated in each session for a total of 60 students. Each session consisted of four treatments, corresponding to the four economies described in Section 1:

1) The Bullish Market in the No-Leverage Economy: the Bull-NL Treatment.


3) The Bearish Market in the No-Leverage Economy: the Bear-NL Treat-

\textsuperscript{18}See Fischbacher (2007).
4) The Bearish Market in the Leverage Economy: Bear-L Treatment.

Note that in each session the same group of students played all four treatments, thus allowing us to study the difference in behavior across treatments with one-sample statistical techniques.

For each of the five sessions, we ran the experiment over two days. In Sessions 1, 2 and 3, we ran Bull – NL and Bear – NL the first day, and Bull – L and Bear – L the second day. In Sessions 4 and 5, we ran Bear – L and Bull – L the first day, and Bear – NL and Bull – NL the second day. Therefore, in Sessions 4 and 5 we inverted both the sequence of Bull vs. Bear and of NL vs. L, thus allowing us to control for order effects in the data.

In each treatment of each session, we ran fifteen rounds of the same economy. The first four rounds of each treatment (both in treatments played on day one and those played on day two) were used for practice and did not determine students’ payments. The experiment lasted on average 2.5 hours each day. Students were paid at the end of the second day. They received on average $35, including a $10 show-up fee paid at the end of the first day.

2.2 The Procedures

We first describe the procedures for the Bull – NL treatment in those sessions (1 to 3) when the NL treatment is played first. Later we will describe the procedures for the other treatments and sessions.

1) At the beginning of the experiment, we gave written instructions to all subjects.\(^{19}\) We read the instructions aloud in order to make the structure of the experiment common knowledge. Then, we gave the subjects time to ask

\(^{19}\)The Instructions and screenshots are included in the Appendix.
questions, which were answered in private by the experimenters.

2) All payoffs were denominated in an experimental currency called E$. The risky asset was referred to as a “widget.” Optimists and Pessimists were referred to as Buyers and Sellers. In our economy, Optimists hold all the cash (and have to decide how much to buy) and Pessimists all the assets (and have to decide how much to sell); therefore, the terms Buyers and Sellers were easier for subjects to understand as they characterized what their role was in the experiment. \(^{20}\) Nevertheless, in the remainder of the paper, when describing the empirical results, we will continue to use the terminology of the theoretical model (i.e., Optimists and Pessimists).

3) At the beginning of the round, each subject was randomly assigned to be either an Optimist or a Pessimist. In every round, there were six Optimists and six Pessimists. Subjects could see their role in the left corner of their computer. Subjects had the same role in any given round of all four treatments they played: that is, if a subject was a Pessimist in the first round of the Bull – NL treatment and an Optimist in the second round, then he was also a Pessimist in the first round and an Optimist in the second round of the other three treatments. We did so in order to increase the statistical power of our tests (see footnote 28).

4) Next, the demand by Optimists and the supply by Pessimists were elicited by presenting them with a list of ten prices and asking them how many units of the asset they wanted to buy (Optimists) or sell (Pessimists) at each price. For each of the 10 prices, Optimists were informed of the maximum number of assets that they could afford to buy. The computer mechanically enforced (weakly) upward sloping supply, and downward sloping supply.

\(^{20}\)Moreover, we wanted to avoid using the terms “Optimist” and “Pessimist” so as not to bias subjects’ behavior.
demand. That is, if an Optimist demanded \( x^1 \) at a price \( p^1 \), he was only allowed to demand \( x^2 \leq x^1 \) at a price \( p^2 > p^1 \).^{21}

5) The list of ten prices was taken from a pre-determined matrix and varied from round to round. Note that the matrix was the same (for each round) across sessions and treatments (i.e., we used the same matrix in the same round of each session and each treatment). We let prices vary slightly from round to round in order to avoid habituation.\(^{22}\)

6) After all the subjects had made their choices, the computer calculated the price at which trading occurred. The price was determined by minimizing the excess supply over the ten prices for which we elicited subjects’ choices. Subjects then learned about the price from the computer screen, and the trades were automatically realized. If excess supply was positive (negative) at the equilibrium price, supply (demand) was proportionally reduced for all Optimists (Pessimists).

7) After trading occurred, the state of the world was realized. In front of all the subjects, an experimenter extracted a ball from an urn with 6 red balls and 4 green balls. If the ball extracted was red (green), the state of the world was High (Low). The outcome of the extraction was shown to all subjects.

8) After the state of the world was realized, subjects could see in the computer screen their final per-round payoff. In order to avoid zero-payoff, a $10,000 bonus was paid to each subject at the end of each round in addition to their payoff.

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\(^{21}\)Since the payoff is defined in terms of final cash only, no rational agent would choose an inverted demand or supply function. Moreover, without the above choice restriction in the experiment, mistakes by even a small number of subjects could have created inversions in some segments of demand or supply. As a result, there could have been multiple prices, far away from each other, for which the distance between demand and supply is low. Given our price-selection rule, this would have generated large changes in the equilibrium price for small changes in subjects’ choices, thus making the equilibrium price less meaningful.

\(^{22}\)The matrix of prices is in the Appendix.
9) After round 1 ended, a new round started. The session continued until all 15 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.

After the 15 rounds were played, students were given the instructions for the Bear – NL treatment, which was played right after. We followed the same procedure described in points 1 to 9. In the Bear – NL treatment, we told subjects that the urn had 4 red balls and 6 green balls (so that the probability of the high state of the world was 40 percent, instead of 60 percent as in the Bullish market).

The same group of students were gathered the following day to play the two L-economy treatments (i.e., the Bull – L treatment and the Bear – L treatment), following the same procedures outlined in points 1 to 9. In the Instructions for the second day, subjects were explained in detail how borrowing worked: the maximum amount of borrowing allowed, its effect on subjects’ budget constraint and the impact of loan repayment on their final payoff. During the experiment, the Optimists’ screenshots indicated how much they needed to borrow to afford a given number of assets at a given price.\footnote{For each price, Optimists were told how many assets they could afford if: a) they did not want to borrow, b) if they wanted to borrow the maximum of 100 per asset, c) if they wanted to borrow only 30 per asset, and d) if they wanted to borrow only 60 per asset. In the Instructions, Optimists were told that this information was for reference only, and that they were not restricted to borrow the quantities indicated in the screen. Indeed, this did not generate any discreetness in the borrowing behavior (borrowing exactly 100, 30 or 60 was not very frequent).}

Finally, after trading decisions were made, the screenshots indicated how much Optimists had borrowed and had to repay at the trading price determined by the computer.

Optimists were not allowed to borrow and keep a positive cash balance (i.e.,
if the price was 300, they could borrow only if they wanted to buy more than 15,000/300 = 50 assets). This allowed us to simplify the choice problem facing the Optimists in that, for each price, they only had to choose the number of assets they wanted to buy. Given the complexity of the experiment, such simplification seemed sensible. Furthermore, not allowing subjects to maintain positive cash balances while borrowing, if anything, reduces the amounts borrowed. This works against finding significant differences in the spread between the prices in the $L$ and $NL$-economies, which is the main result of our paper.

Notice that our procedure to determine the equilibrium price is different from that of a double auction or of a call auction since we elicited the whole demand and supply schedule for each subject and in each round, with a novel methodology reminiscent of the “strategy method.” This is important since eliciting the whole demand and supply schedules is crucial for our understanding of the mechanism generating a spread between the equilibrium prices in the $L$ and the $NL$-treatment. Additionally, running a multiple-unit double auction would have been very difficult in our economy; in particular, in the $L$-treatment, the departure from the standard multiple unit-double auction would have been severe, as subjects would have had to choose prices, quantities and borrowing per asset at the same time.

After the end of the second treatment of the second day of the experiment,

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24 In a strategy method, a subject chooses an action conditional on all possible choices by the other subjects. In the game theory terminology, the subject chooses an action for all the nodes in the game where he may be called upon to act. In contrast, in our method, the subject chooses an action conditional on the market price, which is the result of the choices of all subjects, including himself (the price is in itself an equilibrium outcome and not a node in a game).

25 Note that we could not have possibly run a single-unit double auction since subjects could not have traded 100 units of the asset in a reasonable amount of time. See footnote 8 for a comment on the choice of the number of assets in the economy.
five rounds were extracted out of the last 11 rounds of each treatment (the first four rounds were for practice only). Payoffs were summed up and converted into US$ at the rate of E$20,000 per US$. Identical procedures were followed in Sessions 4 and 5, with the exception that the sequence in which the treatments were played was altered.

In the remainder of the paper we will confront the equilibrium price and quantities of the theoretical model with those that arise in the laboratory.

3 Results

3.1 The Bullish Market

We start by analyzing the equilibrium results in the Bullish market, comparing the equilibrium prices in the Leverage (L) and in the No-Leverage (NL) treatments. Table 4 shows the average equilibrium prices across the five sessions of the experiment and in each session separately.

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
</tr>
</thead>
<tbody>
<tr>
<td>NL</td>
<td>216</td>
<td>213</td>
<td>210</td>
<td>219</td>
<td>210</td>
<td>228</td>
</tr>
<tr>
<td>L</td>
<td>254</td>
<td>241</td>
<td>263</td>
<td>260</td>
<td>241</td>
<td>263</td>
</tr>
<tr>
<td>Spread</td>
<td>38</td>
<td>28</td>
<td>54</td>
<td>42</td>
<td>32</td>
<td>35</td>
</tr>
</tbody>
</table>

Due to a minor programming error in the z-tree code, earnings (“final cash”) of Optimists who did not borrow in the L-treatments were under-reported as a proportion of per-round earnings by an average of 0.0013, which corresponds to $0.002. This minor miscalculation was evidently invisible to subjects, as no subject mentioned this small reduction in experimental earnings.

As we mentioned above, subjects were paid only on their earnings in the last 11 rounds. Therefore, in the analysis, we restrict ourselves to the last 11 rounds of data. The results for all 15 rounds are reported in the Appendix, and are in line with the results reported here.
As theory predicts, the average equilibrium price is higher in the $L$ versus the $NL$-treatment in each session, with an average spread of 38 across sessions. The difference in prices is statistically significant ($p-value = 0.001$),\footnote{We regressed the per-round changes in the equilibrium price between $L$ and $NL$-economy against a constant (remember that, in each round of the two treatments, the same subjects act as Optimists and Pessimists, and face the same price vector). We tested whether the regression constant is significantly different from zero, correcting the standard errors with by-session clustering and obtaining the p-value reported in the main text of the paper. Note that we obtain a similar result if we run a non-parametric sign test on per-round price differences ($p-value=0.000$).} and robust to order effects. Moreover, it is consistent even across rounds of the experiment: out of 55 rounds (11 for each session), the spread between the $L$ and the $NL$-treatment is zero in only 14, and is never negative (see Appendix).

Moreover, as predicted by theory, as we move from the $NL$ to $L$-treatment, the equilibrium level of transactions increases, that is, a larger number of assets is sold by the Pessimists to the Optimists. As Table 5 indicates, the average quantity traded per subject increases from 56 to 69 assets, a difference that is statistically significant and robust to order effects.\footnote{The p-value is 0.000.} Therefore, the relaxation of the collateral constraint between $NL$ and $L$-treatment allows gains from trade to be exploited in the laboratory market to a greater extent: the sum of Optimists and Pessimists payoff increase in expectation by $(69 - 56)(500)(0.6) = 3,900$.

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
</tr>
</thead>
<tbody>
<tr>
<td>NL</td>
<td>56</td>
<td>57</td>
<td>46</td>
<td>63</td>
<td>64</td>
<td>49</td>
</tr>
<tr>
<td>L</td>
<td>69</td>
<td>75</td>
<td>59</td>
<td>70</td>
<td>76</td>
<td>66</td>
</tr>
</tbody>
</table>

Although the experimental results are broadly in line with the theoretical predictions of Section 1, important departures from theory arise: first, in both

\cite{28}
\(NL\) and \(L\)-treatments, the quantities traded per subject (56 in \(NL\) and 69 in \(L\)) are lower than what theory predicts (78 and 100 respectively);\(^{30}\) second, whereas in the \(L\)-treatment the average price is very close to its theoretical counterpart, the equilibrium price in the \(NL\)-treatment (216) is above the theoretical one (190).

![Figure 5: Supply (grey) and Demand (black) in the \(Bull - NL\) Treatment. Solid lines are the experimental results; dotted lines the theoretical functions.](image)

In order to explain these departures, let us first focus on the \(NL\)-treatment. Figure 5 shows the theoretical (dotted lines) and the empirical (thick lines) demand (black) and supply (grey) curves in the \(NL\)-economy; the empirical curves are averaged across subjects, rounds and sessions. Two observations are

\(^{30}\)Note that as a result, the increase in the sum of the expected payoffs of Pessimists and Optimists is lower than what theory predicts, \(22(500)(0.6) = 6600\).
in order. First, the empirical demand is to the left of the theoretical one: in particular, the Optimists’ demand is not determined by the budget constraint as theory predicts. Indeed, as column 1 of Table 6 shows, Optimists’ average final cash holdings—which theoretically should be zero—are on average around $E3,000 (out of an initial endowment of $E15,000).

Second, the average empirical supply is a smoother version of the theoretical one. According to the model, Pessimists should sell 0 assets at a price below their expected value ($E190), and sell all their holdings, 100, at a price above its expected value. Instead, in the experiment, Pessimists offer positive quantities for prices below 190 (that is, the empirical supply is to the right of the theoretical one), and supply less than 100 units for prices above 190 (that is, the empirical supply is to the left of the theoretical one). Although supply monotonically increases in the price, it never reaches 100 units.31

Table 6: Optimists’ Final Cash Holding and Borrowing in the Bullish Market

<table>
<thead>
<tr>
<th></th>
<th>Final Cash</th>
<th>Borrowing per Widget</th>
<th>Aggregate Loan to Value Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>NL</td>
<td>3,065</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>L</td>
<td>1,570</td>
<td>45</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Because the empirical supply is a smooth version of the theoretical one, the price is higher than theory predicts, and the quantity traded is lower. The leftward shift in the empirical demand with respect to theory amplifies the effect of the empirical supply on quantities and dampens the effect on prices. Nevertheless, since the departure of empirical supply from the theoretical one is larger than that of the empirical demand, the price in the laboratory is higher than theory predicts.

31 Note that for a price higher than 250 (Pessimist’s value in state High), supply is very close to 100, which reassures us that Pessimists understood the model. We will discuss more extensively the supply behavior in Section 3.2.
Let us now turn our attention to the $L$-treatment. The left graph of Figure 6 compares the empirical supply and demand in the $L$-treatment (dotted line) with those of the $NL$-treatment (solid line). The right graph compares the empirical supply and demand in the $L$-treatment (solid line) with their theoretical counterparts (dotted line).\footnote{That is, in Figure 6, both graphs show the experimental results for the $L$-treatment, comparing them with the results in the $NL$-treatment (left graph), and with the $L$-treatment theoretical predictions (right graph).}

As the left graph of Figure 6 shows, the empirical supply in the $L$-treatment overlaps with that in the $NL$-treatment (dotted and solid gray lines overlaps).
This is a good check that subjects understood the experiment since the problem that Pessimists face is the same in the two treatments. The empirical demand (dotted black line) shifts rightward with respect to that of the \textit{NL}-treatment (solid black line), as now subjects are allowed to borrow. This rightward shift is what generates the spread between the prices in the \textit{NL} and \textit{L}-treatments.

Note however that, as the right graph of Figure 6 shows, the empirical demand is in the \textit{L}-treatment (solid black line) is still to the left of its theoretical counterpart (dotted black line). That is, subjects do not exhaust all the collateral value of the assets. As the second column of Table 6 shows, each Optimist borrows on average $E45 per unit of the asset he buys, whereas in the theoretical equilibrium he borrows $E100. Nevertheless, because in the region determining the price, the empirical supply is to the left of the theory, the price in the \textit{L}-treatment is very close to the theoretical one (although the quantity traded is lower, see Table 5).

To summarize the previous discussion, the increase in price due to leverage stems from the fact that Optimists’ demand shifts to the right when we move from the \textit{NL} to the \textit{L}-treatment. This rightward shift in aggregate demand is somewhat puzzling. In the \textit{NL}-treatment, the demand curve was not determined by the Optimists’ budget constraint, that is, Optimists were not spending all their cash endowment. One would expect that in such circumstances allowing subjects to borrow should not affect their behavior; instead, we observe the opposite.

This shift in demand cannot be explained by risk aversion or by risk loving behavior. In the Appendix, we show that, under very general conditions on subjects’ payoff functions, if an Optimist chooses not to use all the available cash in the \textit{NL}–economy, he should chose not to borrow in the \textit{L}–economy.
Table 7: Optimists’ Borrowing Per Widget

<table>
<thead>
<tr>
<th>Percentage of Subjects</th>
<th>20</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>95</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borrowing Per Widget Lower than E$5</td>
<td>0.00</td>
<td>4.68</td>
<td>35.71</td>
<td>65.51</td>
<td>97.62</td>
</tr>
</tbody>
</table>

Note that this aggregate shift in demand is the result of the heterogeneity in borrowing choices by subjects: as Table 7 shows, 20 percent of subjects decide not to borrow at all, and 25 percent of subjects borrow on average less than E$5. There are subjects who instead do exploit the collateral capacity of the asset. Indeed, 50 percent of subjects borrow on average more than 35.71 and 25 percent of subjects borrow on average more than 65.51 per asset.

Who are the subjects that do borrow? Primarily those who are at (or close to) the budget constraint in the NL-treatment, that is, who are more sanguine about the asset to start with. As Figure 7 shows, the amount of borrowing per widget in the L-treatment is negatively associated with the Optimists’ final cash holdings in the NL-treatment. That is, the closer subjects are to their budget constraint in the NL-treatment, the more they borrow in the L-treatment.

To conclude, let us describe subjects’ payoffs in the Bullish market. Table 8 reports the average per round payoffs in the NL and L-treatments in both states of the world, their expected value and standard deviation, and compare them with the theoretical benchmark. In the NL-treatment, Optimists’ expected payoff is lower than theory predicts, as they buy fewer assets. Pessimists, in contrast, have a higher payoff than the theoretical one: although they do sell fewer assets, this is offset by a higher price than the theoretical one. Since fewer assets exchange hands, Optimists’ payoff volatility is lower

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33 The slope of the regression line (in the chart) is negative and significant (p-value 0.01, after correcting for session clusters).

34 The reported payoffs are net of the E$ 10,000 that subjects received in each round of the experiment (see subsection “The Procedures”).
Figure 7: Scatter Plot of the Average Individual Percentage Borrowing Per Asset in the $L$-treatment over Final Cash Holding in the $NL$-treatment

than in the theoretical model, and Pessimists’ payoff volatility is higher.

Table 8: Average Per Round Payoffs in the Bullish Market

<table>
<thead>
<tr>
<th></th>
<th>$NL$-Treatment</th>
<th>$L$-Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Empirical</td>
<td>Theory</td>
</tr>
<tr>
<td>Optimists</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>44,423</td>
<td>59,212</td>
</tr>
<tr>
<td>Low</td>
<td>8,677</td>
<td>7,895</td>
</tr>
<tr>
<td>Mean</td>
<td>30,125</td>
<td>38,685</td>
</tr>
<tr>
<td>Std</td>
<td>17,512</td>
<td>25,140</td>
</tr>
<tr>
<td>Pessimists</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>23,152</td>
<td>20,262</td>
</tr>
<tr>
<td>Low</td>
<td>16,324</td>
<td>17,105</td>
</tr>
<tr>
<td>Mean</td>
<td>20,421</td>
<td>18,999</td>
</tr>
<tr>
<td>Std</td>
<td>3,345</td>
<td>1,547</td>
</tr>
</tbody>
</table>
When we look at the $L$-treatment, the payoffs for both Optimists and Pessimists increase, as gains from trade are realized; Pessimists’ payoff increases by far more (as in the theoretical model), since the price moves in their direction. Compared to the theoretical benchmark, however, both payoffs are lower, as opposed to $NL$-treatment; this happens because the price is now close to the theoretical price. Volatility for Optimists increases with respect to the $NL$-treatment, and that of Pessimists decreases, as the asset changes hands. The increase in Optimists’ volatility and the drop in that of Pessimists, however, is not as dramatic as the one predicted by the theoretical model.

3.2 The Bearish Market

In this section, we analyze the experimental results when we lower the value of $q$ to 0.4 (i.e., in the Bearish Market). Let us recall what the theory predicts should happen by looking at how demand and supply functions move when $q$ goes from 0.6 to 0.4 (as we had shown on Figure 4). In both $L$ and $NL$-economies, the Optimists’ demand function does not shift with respect to the Bullish Market. In contrast, the Pessimists’ supply function shifts downward. As we mentioned in the theoretical section of the paper, in the $NL$-economy the price decreases because of the downward shift in supply. In the $L$—economy, in contrast, the downward shift in supply leaves equilibrium price unaffected. As a result, the spread between the $L$ and $NL$ economies increases when we move from the Bullish to the Bearish Market.

Let us now turn our attention to whether the data bear out the theory’s predictions. As theory predicts, the empirical supply curve (both in $L$ and in $NL$-treatments), averaged across rounds and across sessions, shifts rightward,
Figure 8: Supply curves in the Bull (gray) and Bear (black) Treatments. Solid lines are the results in the NL-economies; dotted lines in the L-economies.

reflecting the decrease in the asset’s expected value (see Figure 8).\textsuperscript{35}

In contrast, Optimists’ demand does not shift significantly as $q$ changes (i.e., with respect to the Bullish market), in accordance with what theory predicts: i.e., the movement in demand between $L$ and $NL$-treatment is unaffected by the change in probability (see Figure 9).

\textsuperscript{35}Moreover, as theory predicts (and as was the case in the Bullish market), there is no significant difference in the empirical supply curve between the $NL$ and the $L$-treatment, which is to be expected as subjects face exactly the same decision problem.
Figure 9: Demand curves in the *Bull* (gray) and *Bear* (black) Treatments. Solid lines are the results in the *NL*-economies; dotted lines in the *L*-economies.

Table 9: Average Equilibrium Prices in the Bearish Market Treatments

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NL</strong></td>
<td>188</td>
<td>182</td>
<td>187</td>
<td>203</td>
<td>195</td>
<td>175</td>
</tr>
<tr>
<td><strong>L</strong></td>
<td>230</td>
<td>228</td>
<td>236</td>
<td>230</td>
<td>230</td>
<td>227</td>
</tr>
<tr>
<td><strong>Spread</strong></td>
<td>42</td>
<td>46</td>
<td>49</td>
<td>27</td>
<td>35</td>
<td>52</td>
</tr>
</tbody>
</table>

Therefore, as in the Bullish Market, the relaxation of the collateral constraint from *NL* to *L* shifts demand upwards, and the price is higher in the *L* than in the *NL*-treatment. As Table 9 shows, the average equilibrium price is 188 in *NL*, and 230 in *L*. That is, the asset price increases when it can be used as collateral. The difference in prices between *L* and *NL* is statistically
significant (p-value= 0.00) and robust to order effects.\textsuperscript{36}

Nevertheless, in contrast to what theory predicts, in the $L$-treatment the price is lower than it was in the Bullish $L$-treatment— it decreases from 253 to 230. As a result, the spread between $NL$ and $L$-treatment does not increase when we move from the Bullish to the Bearish market, i.e., when $q$ goes from 0.6 to 0.4 (the spread moves from 38 to 42, a statistically insignificant difference).\textsuperscript{37}

Why does the spread between $NL$ and $L$ not increase in the Bearish Market treatments? As we mentioned in the theory section, the spread between $L$ and $NL$ increases as we move from Bullish to Bearish because the price in the $L$-economy does not change with $q$. This occurs because the supply function is a step function, which crosses demand in its vertical segment; as the function shifts downward, equilibrium prices and quantities are unaffected. In the laboratory, however, the supply function is not a step function: as we commented before, supply increases smoothly as the price goes up. As a result, when we move from Bullish to Bearish, the equilibrium price decreases even in the $L$-treatment—and the equilibrium quantity increases. This decrease in the price for the $L$-treatment implies that the behavior of the $L – NL$ spread is not obvious. In fact, at the aggregate level in the laboratory, the spread is constant across Bullish and Bearish Market treatments. That is, we do not observe “Flight to Collateral” in the laboratory.

As we commented in Section 3.1, the behavior of the aggregate supply explains why in the NL-Bullish treatment the price is higher than theory predicts; moreover, as we just discussed, the same supply behavior is the reason

\textsuperscript{36}The p-value is 0.000.

\textsuperscript{37}When regressing the per-round spread on a constant, the p-value is 0.61 (correcting for by-session clustering).
why we do not observe Flight to Collateral in the laboratory. It is therefore important to discuss what drives the shape of the aggregate supply.

Note that the behavior of the aggregate supply cannot be reconciled with subjects having a uniform attitude toward risk: subjects supply a positive quantity of the asset for a price lower than the asset’s expected value (thus suggesting risk aversion), but do not supply all their asset endowments for a price higher than the asset’s expected value (thus suggesting a risk loving behavior).

Indeed, Figure 10 shows the histogram of the Pessimist individual average deviation from the theoretical supply across rounds.\textsuperscript{38} As the figure shows, only less than 20 percent of subjects are deviating from the theoretical supply curve on average less than 5 units of the asset. A similar proportion of subjects supply on average five units or more than predicted by theory, with 5 percent

\textsuperscript{38}Note that since the behavior of the aggregate supply is similar across treatments, for the purpose of this analysis we pooled all the experimental data for the last 4 treatments. Moreover, we consider only the choices of subjects when acting as Pessimists (since we are studying supply behavior).
supplying an excess of 15 units or more. These subjects exhibit a behavior that is consistent with some form of aversion to risk. On the other hand, a full 63 percent of subjects are selling on average at least 5 units less than predicted by the theoretical supply, with 13 percent supplying an excess of 15 units or more.\footnote{Note that the same subjects, willing to hold more assets than theory predicts, would not be able to do so when acting as an Optimist (because the optimal choice is on the budget and borrowing constraints, in both $L$ and $NL$-economies). Therefore, these subjects would not generate deviations of the aggregate demand curve with respect to the theoretical one.} These subjects exhibit a behavior that is consistent with risk loving (since they keep a risky asset when they should sell it) or some form of endowment effect. As a result of the heterogeneity of individual behavior by subjects in the laboratory, the empirical aggregate supply function is a smooth version of its theoretical counterpart.

References


Araujo, Aloisio, Felix Kubler and Susan Schommer. 2011.“Regulating Collateral-Requirements when Markets are Incomplete.” Forthcoming *Journal of Economic Theory*.


Fostel, Ana and John Geanakoplos. 2008. “Leverage Cycles and the Anx-


A Two-Asset Economy

We consider a two-period financial economy, with time $t = 0, 1$. At time 1, there are two states of the nature, $s = High$ and $s = Low$, with probability $q$ and $1 - q$.

There are three assets in the economy, cash and two risky assets $X$ and $Y$ with payoffs in units of cash. Assets $X$ and $Y$ have the same payoff as in our benchmark model, and are independently distributed. All the other features of the model hold. In particular, agents' payoff function is given by $u^i(s) = w + D^i_{y,s} y + D^i_{x,s} x - \varphi$.

Agents cannot borrow using asset $X$ as collateral, whereas they can use asset $Y$ as collateral with $\varphi \leq D_{y,Low}$. Taking as given the asset price, agents choose asset holdings $y, x$ and cash holdings $w$ in order to maximize the payoff function subject to their budget and borrowing constraints: $w + px + py \leq m^i + pa^i_x + pa^i_y + \varphi$ and $\varphi \leq D_{y,Low}y$.

We compute the equilibrium for the same parameter values as in the Bullish market described in Table 1. The equilibrium is described in the table below:

<table>
<thead>
<tr>
<th></th>
<th>$p_y$</th>
<th>$p_x$</th>
<th>$y$</th>
<th>$x$</th>
<th>$u_{High}$</th>
<th>$u_{Low}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimists</td>
<td>250</td>
<td>190</td>
<td>100</td>
<td>0</td>
<td>75,000</td>
<td>10,000</td>
</tr>
<tr>
<td>Pessimists</td>
<td>0</td>
<td>100</td>
<td>40,000</td>
<td>25,000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The equilibrium price for asset $X$ (which cannot be used as collateral) is the same as the asset price in the \textit{NL}-economy, whereas the equilibrium price of asset $Y$ (which can be used as collateral) is the same as the asset price in the \textit{L}-economy. Note also that, as in the \textit{L}-economy, Optimists hold all the supply of the collateralizable asset.

Attitudes toward Risk and the Shift in Demand

Consider the following two problems. The first problem, \textit{NL}, is the problem that an Optimist faces in the \textit{NL}-economy.
\[
\begin{aligned}
&\max_y \quad U(y), \\
&s.t. \quad py \leq m \\
&\quad y \geq 0.
\end{aligned}
\]

The second problem, \(L\), is the one that an Optimist faces in the \(L\)-economy.

\[
\begin{aligned}
&\max_{y, \phi} \quad U(y, \phi) \\
&s.t. \quad py \leq m + \phi \\
&\quad \phi \leq D_{Low}y \\
&\quad \phi \geq 0 \\
&\quad y \geq 0
\end{aligned}
\]

We want to show that if \(y^*\) is an interior solution to \(NL\) and if \(U\) is strictly concave, \(y^*\) also solves \(L\).

From the Kuhn-Tucker conditions, for the \(NL\) problem we have that \(U'(y^*) = 0\). Since in the \(L\)-problem \(\phi \geq 0\), \(y^*\) is feasible. By concavity, it is also optimal. Note that since we have only one good (cash), concavity can be interpreted as risk-aversion, even if subjects are not expected-utility maximizers. Therefore, risk-averse behavior cannot explain the shift in demand observed in the laboratory. Additionally, if \(U\) were strictly convex (risk-loving behavior), \(y^*\) cannot be an interior solution to the \(NL\)-problem. Therefore, risk-loving behavior also cannot explain the shift in demand that we observe in the laboratory.

The Spread Across Rounds in the NL and L-Bullish Treatments

The following table reports in the prices and spread across the eleven rounds used for final payments in the \(NL\) and \(L\)-Bullish treatment.
Table: Per-round Equilibrium Prices across Sessions in the Bullish Market

<table>
<thead>
<tr>
<th>Round</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
</tr>
</thead>
<tbody>
<tr>
<td>NL</td>
<td>L</td>
<td>S</td>
<td>NL</td>
</tr>
<tr>
<td>5</td>
<td>210</td>
<td>240</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>220</td>
<td>220</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>200</td>
<td>230</td>
<td>30</td>
</tr>
<tr>
<td>8</td>
<td>225</td>
<td>255</td>
<td>30</td>
</tr>
<tr>
<td>9</td>
<td>195</td>
<td>285</td>
<td>90</td>
</tr>
<tr>
<td>10</td>
<td>195</td>
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<tr>
<td>11</td>
<td>205</td>
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<td>12</td>
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<tr>
<td>13</td>
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</tr>
<tr>
<td>15</td>
<td>225</td>
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</table>

<table>
<thead>
<tr>
<th>Round</th>
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<th>S5</th>
</tr>
</thead>
<tbody>
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<td>7</td>
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<td>14</td>
<td>200</td>
<td>230</td>
</tr>
<tr>
<td>15</td>
<td>205</td>
<td>225</td>
</tr>
</tbody>
</table>
Results Across All 15 Rounds of the Experiment

The following tables incorporate data from all fifteen rounds of experimentation (the first four mock rounds, and the eleven rounds used to determine final payments) and can be compared with tables 4, 5, 6 and 9 in the text of the paper.

Table: Average Equilibrium Prices in the Bullish Market

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
</tr>
</thead>
<tbody>
<tr>
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<td>223</td>
<td>205</td>
<td>215</td>
<td>208</td>
<td>230</td>
</tr>
<tr>
<td>L</td>
<td>251</td>
<td>244</td>
<td>254</td>
<td>260</td>
<td>242</td>
<td>256</td>
</tr>
<tr>
<td>Spread</td>
<td>33</td>
<td>21</td>
<td>49</td>
<td>45</td>
<td>34</td>
<td>26</td>
</tr>
</tbody>
</table>

Table: Per-Subject Average Transactions in the Bullish Market

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
</tr>
</thead>
<tbody>
<tr>
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<td>45</td>
<td>62</td>
<td>66</td>
<td>49</td>
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<td>73</td>
<td>61</td>
<td>70</td>
<td>78</td>
<td>69</td>
</tr>
</tbody>
</table>

Table: Optimists’ Final Cash Holding and Borrowing in the Bullish Market

<table>
<thead>
<tr>
<th></th>
<th>Final Cash</th>
<th>Borrowing per Widget</th>
<th>Aggregate Loan to Value Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>NL</td>
<td>3,156</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>L</td>
<td>1,551</td>
<td>44</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Table: Average Equilibrium Prices in the Bearish Market

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
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</thead>
<tbody>
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<td>207</td>
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<tr>
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<td>47</td>
<td>48</td>
<td>26</td>
<td>47</td>
<td>56</td>
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</tbody>
</table>
The Matrix of Prices

The Table contains the price matrix that subjects faced (each column, containing 10 prices, corresponds to one round of the experiment). The same price matrix was used across the different treatments of the experiment, and in all sessions.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
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<td>145</td>
<td>130</td>
<td>140</td>
<td>120</td>
<td>145</td>
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<td>150</td>
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<td>255</td>
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</tr>
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<td>385</td>
<td>390</td>
<td>400</td>
<td>380</td>
<td>405</td>
<td></td>
</tr>
</tbody>
</table>
Instructions

We report the Instructions for each of the four parts of the experiment, and some of the screenshots.
Appendix C: Instructions.

Thank you for participating in today’s experiment. You have earned a $5 show-up bonus for arriving on time. Whatever you earn in this session will be in addition to this $5. If you read the instructions below carefully, you have the potential to earn significantly more.

The experiment will be run over two days, today and tomorrow. You will be paid in cash at the end of tomorrow’s experiment.

In the experiment you will earn Experimental Dollars (E$), which will be converted into cash (US Dollars) at the end of the experiment. For every 20,000 E$ you have at the end of the experiment you will be paid 1 US Dollar in cash.

You will participate in the experiment along with 11 other students. Neither before nor after the experiment will you 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 four parts: Part A, B, C and D. We will first distribute the instructions for Part A. You will read them, answer a brief questionnaire, and then you will start playing. After you finish playing part A, we will distribute the instructions for part B, and you will play part B. Tomorrow, you will play Part C and Part D.

Instructions for Part A

Overview

In today’s experiment, you will buy and sell a product that we will call from now on a “widget.” You will be able to buy or sell the widgets, by trading with the other participants.

You will play 15 rounds with the same procedures. The first 4 rounds are for practice only, whereas the remaining 11 rounds will determine your final payment.
Description of the each round

The Final Value of the Widgets

The final value of the widgets can be High or Low. This is determined by randomly choosing a ball from a box with 6 red balls and 4 green balls. If the ball turns out to be red, the value of the widget is High; if the ball turns out to be green, the value of the widget is Low. Since there are 6 red and 4 green balls in the box, the chance of the value of the widgets being High is 60 percent; the chance of the value of the widgets being Low is 40 percent.

We can represent the final value of the widgets by the following picture:

```
60%  High
/
40%  Low
```

The ball is extracted from the box at the end of each round.

In each round we choose the ball from a new box. There are always 6 red and 4 green balls in the box, so the chance of the final value of the widgets being High or Low does not depend on whether it was High or Low in the previous round.

Buyers and Sellers

At the beginning of each round, you are randomly assigned to be either a Buyer or a Seller. Half of the participants (6 students) will be Buyers, and half of the participants (6 students) will be Sellers. In each round, you see whether you are a Buyer or a Seller by looking at the left column in your screen.

Here is why whether you are a Buyer or a Seller matters.
a) At the beginning of the round Buyers are given cash and Sellers are given widgets:

   If you are a Buyer, you are given 15,000 ES

   If you are a Seller, you are given 100 widgets

b) Whether you are a Buyer or a Seller also determines the final value of the widgets for you.

   When the value of the widget is Low, its final value is 100 ES for both Buyers and Sellers.

   However, when the value of the widget is High, its final value is 750 ES for Buyers and 250 ES for Sellers. We can represent the final value of the widgets by the following picture:

   ![Diagram showing Low and High values for Buyers and Sellers]

   When the final value of the widgets is Low, it is the same value for both Buyers and Sellers; but when the value of the widgets is High, widgets pay more to Buyers than to Sellers.

   **How to buy or sell widgets**

   The column labeled “Price” of your computer screen displays an array of prices. For each of those prices, Buyers should indicate the number of widgets they want to buy and Sellers should indicate the number of widgets they want to sell. After you made your choices, you should press OK. You can see how the screenshot appears for both buyers and sellers in the attached leaflet.

   The computer requires you to be consistent in your choices. For instance, if you write that you want to buy 40 widgets at the price of 300, you are not allowed to buy more than 40 widgets at a price of 330. The opposite is true for a Seller: if you want to sell 40 widgets at the price of 300, you are not allowed to sell more than 40 widgets at the price of 270.

   **How Buyers pay for widgets**
In each round, Buyers are allowed to buy widgets with the cash that they have.

In the computer screen, to the right of the price column there is a column that shows the maximum number of widgets Buyers can buy for each price.

Suppose you are a Buyer and are deciding how many widgets to buy at the price 300. You can at most buy 50 widgets (300*50=15,000 E$, which is the cash Buyers have at the beginning of the round).

**The final price**

At which price does trading occur? **For each price**, we will sum up the number of widgets that all Buyers want to buy, and the number of widgets that all Sellers want to sell. We will choose the price for which the difference between these two numbers is the smallest. This is the **final price** in the round.

**Example**: Suppose that at the price of 300, each Buyer wants to buy 40 widgets, and each seller wants to sell 10. Therefore, at 300, all Buyers together want to buy 40*6=240 widgets, and all sellers together want to sell 10*6=60 widgets. The difference between amount bought and amount sold is 240-60=180. We compute this difference for all the other prices in the list, and **we choose the price for which the difference is the smallest (that is, the price for which the difference is the closest to zero)**. This is the final price in the round.

You learn which is the final price **only after all participants have made their choices**. Therefore, at each price, you should indicate the number of widgets you want to buy or sell **as if that price were the one at which transactions occur**.

At the final price, each Buyer will buy (at most) the number of widgets he/she indicated he/she would buy at that price. Each Seller will sell (at most) the number of widgets he/she indicated he/she would sell at that price.

Why at most? Because sometimes you may not be able to buy or sell exactly the quantity you had indicated. It may happen that, at the final price, the number of widgets Buyers want to buy is larger (or smaller) than the number of widgets Sellers want to sell. In this case, we will reduce the widgets bought by Buyers (or sold by Sellers) by the same proportional amount. For instance, if the final price is 300 and the number of widgets sold by Sellers is 10% higher than the number of widgets that Buyers want to buy at this price, we will reduce the sale of each Seller by 10%.
The bonus

In each round, you are given a per-round bonus of 10,000 E$. The extra bonus is given only at the end of the round, and cannot be used to buy widgets. This bonus is in addition to the show-up bonus you received for arriving on time.

The end of the Round

After the final price is determined, buying and selling occurs automatically. A summary on your screen will indicate the price for the widget, and how many widgets you bought or sold. Then, the value of the widgets will be extracted from the box, and your payoff for the round will appear on the computer screen.

Your payoff is computed in the following way:

1) If you are a Buyer

Your payoff = your remaining cash
+ (number of widgets you bought)*(final value of the widgets)
+ bonus

2) If you are a Seller

Your payoff = the cash from selling the widgets
+ (number of widgets you did not sell)*(final value of the widgets)
+ bonus

Examples

1) Let’s say the final value of the widgets is High, you are Buyer, and you bought 30 widgets at a price of 300. Your payoff is going to be

Cash=15,000-300*30=15,000-9,000=6,000
Final value of the widgets=750*30=22,500
Bonus=10,000
Final payoff in the round=22,500+6,000+10,000=38,500 E$
Note that you made money out of the purchase of widgets, since you bought for 300 something that is worth 750.

2) Let’s say now you are a Seller and you sold 90 widgets (and kept 10) at a price of 150. The final value of the widgets is 100. Your payoff is going to be

\[ \text{Cash}=90\times150=13,500 \]
\[ \text{Final value of the remaining widgets}=100\times10=1,000 \]
\[ \text{Bonus}=10,000 \]

Final payoff in the round=13,500+1,000+10,000=24,500 E$

Note that you made money out of the sale, since you sold for 150 something that is worth to you only 100.

The new round

After the first round ends, you will move to round 2, then to round 3 and so on. At the beginning of each round, you will be told whether you are a Buyer or a Seller and you will be given cash (if a buyer) or widgets (if a seller) to play in the round. Each round is independent: you will never be able to use the widgets or cash from previous rounds. Your per-round payoff only matters to compute your final payment in dollars.

After the game ends

After you have seen the payoff of the round, a new round starts. At the end of the 15th round, part A ends, and we will distribute the instructions for part B.

How is your final payment determined? For both part A and part B, we will discard the first 4 rounds, which are only for practice. Out of the remaining 22 rounds (11 for part A and 11 for part B), we will randomly draw 10 rounds (5 from part A and 5 from part B) and we will add your earnings from these randomly chosen 10 rounds. Finally, we will convert the earnings from E$ into US Dollars at the exchange rate of 20,000.

Tomorrow, after playing the second day of the experiment, you will be paid the sum of today’s and tomorrow’s earnings. 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.
Instructions for Part B

The experiment is exactly the same as in part A. The only difference is in the proportion of red and green balls that determine the final value of the widgets in each round. Now, there are 4 red ball and 6 green balls in the box.

Since there are 4 red and 6 green balls in the box, the chance of the value of the widgets being High is 40 percent (when before it was 60 percent); the chance of the value of the widgets being Low is 60 percent (when before it was 40 percent). We can represent this by the following picture:

![Diagram showing 40% chance of High and 60% chance of Low]

As for Part A, Part B last for 15th rounds. When it ends, for both part A and part B, we will discard the first 4 rounds, which are only for practice. Out of the remaining 22 rounds (11 for part A and 11 for part B), we will randomly draw 10 rounds (5 from part A and 5 from part B) and we will add your earnings from these randomly chosen 10 rounds. Finally, we will convert the earnings from E$ into US Dollars at the exchange rate of 20,000.

Tomorrow, after playing the second day of the experiment, you will be paid the sum of today’s and tomorrow’s earnings. 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.
This is the second day of the experiment. Today you will play parts C and D.

As in yesterday’s experiment, today you will earn Experimental Dollars (E$), which will be converted into cash (US Dollars) at the end of the experiment. For every 20,000 E$ you have at the end of the experiment you will be paid 1 US Dollar in cash.

You will participate in the experiment along with 11 other students. Neither before nor after the experiment will you 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.

Instructions for Part C

Overview

In today’s experiment, you will buy and sell a product that we will call from now on a “widget.” You will be able to buy or sell the widgets, by trading with the other participants.

You will play 15 rounds with the same procedures. The first 4 rounds are for practice only, whereas the remaining 11 rounds will determine your final payment.

Description of the each round

The Final Value of the Widgets

The final value of the widgets can be High or Low. This is determined by randomly choosing a ball from a box with 6 red balls and 4 green balls. If the ball turns out to be red, the value of the widget is High; if the ball turns out to be green, the value of the widget is Low. Since there are 6 red and 4 green balls in the box, the chance of the value of the widgets being High is 60 percent; the chance of the value of the widgets being Low is 40 percent.
We can represent the final value of the widgets by the following picture:

![Diagram of a decision tree]

The ball is extracted from the box at the end of each round.

In each round we choose the ball from a new box. There are always 6 red and 4 green balls in the box, so the chance of the final value of the widgets being High or Low does not depend on whether it was High or Low in the previous round.

**Buyers and Sellers**

At the beginning of each round, you are randomly assigned to be either a Buyer or a Seller. Half of the participants (6 students) will be Buyers, and half of the participants (6 students) will be Sellers. In each round, you see whether you are a Buyer or a Seller by looking at the left column in your screen.

Here is why whether you are a Buyer or a Seller matters.

a) At the beginning of the round Buyers are given cash and Sellers are given widgets:

   - If you are a Buyer, you are given **15,000 ES**
   - If you are a Seller, you are given **100 widgets**

b) Whether you are a Buyer or a Seller also determines the final value of the widgets for you.

When the value of the widget is Low, its final value is **100 ES** for both Buyers and Sellers.

However, when the value of the widget is High, its final value is **750 ES** for Buyers and **250 ES** for Sellers. We can represent the final value of the widgets by the following picture.
When the final value of the widgets is Low, it is the same value for both Buyers and Sellers; but when the value of the widgets is High, widgets pay more to Buyers than to Sellers.

How to buy or sell widgets

The column labeled “Price” of your computer screen displays an array of prices. For each of those prices, Buyers should indicate the number of widgets they want to buy and Sellers should indicate the number of widgets they want to sell. After you made your choices, you should press OK. You can see how the screenshot appears for both buyers and sellers in the attached leaflet.

The computer requires you to be consistent in your choices. For instance, if you write that you want to buy 40 widgets at the price of 300, you are not allowed to buy more than 40 widgets at a price of 330. The opposite is true for a Seller: if you want to sell 40 widgets at the price of 300, you are not allowed to sell more than 40 widgets at the price of 270.

How Buyers pay for widgets

In each round, Buyers are allowed to buy widgets not only with the money that they have, but also by borrowing from a bank.

How does borrowing work? For each widget that a Buyer buys, the bank is going to lend him/her up to 100 E$. Hence, for any given price, borrowing allows the Buyers to buy more widgets than if they could not borrow. At the end of the round Buyers will have to return what they borrowed.
In the computer screen, to the right of the price column, there are 4 columns that show the maximum number of widgets Buyers can buy for each price if:  

i) they do not want to borrow  

ii) if they want to borrow the maximum (100 E$ per widget),  

iii) if they want to borrow only 30 E$ per widget and  

iv) if they want to borrow only 60 E$ per widget.

Buyers will indicate on the screen how many widgets they want to buy for each of the prices in the list. **Obviously you are not limited to borrowing 0, 30, 60 or 100.** Suppose the computer tells you that you can buy 150 widgets when borrowing 30 and 214 when borrowing 60, you can decide to buy a number between 150 and 214. In that case, you will borrow something between 30 and 60 per widget.

The following example shows how borrowing increases how many widgets Buyers can buy. Suppose you are deciding how many widgets to buy at the price 300. If you do not borrow, you could at most buy 50 widgets (300*50=15,000 E$, which is the cash Buyers have at the beginning of the round).

If you borrow, for each widget you buy you can get up to 100 E$ in loans. Suppose you borrow 100 E$, i.e. the maximum amount per widget. This means that for each widget you buy, you only need to put down 300-100=200 E$ of your own cash. So with your 15,000 E$ of cash, you can now afford to buy 75 widgets (200*75= 15,000 E$), 25 more than if you did not borrow.

At the end of the round, you will have to repay your loan. Since you bought 75 widgets, you will have to repay 75*100=7,500 E$. If the value of the widgets turns out to be High (750 E$), your payoff is 750*75=56,250 E$ minus your 7,500 E$ loan, that is, 56,250-7,500=48,750 E$.

If instead you only borrow 60 E$ per widget, then for each widget you buy you need to put down 300-60=240 E$; with your 15,000 E$ of cash, you can now afford to buy 62 widgets (240*62=14,880 E$; you are left with 120 E$ of cash, which are not enough to be an additional widget), 12 more than if you were not allowed to borrow (but 12 less than if you had borrowed the maximum amount of 100 E$ per widget).

*The final price*
At which price does trading occur? **For each price**, we will sum up the number of widgets that all Buyers want to buy, and the number of widgets that all Sellers want to sell. We will choose the price for which the difference between these two numbers is the smallest. This is the **final price** in the round.

**Example:** Suppose that at the price of 300, each Buyer wants to buy 40 widgets, and each seller wants to sell 10. Therefore, at 300, all Buyers together want to buy 40*6=240 widgets, and all sellers together want to sell 10*6=60 widgets. The difference between amount bought and amount sold is 240-60=180. We compute this difference for all the other prices in the list, and we choose the price for which the difference is the smallest (that is, the price for which the difference is the closest to zero). This is the final price in the round.

You learn which is the final price **only after all participants have made their choices**. Therefore, at each price, you should indicate the number of widgets you want to buy or sell as if that price were the one at which transactions occur.

At the final price, each Buyer will buy (at most) the number of widgets he/she indicated he/she would buy at that price. Each Seller will sell (at most) the number of widgets he/she indicated he/she would sell at that price.

Why at most? Because sometimes you may not be able to buy or sell exactly the quantity you had indicated. It may happen that, at the final price, the number of widgets Buyers want to buy is larger (or smaller) than the number of widgets Sellers want to sell. In this case, we will reduce the widgets bought by Buyers (or sold by Sellers) by the same proportional amount. For instance, if the final price is 300 and the number of widgets sold by Sellers is 10% higher than the number of widgets that Buyers want to buy at this price, we will reduce the sale of each Seller by 10%.

**The bonus**

In each round, you are given a per-round bonus of 10,000 E$. The extra bonus is given only at the end of the round, and cannot be used to buy widgets. This bonus is in addition to the show-up bonus you received for arriving on time.

---

*The end of the Round*
After the final price is determined, buying and selling occurs automatically. A summary on your screen will indicate the price for the widget, and how many widgets you bought or sold. Then, the value of the widgets will be extracted from the box, and your payoff for the round will appear on the computer screen.

Your payoff is computed in the following way:

1) If you are a Buyer
   
   Your payoff = your remaining cash
   
   + (number of widgets you bought)*(final value of the widgets)
   
   + bonus
   
   - loan repayment

   where the final term is there because you need to repay the amount you borrowed for each widget you bought.

2) If you are a Seller
   
   Your payoff = the cash from selling the widgets
   
   + (number of widgets you did not sell)*(final value of the widgets)
   
   + bonus

Examples

1) Let’s say the final value of the widgets is High and you are Buyer. You bought 60 widgets at a price of 300, and you borrowed 50 E$ per widget. Your payoff is going to be

\[
\text{Cash}=15000-(300-50)*60=15,000-15,000=0
\]

\[
\text{Loan repayment}=50*60=3,000
\]

\[
\text{Final value of the widgets}=750*60=45,000
\]

\[
\text{Bonus}=10,000
\]

Final payoff in the round=45,000-3,000+10,000=52,000 E$
2) Let’s say now you are a Seller and you sold 90 widgets (and kept 10) at a price of 150.

The final value of the widgets is 100. Your payoff is going to be

Cash=90*150=13,500

Final value of the remaining widgets=100*10=1,000

Bonus=10,000

Final payoff in the round=13,500+1,000+10,000=24,500 E$

Note that you made money out of the sale, since you sold for 150 something that is worth to you only 100.

The new round

After the first round ends, you will move to round 2, then to round 3 and so on. At the beginning of each round, you will be told whether you are a Buyer or a Seller and you will be given cash (if a buyer) or widgets (if a seller) to play in the round. Each round is independent: you will never be able to use the widgets or cash from previous rounds. Your per-round payoff only matters to compute your final payment in dollars.

After the game ends

After you have seen the payoff of the round, a new round starts. At the end of the 15th round, part C ends, and we will distribute the instructions for part D.

How is your final payment determined? For both part C and part D, we will discard the first 4 rounds, which are only for practice. Out of the remaining 22 rounds (11 for part C and 11 for part D), we will randomly draw 10 rounds (5 from part C and 5 from part D) and we will add your earnings from these randomly chosen 10 rounds. Finally, we will convert the earnings from E$ into US Dollars at the exchange rate of 20,000.

After playing part D, yesterday’s and today’s earnings will be summed up, and you will be paid in cash. This is the end of the instructions for part C. If you have any questions, please raise your hand and an experimenter will assist you.
Instructions for Part D

The experiment is exactly the same as in part C. The only difference is in the proportion of red and green balls that determine the final value of the widgets in each round. **Now, there are 4 red ball and 6 green balls in the box.**

Since there are 4 red and 6 green balls in the box, the chance of the value of the widgets being High is 40 percent (when before it was 60 percent); the chance of the value of the widgets being Low is 60 percent (when before it was 40 percent). We can represent this by the following picture:

![Diagram showing 40% chance of High and 60% chance of Low]

As for Part C, Part D last for 15th rounds. When it ends, for both part C and part D, we will discard the first 4 rounds, which are only for practice. Out of the remaining 22 rounds (11 for part C and 11 for part D), we will randomly draw 10 rounds (5 from part C and 5 from part D) and we will add your earnings from these randomly chosen 10 rounds. Finally, we will convert the earnings from E$ into US Dollars at the exchange rate of 20,000.

After finishing playing part D, we will sum today’s and yesterday’s dollar earnings and pay you in cash. This is the end of the instructions for part D. If you have any questions, please raise your hand and an experimenter will assist you.
### The Buyers’ Screenshot

**You are a BUYER.**
- You have $10000 in cash.
- Widget Value if HIGH: $750
- Widget Value if LOW: $100
- You are in Part A.

<table>
<thead>
<tr>
<th>Price</th>
<th>Maximum number of widgets you can buy</th>
<th>Number of widgets you want to buy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>130</td>
<td>115</td>
</tr>
<tr>
<td>2</td>
<td>160</td>
<td>93</td>
</tr>
<tr>
<td>3</td>
<td>190</td>
<td>78</td>
</tr>
<tr>
<td>4</td>
<td>210</td>
<td>71</td>
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<tr>
<td>5</td>
<td>240</td>
<td>62</td>
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<td>6</td>
<td>300</td>
<td>50</td>
</tr>
<tr>
<td>7</td>
<td>330</td>
<td>45</td>
</tr>
<tr>
<td>8</td>
<td>360</td>
<td>41</td>
</tr>
<tr>
<td>9</td>
<td>370</td>
<td>40</td>
</tr>
<tr>
<td>10</td>
<td>390</td>
<td>38</td>
</tr>
</tbody>
</table>

*For each of the above prices, you should indicate the number of widgets you want to buy. When you are done, click OK.*

**OK**

### The Sellers’ Screenshot

**You are a SELLER.**
- You have 100 widgets.
- Widget Value if HIGH: $280
- Widget Value if LOW: $100
- You are in Part A.

<table>
<thead>
<tr>
<th>Price</th>
<th>Maximum number of widgets you can sell</th>
<th>Number of widgets you want to sell</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>130</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>160</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>190</td>
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</tr>
<tr>
<td>10</td>
<td>390</td>
<td>100</td>
</tr>
</tbody>
</table>

*For each of the above prices, you should indicate the number of widgets you want to sell. When you are done, click OK.*

**OK**
### The Buyers’ Screenshot

<table>
<thead>
<tr>
<th>Round</th>
<th>1 of 1</th>
<th>Remaining time (sec)</th>
<th>117</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>Maximum number of widgets you can buy</td>
<td>If you don’t borrow</td>
<td>If you borrow 30</td>
</tr>
<tr>
<td>1</td>
<td>130</td>
<td>115</td>
<td>130</td>
</tr>
<tr>
<td>2</td>
<td>160</td>
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<tr>
<td>10</td>
<td>390</td>
<td>38</td>
<td>42</td>
</tr>
</tbody>
</table>

For each of the above prices, you should indicate the number of widgets you want to buy. When you are done, click OK.

### The Sellers’ Screenshot

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<td>100</td>
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</tbody>
</table>

For each of the above prices, you should indicate the number of widgets you want to sell. When you are done, click OK.