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**Working Paper**

## Leverage and Bubbles: Experimental Evidence

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# Leverage and Bubbles: Experimental Evidence

SAFE Working Paper No. 239

**SAFE | Sustainable Architecture for Finance in Europe**

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# Leverage and Bubbles: Experimental Evidence\*

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February 10, 2020

## Abstract

We investigate the effect of leverage on bubbles in an asset market experiment. We expect higher leverage to produce larger bubbles because (i) it creates moral hazard in a setup with limited liability and (ii) it increases aggregate liquidity. Inconsistent with the moral hazard channel, which we test by holding aggregate liquidity constant, higher leverage does not produce larger bubbles. To understand this unexpected result, we run the same experiment with a different framing: instead of repaying debt, participants can earn a bonus. This bonus treatment produces larger bubbles, suggesting that more leveraged participants trade more cautiously to avoid default. Finally, bubbles are larger and increase over time when we keep leverage constant over time by injecting liquidity in the economy. Overall, these results suggest that higher leverage inflates bubbles not because of moral hazard but because of more abundant liquidity.

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# 1 Introduction

Higher leverage may inflate asset price bubbles through at least two channels. First, high leverage is associated with greater aggregate liquidity, which fuels asset prices by increasing demand (*the liquidity channel*). Second, high leverage may encourage excessive risk-taking because more leveraged investors are more likely to benefit from regulations (e.g. deposit insurance, implicit bailouts, limited liability) that limit the downside risk of investors (*the moral hazard channel*).

In this paper, we study the relationship between leverage and bubbles in a laboratory asset market experiment. This approach allows us to disentangle between the two channels outlined above. First, we can vary leverage while holding aggregate liquidity constant. Second, we can hold leverage constant and let aggregate liquidity vary. The laboratory approach also gives us the unique opportunity to observe bubbles and to study the aggregate implications of different environments.

We first test the moral hazard channel by conducting an asset market experiment in which we vary leverage and keep aggregate liquidity constant. Inconsistent with the moral hazard channel, bubbles are smaller in sessions with higher leverage.

The participants start the experiment with an initial endowment of liquidity (cash), assets, and debt. This endowment is the same for all participants in a session. We defined leverage as the ratio of debt to portfolio value:

$$Leverage = \frac{Debt}{Liquidity + Asset * Price}. \quad (1)$$

To increase leverage, we increase the level of debt that participants have to repay and keep the initial endowments of liquidity and assets the same.

The moral hazard channel implies that higher leverage should lead to larger bubbles. This is because higher leverage brings participants closer to default and because they are protected by limited liability. Thus, higher leverage should fuel bubbles because it increases the value of assets by limiting the downside risk. However, our findings do not support this moral hazard channel since we observe lower asset prices in treatments with higher leverage.

Why do more indebted participants not value assets more since they face less downside risk? We conjectured that participants may try to avoid default by buying fewer assets and at a lower price. To test this conjecture, we ran the same experiment with identical payoffs but with a more positive framing. Instead of having to repay debt, participants received a bonus if their performance exceeded a certain threshold. We find that asset prices are higher in the bonus treatment than in the debt treatment. Then, the lack of support for the moral hazard channel may be explained by more cautious trading by more leveraged participants to try to avoid default.

Finally, we test the liquidity channel by studying a setup in which we inject or withdraw liquidity in the economy to keep leverage constant over time. Unlike the setup studied so far, aggregate liquidity is no longer constant but leverage stays constant throughout the experiment.

For example, an increase in asset prices decreases leverage for all the participants who hold assets. To maintain their leverage constant, we increase their level of debt and transfer them cash until their leverage is back to its initial level. This operation increases the aggregate liquidity – or the cash-to-asset ratio – in the economy, which the previous literature has shown can fuel bubbles (Caginalp et al., 2001).

Consistent with the liquidity channel, we find that bubbles increase when we inject liquidity in the economy to keep leverage constant. Since higher asset prices decrease leverage, we further inject liquidity in the economy to keep leverage constant, which creates a positive spiral between liquidity injections and asset prices. Compared to the treatment with constant liquidity where asset prices stayed roughly constant over time, we observe in this constant leverage treatment not only larger bubbles because of the liquidity injection but also bubbles that increase over time because they are followed by additional liquidity injections.

To summarize, we find that higher leverage does not produce larger bubbles when aggregate liquidity is fixed and that higher liquidity produces larger bubbles when leverage is fixed. While higher leverage and higher liquidity are likely to move together in practice, making it difficult to disentangle the two channels, our experimental setup allows us to separate these two variables and suggests that higher leverage fuels bubbles because of more liquidity and not because of moral hazard.

The main contribution of the paper is to propose an experimental framework to disentangle the liquidity and moral hazard channels in the link between leverage and asset prices, something that was not possible in earlier experimental studies because they changed both leverage and liquidity at the same time. Caginalp et al. (2001) do not study leverage and show that experimental asset markets with a higher cash-to-asset ratio, that is, more liquidity, have larger bubbles. In a setup in which debt is associated with an injection of liquidity in the economy, Ackert et al. (2006) observe higher asset prices when participants have debt compared to a setup where they do not have debt. In a setup in which leverage is a choice variable and increases liquidity in the economy, Cipriani et al. (2020) find that leverage increases bubbles. Cipriani et al. (2018) study an economy with two assets and find that the price of collateralizable assets is higher than the price of non-collateralizable assets, in spite of identical payoffs. Fenig et al. (2018) run a macroeconomic experiment with both borrowing and labor supply decisions. They find that higher leverage, which increases liquidity in the economy, inflates bubbles. They also find that participants try to circumvent their borrowing constraints by increasing their labor supply and that leaning against the wind can stabilize asset prices. Füllbrunn and

Treatment	0	50%	80%	Bonus	Constant
Debt	0	750	1200	(1200)	1200
Initial cash / asset endowment	1000 / 5	1000 / 5	1000 / 5	1000 / 5	1000 / 5
High dividend / low dividend	200 / 75	200 / 75	200 / 75	200 / 75	200 / 75
Prob. high dividend / low dividend	.2 / .8	.2 / .8	.2 / .8	.2 / .8	.2 / .8
Exchange rate (ECU/EUR)	180	90	36	36	36
Expected payoff in EUR	8.33	8.33	8.33	8.33	8.33
Number of sessions	7	7	7	7	7

Table 1: Summary of Treatment Parameters.

Neugebauer (2013) study the role of limited liability on risk-taking, but in the context of a social dilemma. They find that participants behave in a more socially responsible way when excessive risk-taking imposes losses on the group Fischbacher et al. (2013) study the effect of monetary policy and liquidity requirements in an asset market experiment. They find that higher interest rates decrease liquidity but fail to contain asset price bubbles. They also find that announcing the possibility of higher reserve requirements can successfully deflate asset price bubbles. Finally, Meissner (2016) studies a consumption-saving experiment and finds that participants are reluctant to use debt to smooth their consumption, indicating debt aversion. Relatedly, we find that participants behave more cautiously when we use a debt framing.

The paper is organized as follows. Section 2 introduces the experimental design. Section 3 presents the results. Section 4 concludes.

## 2 Experimental Design

**Environment.** A group of subjects can trade in an asset market. Each subject receives an initial endowment of 5 assets and 1000 ECU (Experimental Currency Unit). There are 10 trading periods, that each last 120 seconds. Each asset pays a dividend of 200 ECU with probability 20% or of 75 ECU with probability 80%. The expected dividend, which is communicated to the participants, is thus 100 ECU. All the assets pay the same dividend at the end of the last period. Subjects can trade assets against ECU by posting bids or asks that can be seen by everyone (continuous multi-unit open-book double auction). Interested subjects can then accept these offers. Short-selling and margin buying are not allowed. Portfolios are carried over from one period to the next.

Table 1 summarizes the parameters of the environment and the treatment differences.

**Leverage.** Our first treatment variation is the level of debt that participants have to repay at the end of the experiment. The level of debt determines the leverage ratio, defined by equation 1. The levels of debt were either 0, 750, or 1200 ECU and all

the participants in a session had to repay the same amount of debt. Given the initial asset value of 1500 ECU, this corresponds to initial leverage ratios of 0, 50%, or 80%, respectively. We vary the exchange rate across these treatments to ensure that subjects all have the same expected payoff in EUR before trading starts. See Table 1 for the specific exchange rates we used. In the treatment with no debt, payoffs depend linearly on the final ECU holdings. In the treatments with positive debt, subjects may default. If this happens, they are protected by limited liability, which limits their downside risk, as illustrated in Figure 1.

**Bonus.** This treatment has the same payoff structure as with a debt of 1200 but a different framing. Instead of having to repay debt, subjects receive a bonus if their final ECU holdings exceed 1200. This bonus is equal to their final ECU holdings minus 1200.

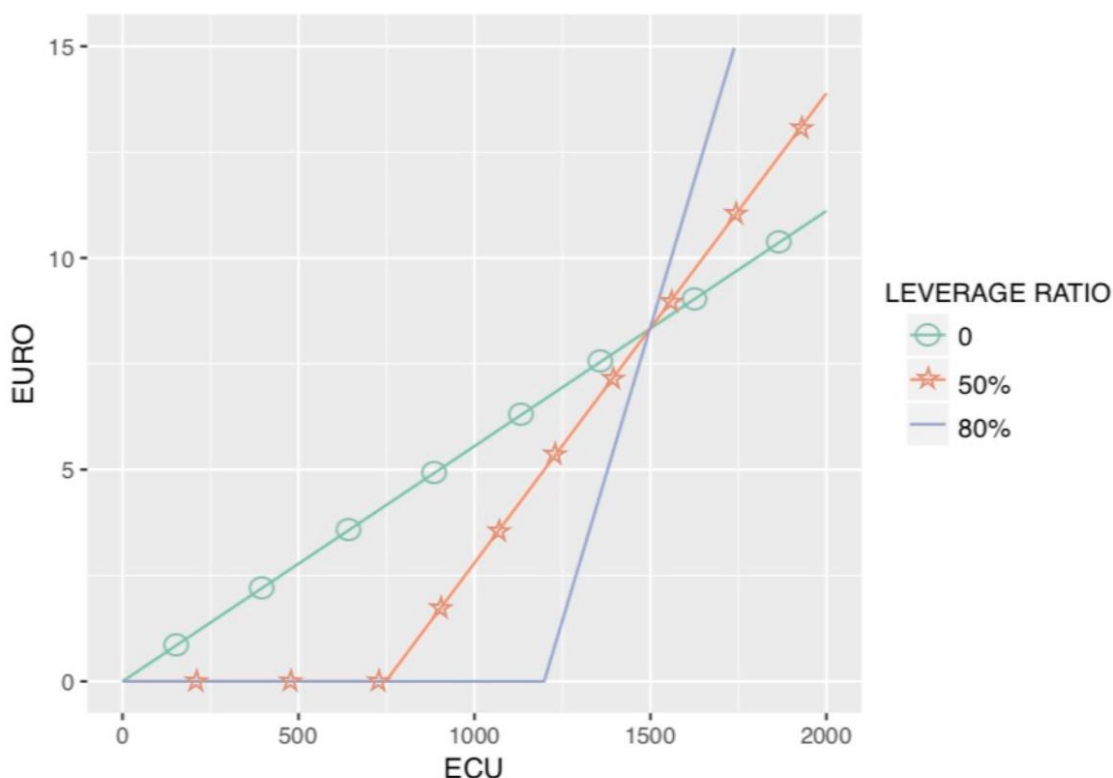


Figure 1: Payoffs and Leverage.

**Constant leverage.** In the treatments considered so far, we set the initial leverage and keep aggregate liquidity constant. Leverage, however, may change over time depending on the evolution of asset prices. For example, a higher asset price reduces leverage.

To shed light on the liquidity channel, we run an additional treatment with constant leverage where debt is adjusted every period to bring leverage back to its initial value.

While leverage is constant in this treatment, aggregate liquidity is no longer constant because we inject or withdraw liquidity in the economy whenever the level of debt needs to be adjusted to keep leverage constant.

The initial conditions of the constant leverage are the same as in the treatment with 80% leverage. However, we now force subjects to maintain this leverage as the asset value fluctuates. When the asset value of participants increases, for example, we increase their cash position as well as the debt they have to repay at the end of the experiment. If the asset value decreases, we force them to repay some of their debt and reduce their cash positions accordingly.

For example, consider a subject with an initial asset value of 1500 and debt of 1200. The leverage ratio is 80%. If the asset value increases to 1600, the leverage increases to 75%. In this case, we lend an additional 400 to the participant. Asset value increases to 2000, debt increases to 1600, and the leverage is restored to 80%.

Assume now that the asset value decreases to 1400, which brings the leverage to 86%. In this case, we take 400 of cash from the participant and reduce his debt position by 400. Asset value is now 1000, debt is 800, and the leverage is restored to 80%.

In some cases, participants may not have enough cash available to repay enough debt and keep their leverage constant. In these cases, we keep things simple by taking all their cash and letting them operate at a too high leverage. An alternative would have been to implement a liquidation procedure to force subjects to sell their assets in case their cash position was not sufficient, but such an extension would have further complicated the experiment. Although participants can be temporarily above the desired leverage, we take all their cash and they can thus only sell assets, which is exactly what a liquidation procedure would try to achieve. Only one out of the 70 participants who played the constant leverage treatment did not have enough cash to keep a constant leverage. This participant aggressively bought stocks from the start and quickly became illiquid. After we reduced his cash position to 0 and let him operate at too high a leverage, he slowly sold his stocks over the course of 5 periods and finished the experiment with 80% leverage and a positive cash position.

**Elicitation of Risk Preferences.** We elicit risk preferences before the start of the asset market experiment with a standard investment task (Gneezy and Potters, 1997). Subjects are endowed with 2 EUR of cash. They can invest a fraction of this amount in a risky project. The project either succeeds or fails with equal probability. The amount invested is doubled in case of success and is halved in case of failure. Project proceeds are paid together with the amount not invested. The success or failure of a project is announced to the subjects at the end of the experiment. The amount that subjects invest in the lottery gives us a measure of their risk tolerance.



**Procedures.** The experiments were conducted in the Frankfurt Laboratory of Experimental Economics (FLEX) during the Fall 2016 and Spring 2017. ORSEE (Greiner, 2015) was used to recruit subjects. We ran a total of 35 sessions, more specifically 7 sessions for each of the 5 treatments. The number of participants varied between 7 and 11 per session. A total of 229 subjects participated in the experiment. Each session lasted approximately 75 minutes. The experiment started after subjects read the instructions, answered a number of control questions that tested their understanding both of the investment game and of the market structure, and played three practice periods to familiarize themselves with the asset market. The investment game was conducted before the asset market, with instructions described on screen. Programming was done in z-Tree (Fischbacher, 2007). At the end of the experiment, subjects were called forward one by one and paid privately. The average payment was about 15 EUR.

## 3 Results

### 3.1 Leverage

Figures 2, 3, and 4 show the evolution of asset prices in each session for leverage ratios of, respectively, 80%, 50%, and 0. Treatment mean asset prices overall lie between 110 and 130, which is higher than the fundamental value of 100 and indicates bubbles in all treatments. Furthermore, higher leverage is associated with larger bubbles. Mean asset prices are a bit below 120 when leverage is 80% while they are a bit higher than 120 with 50% leverage. They are even higher with 0 leverage. Finally, there is a lot of heterogeneity within treatment. Some sessions experience asset prices as high as 160 while prices stay below the fundamental value in one session. Prices stay relatively stable in some sessions while they oscillate wildly in others.

To study the significance of these initial observations, we estimate a pooled OLS regression that relates mean asset prices in a session/period to leverage dummies, where the omitted category is 0 leverage. Standard errors are clustered at the individual level. The results are displayed in column 1 of table 2. The results confirm the initial observations that asset prices are lower when participants are indebted, as indicated by the significantly negative coefficients on the leverage dummies.

In column 2, we additionally control for gender and for risk tolerance, which is equal to the average fraction of the endowment invested during the risk preference elicitation task. On average, traders invested 64% of their initial endowment in the risky asset with a standard deviation of 26%. The coefficient on risk tolerance is large but insignificant. A 10 percentage point increase in risk tolerance increases prices on average by more than 3 ECU. This is consistent with the idea that more risk averse traders demand a higher risk premium. The coefficient on the male dummy is negative but insignificant. The size

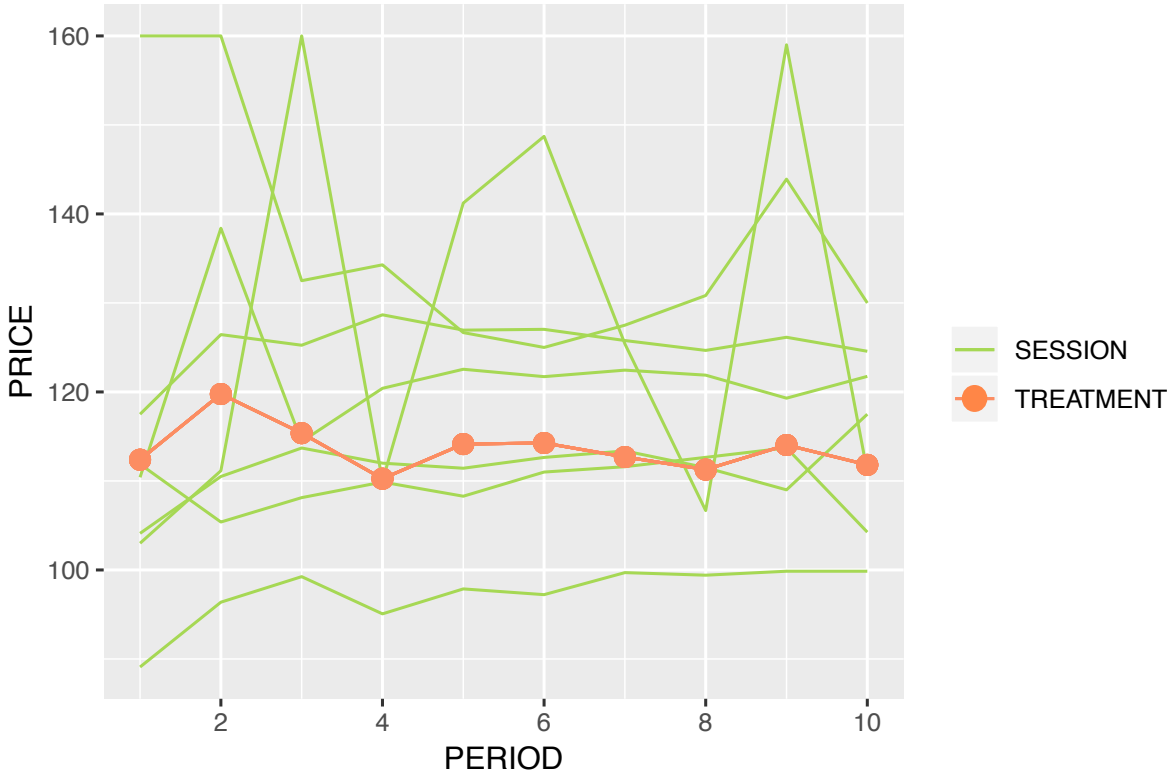


Figure 2: Evolution of Asset Prices - 80% Leverage

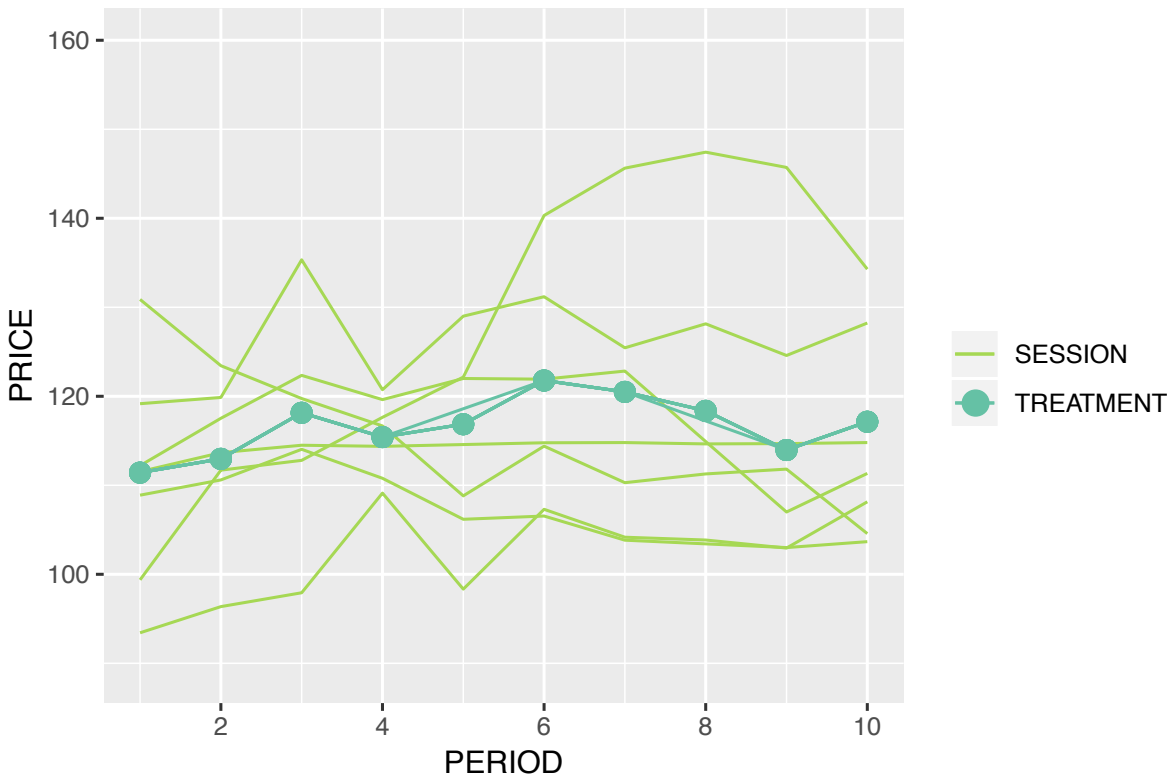


Figure 3: Evolution of Asset Prices - 50% Leverage

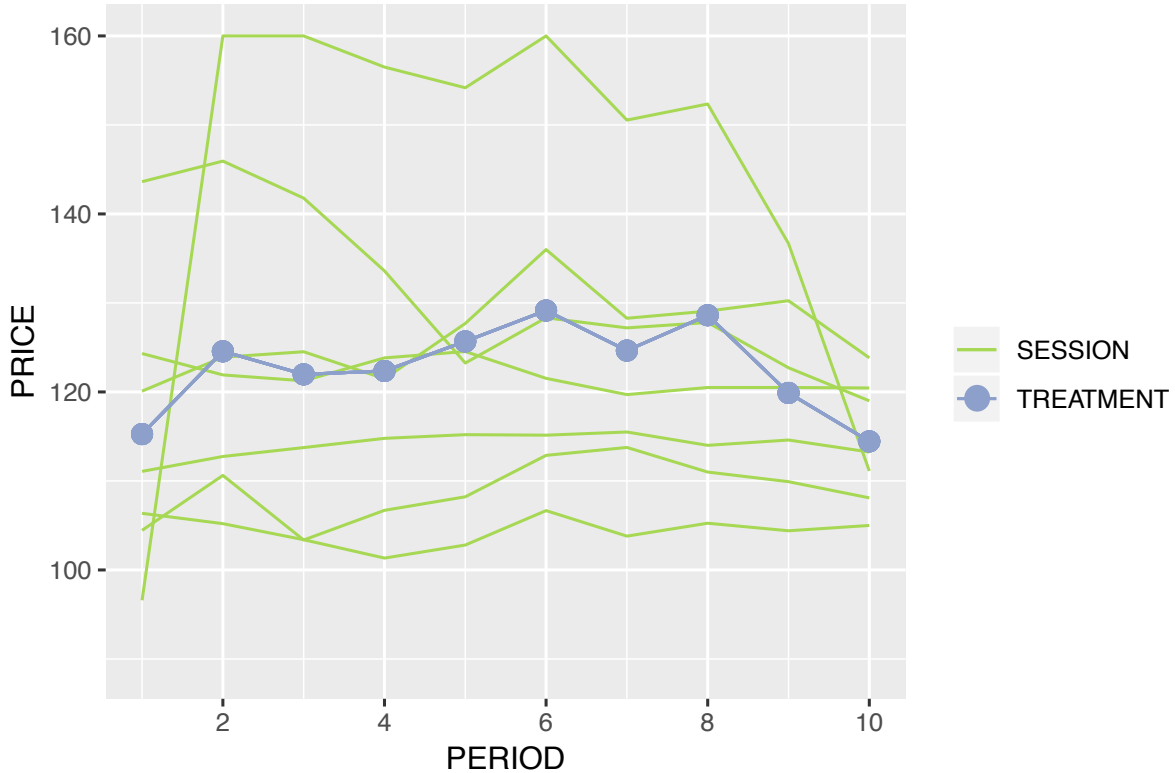


Figure 4: Evolution of Asset Prices - 0 Leverage

and significance of the coefficients on the leverage dummies remain stable.

These initial results are surprising because we expected larger bubbles in treatments with higher leverage. Investors face less downside risk with higher leverage, which should result in a higher willingness to pay for the assets and hence larger bubbles. However, we do not find support for this prediction. Treatments with positive leverage experience smaller bubbles than the treatment with no leverage.

**Individual data.** We now study the effect of leverage on individual trading behavior in the 80% and 50% leverage treatments. While the initial leverage is the same for all participants in a session, leverage subsequently changes as a result of trading activity and the evolution of asset prices. For example, the leverage of a participant who holds assets decreases if asset prices increase, as can be seen from equation 1.

We can then check whether participants change their trading decisions as a result of these changes in leverage. As before, we expect higher leverage to increase the willingness to pay for assets because of the lower downside risk resulting from limited liability. Participants should thus be willing to pay a higher price and to buy more assets.

Note that individual leverage only changes in treatments with 80% and 50% initial leverage. In the treatment with 0 leverage, individual leverage is always 0. We thus exclude this treatment from the analysis in this section since it does not feature individual

	Asset prices	
	(1)	(2)
Leverage 80%	-3.586*	-3.814*
	(0.091)	(0.079)
Leverage 50%	-6.160***	-6.079***
	(0.001)	(0.001)
Risk Tolerance		3.865
		(0.193)
Male		-0.404
		(0.811)
Constant	121.3***	119.1***
	(0.000)	(0.000)
Observations	1932	1932
Adjusted $R^2$	0.032	0.036

Table 2: **Asset Prices and Leverage.** The dependent variable is the mean asset price in a period/session. The results are from pooled OLS regressions. In column (1), we only control for treatment dummies. Column (2) additionally controls for risk tolerance measured as the fraction invested in the investment task and for a male dummy. Standard errors clustered at the individual level in parentheses. Significance levels denoted by \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

variation in leverage.

We use a fixed effects regression to study the relationship between trading behavior and leverage. Fixed effects control for individual fixed characteristics and let us evaluate whether participants behave differently when their leverage changes.

Leverage is measured as the ratio of debt to portfolio value at the beginning of the trading period, where each asset is valued at the mean session asset price of the previous period. In the 80% initial leverage treatment, the mean leverage ratio is 82% and ranges from 58 to 224%. In the 50% initial leverage treatment, the mean leverage ratio is 51% and ranges from 35 to 116%. Thus, while the mean treatment leverage stays relatively close to its initial value, subsequent trading activity introduces heterogeneity in the levels of individual leverage.

To measure individual trading behavior, we use the mean ask and bid prices as well the total ask and bid quantities each participant post in a period. On average, in the two treatments considered, participants were willing to sell 3.0 assets each period at a price of 141 and to buy 4.1 assets each period at a price of 98.

We expect that more leveraged participants should have a higher demand for assets because the lower downside risk should make assets more valuable to them. This should result in both higher bid and ask prices, as well as larger bid quantities and lower ask quantities.

These measures of trading behavior may not only be impacted by leverage but also by liquidity. For example, more liquid participants can more easily buy assets and can pay a higher price. We thus also control for liquidity when explaining trading behavior.

Liquidity is measured as the ratio of liquidity to portfolio value at the beginning of the trading period, where each asset is valued at the mean asset price of the previous period. In the two treatments considered, the mean liquidity ratio is 65% and ranges from 1 to 100%.

Table 3 shows the results. We find that participants are willing to pay a significantly lower price for the assets when they become more leveraged. A 10 percent point increase in leverage is associated with a 8 ECU lower bid. Participants who become more leveraged are also willing to sell assets at a lower price but the effect is small and insignificant. They also reduce both their bid and ask quantities, but the effects are small and insignificant. As expected, more liquid participants significantly increase both their bid price and bid quantity.

	(1)	(2)	(3)	(4)
	Ask Price	Bid Price	Ask Quantity	Bid Quantity
Leverage	-5.417 (27.04)	-81.19*** (22.53)	-0.473 (1.027)	-0.805 (1.765)
Liquidity	-72.05*** (18.53)	29.60*** (10.88)	-3.858*** (0.587)	2.919*** (0.656)
Constant	143.6*** (20.39)	91.71*** (14.68)	4.732*** (0.779)	1.187 (1.193)
Ind Fixed Effects	YES	YES	YES	YES
Observations	1232	1232	1232	1232
Adjusted $R^2$	0.026	0.033	0.100	0.026

Table 3: **Individual Trading Behavior and Leverage.** The regressions use the data of the treatments with 80% and 50% leverage. *Ask Price* is the average price that a participant posted in a period to sell an asset. *Bid Price* is the average price that a participant posted in a period to buy an asset. *Ask Quantity* is the number of assets that a participant desired to sell in a period. *Bid Quantity* is the number of assets that a participant desired to buy in a period. All regressions include individual fixed effects. Bid and ask prices are quantity weighted. Leverage is the ratio of debt to asset value measured before trading starts, where each asset is valued at the mean session asset price of the previous period. Liquidity is the ratio of cash to total asset value measured before trading starts, where each asset is valued at the mean session asset price of the previous period. Standard errors clustered at the individual level in parentheses. Significance levels denoted by \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Overall these results are consistent with the analysis above on asset prices. Participants who are more leveraged value assets less, even though they benefit from a lower downside risk. This lower valuation may explain why we observe smaller bubbles in treatments with higher leverage.

## 3.2 Framing

More leveraged participants may not value assets more, in spite of the lower downside risk, because they try to avoid default. They are indeed closer to default and a lower

demand for assets offers some protection by increasing their expected payoff and by decreasing their portfolio risk. The negative effect of default aversion on asset prices would be stronger when leverage is higher, which may explain why higher leverage does not produce higher asset prices.

We shed some light on this conjecture by studying the role of framing in our experiment. We now tell participants that they will receive a bonus if their final payoff exceeds 1200 ECU and nothing otherwise. The bonus they receive is equal to their final payoff minus 1200. Thus, payoffs are unchanged compared to the treatment with a debt of 1200. We expect this more positive framing to produce larger bubbles.

Figure 5 shows the evolution of asset prices for the bonus treatment. Mean asset prices start a bit above 140, quickly decline, and then slowly converge towards 120. Prices follow this pattern in four sessions while they stay at around 160 in one session and stay at around 110 in the two remaining sessions. Compared to the 80% leverage treatment where mean prices do not exceed 120, mean asset prices are thus generally higher. This difference suggests that the bonus framing increases the value that participants attach to the assets compared to the debt framing.

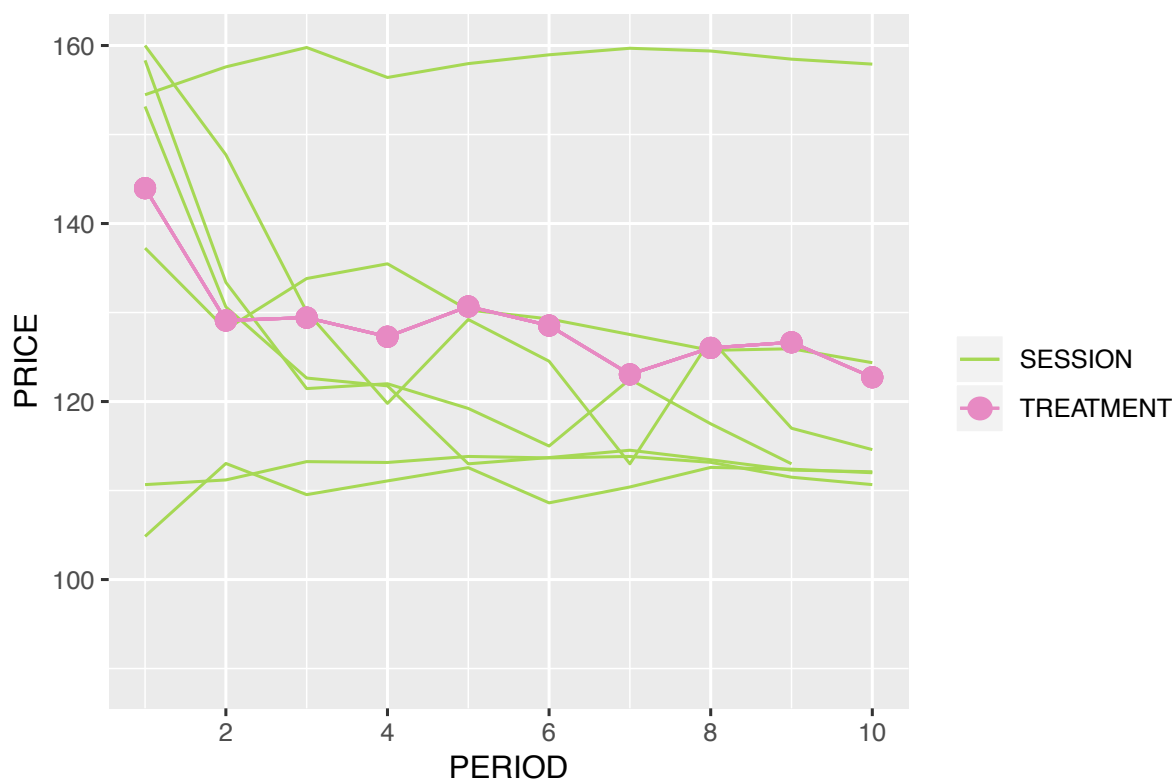


Figure 5: Evolution of Asset Prices - Bonus Framing

To study the significance of these initial observations, we combine the data from both the bonus and the 80% leverage treatments and estimate a pooled OLS regression that

relates mean asset prices in a period/session to a bonus treatment dummy. Column 1 of table 4 shows the results. The coefficients on the framing treatment dummy is positive and significant. Asset prices are 11 ECU higher in the bonus treatment than in the 80% leverage treatment. In column 2, we additionally control for risk tolerance and gender. These additional controls are not significantly related to asset prices. The size and the significance of the coefficient on the treatment dummy remain similar.

	Asset prices	
	(1)	(2)
Bonus	11.01*** (0.000)	11.44*** (0.000)
Risk Tolerance		-2.535 (0.503)
Male		-2.420 (0.271)
Constant	115.2*** (0.000)	117.7*** (0.000)
Observations	1370	1370
Adjusted $R^2$	0.126	0.135

Table 4: **Asset Prices and Framing.** The regressions use the data from the 80% leverage and bonus treatments. The dependent variable is mean asset price in a period/session. The results are from pooled OLS regressions. In column (1), we only control for a bonus treatment dummy. Column (2) additionally controls for risk tolerance measured as the fraction invested in the investment task and for a male dummy. Standard errors clustered at the individual level in parentheses. Significance levels denoted by \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

**Individual data.** We now study the effect of leverage on trading behavior in the bonus treatment. We use the same estimation procedure and the same variables as in the previous section. Since this framing removes the mention of debt, we expected that the effect of higher leverage on trading behavior would be more in line with the moral hazard channel original hypothesis, that is, more leveraged participants would value assets more because of the lower downside risk. While the concept of leverage has little meaning in this treatment without debt, we keep this label for consistency. A higher individual leverage in this treatment should be thought of as a smaller expected bonus, since the current asset value of a more leveraged participant is closer to the 1200 threshold above which a bonus is paid.

Table 5 shows that some of the results have been affected by the change in framing. In line with the moral hazard channel, participants who become more leveraged post higher bid prices, but the effect is insignificant. By contrast, participants posted significantly lower bid prices in the 80% leverage treatment. Furthermore, participants who become more leveraged post significantly lower ask prices, which is inconsistent with the moral hazard channel. A 10 percent point increase in leverage leads to a 8 ECU lower ask price.

By contrast, this effect was insignificant and much smaller in the 80% leverage treatment. Finally, the coefficients on both ask and bid quantities are insignificant and the effects of liquidity on trading behavior are similar to the 80% leverage treatment.

	(1)	(2)	(3)	(4)
	Ask Price	Bid Price	Ask Quantity	Bid Quantity
Leverage	-79.41* (44.20)	12.82 (13.88)	-0.532 (0.744)	1.022 (0.721)
Liquidity	-83.00*** (22.76)	53.36*** (12.04)	-6.537*** (0.694)	2.374** (0.945)
Constant	225.4*** (32.86)	10.26 (14.05)	6.972*** (0.598)	-0.00112 (0.709)
Ind Fixed Effects	YES	YES	YES	YES
Observations	740	740	740	740
Adjusted $R^2$	0.031	0.033	0.225	0.008

Table 5: **Individual Trading Behavior with Bonus Framing.** The regressions use the data of the bonus treatment. *Ask Price* is the average price that a participant posted in a period to sell an asset. *Bid Price* is the average price that a participant posted in a period to buy an asset. *Ask Quantity* is the number of assets that a participant desired to sell in a period. *Bid Quantity* is the number of assets that a participant desired to buy in a period. All regressions include individual fixed effects. Bid and ask prices are quantity weighted. Leverage is the ratio of debt to asset value measured before trading starts, where each asset is valued at the mean session asset price of the previous period. Liquidity is the ratio of cash to total asset value measured before trading starts, where each asset is valued at the mean session asset price of the previous period. Standard errors clustered at the individual level in parentheses. Significance levels denoted by \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

This section tried to understand our main result that higher leverage is associated with lower asset prices. This unexpected result may be explained by default aversion. First, we observe larger bubbles when participants can earn a bonus rather have to repay debt, even though the payoff structure is identical. Furthermore, individual trading behavior is affected by framing.

### 3.3 Constant Leverage

We have so far studied the effects of leverage on asset prices without changes in aggregate liquidity to shed light on the moral hazard channel. To explore the liquidity channel, we keep leverage constant over time by injecting or withdrawing liquidity and study the effect on asset prices.

Figure 6 shows the evolution of asset prices in the constant leverage treatment. Mean asset prices are increasing over time from about 120 to about 130. While 6 out of the 7 sessions follow this pattern, there is also one session where asset prices decline for most of the experiment. By contrast, mean asset prices in the 80% leverage treatment, which



has the same initial conditions as this constant leverage treatment, were overall lower and stayed roughly constant over time.

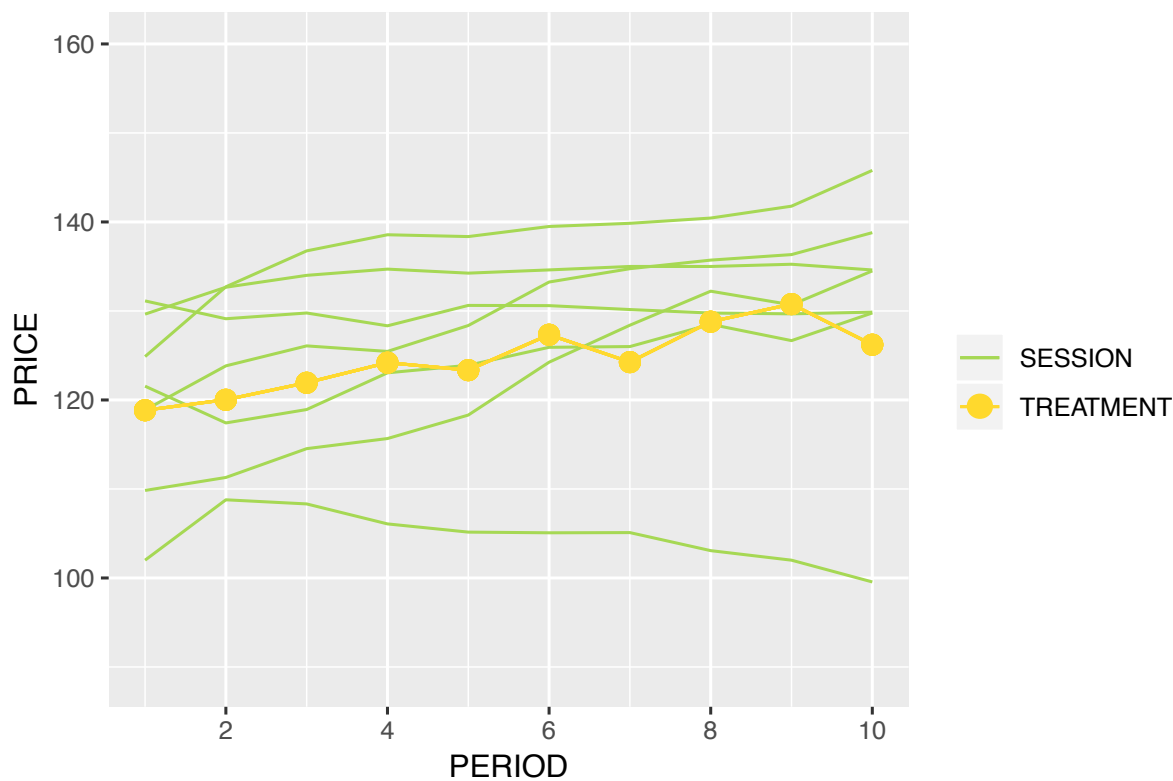


Figure 6: Evolution of Asset Prices - Constant Leverage

To study the significance of these initial observations, we use the data of the 80% initial leverage and constant leverage treatments and estimate a pooled OLS regression that relates average asset prices in a period/session to a constant leverage dummy. Column 1 of table 6 shows the results. The coefficients on the constant leverage treatment dummy is positive and significant. Asset prices are on average 8 ECU higher in the constant leverage treatment than in the 80% initial leverage treatment. In column 2, we additionally control for the average risk tolerance and gender. These additional controls are not significantly related to asset prices and do not affect the coefficient on the constant leverage treatment dummy. In column 3, we additionally control for the interaction between period and each treatment dummy to test for the significance of the trends. The interaction between period and constant leverage dummy is positive and significant, indicating a positive trend in asset prices, as suggested by the figure. Each period, asset prices increase by about 1.1 ECU. By contrast, the interaction between 80% leverage and period is insignificant and close to 0. This confirms the initial observation that asset prices remain stable with constant aggregate liquidity.

	Asset prices		
	(1)	(2)	(3)
Constant Leverage	8.319*** (0.000)	8.340*** (0.000)	3.419 (0.198)
Risk Tolerance		0.597 (0.861)	0.586 (0.864)
Male		-0.199 (0.785)	-0.380 (0.599)
80% Leverage*Period			0.216 (0.272)
Constant Leverage*Period			1.111*** (0.000)
Constant	117.8*** (0.000)	117.4*** (0.000)	116.3*** (0.000)
Observations	1280	1280	1280
Adjusted $R^2$	0.090	0.095	0.124

Table 6: **Asset Prices and Constant vs 80% Initial Leverage.** The regressions use the data from the treatments 80% initial leverage and constant leverage. The dependent variable is mean asset price in a period/session. The results are from pooled OLS regressions. In column (1), we only control for a constant leverage dummy. Column (2) additionally controls for risk tolerance measured as fraction invested in the investment task and for a male dummy. Column (3) controls for the interaction between period and constant or 80% initial leverage dummies. Standard errors clustered at the individual level in parentheses. Significance levels denoted by \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

**Individual data.** We now study individual trading behavior in the constant leverage treatment. We use the same measures of trading behavior and liquidity as above. Since leverage is constant in this treatment, the regressions no longer control for this variable. Table 7 shows the results. More liquid participants post lower ask prices and quantities as well as higher bid prices and quantities, consistently with the other treatments.

The main difference between constant and 80% initial leverage is that the cash-to-asset ratio increases with constant leverage. As asset prices increase, subjects are given additional cash (and debt) while the number of assets in the economy stays constant. A well-known result in the literature is that a higher cash-to-asset ratio increases asset prices (Caginalp et al., 2001) and a similar mechanism may be at work in our setup. More liquid participants are indeed willing to pay a higher price, buy more assets, and sell fewer assets (although, at a lower price). This would explain why we observe a positive trend in asset prices with constant leverage. Since the asset prices are higher than the fundamental value in the first period, subjects receive additional liquidity compared to the 80% leverage treatment. This additional liquidity in turn increases the demand for assets and asset prices. This creates a spiral where higher prices increase aggregate liquidity, which in turn increases asset prices. With constant liquidity, by contrast, higher asset prices do not increase aggregate liquidity, which stabilizes asset prices.

	(1)	(2)	(3)	(4)
	Ask Price	Bid Price	Ask Quantity	Bid Quantity
liquidity	-83.60*** (16.53)	28.85*** (10.09)	-3.809*** (1.016)	1.704* (0.989)
Constant	145.6*** (11.49)	48.16*** (7.018)	4.566*** (0.707)	1.781** (0.688)
Observations	700	700	700	700
Adjusted $R^2$	0.042	0.010	0.128	0.004

Table 7: **Individual Trading Behavior and Leverage.** The regressions use the data of the treatment with constant leverage. The dependent variables are shown in the first column. *Ask Price* is the average price that a participant posted in a period to sell an asset. *Bid Price* is the average price that a participant posted in a period to buy an asset. *Ask Quantity* is the number of assets that a participant desired to sell in a period. *Bid Quantity* is the number of assets that a participant desired to buy in a period. All regressions include individual fixed effects. Bid and ask prices are quantity weighted. Liquidity is the ratio of cash to total asset value measured before trading starts, where each asset is valued at the mean session asset price of the previous period. Standard errors clustered at the individual level in parentheses. Significance levels denoted by \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

## 4 Conclusion

We study the relationship between leverage and bubbles in a laboratory experiment. We first find that higher leverage does not produce larger bubbles when aggregate liquidity is constant. Consistent with this result, the individual data shows that more leveraged participants pay lower prices. These results are surprising since participants face less downside risk with higher leverage, which should increase their willingness to pay for assets.

A possible explanation is that more leveraged participants trade more cautiously because they try to avoid default. The higher the leverage, the closer they are to default. Consistent with this explanation, we find that asset prices are higher when participants can receive a bonus instead of having to repay debt, even though the payoff structure is unchanged.

Finally, we inject or withdraw liquidity in the economy to study the implications of constant leverage. In this economy, constant leverage implies a sustained injection of liquidity, which fuels bubbles.

Overall, these results cast some doubt on mechanisms suggesting that higher leverage may cause excessive risk taking because of moral hazard. Instead, our results suggest that excessive risk-taking and bubbles may result from the more abundant liquidity created by higher leverage.

Leverage has become central in discussions about financial stability. Laboratory experiments that use modified versions of our setup could contribute to these discussions by studying the effects of various macroprudential policies on financial stability. Leverage was not a choice variable in our experiment and another possible extension would be to

let participants choose their leverage.

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## 5 Instructions

### **Instructions - Leverage and Bubbles: Experimental Evidence**

*Note: These are translations of the instructions from the German original into English. The instructions for 80% Leverage are printed in full. We omit the instructions for the 50% and 0 Leverage treatments because they are similar. The only change with the 50% Leverage treatment is the level of debt that has to be repaid (750 instead of 1200). The instructions for the 0 Leverage treatment do not mention debt. For the Framing treatment and the Constant Leverage treatment, only the relevant changes are included (and color-coded).*

### **80% Leverage**

#### **1. General Instructions**

This is an experiment where you trade in a market. At the end of the experiment you will be paid in cash. The payout will be anonymous. Your payoff depends both on your decisions and on the decisions of others. The experiment will take part on the computer where you sit. If you have any questions during the experiment, please raise your hand, an experimenter will come to you and answer the question.

In this experiment, you trade with other participants in a market. Trade in the market is anonymous. This means the decisions you make in the market cannot be traced back to you, but you also cannot know the identity of the others' decisions in the market.

The market is a fictitious stock market, so you will trade stock. Trade will be settled in Taler, a fictitious currency.

In addition to the market, there will be another task, described on your screen. You can also earn money with this task.

Your Taler holdings from both the stock market and the additional task, will be paid out at the end of the experiment. To that end, they will be converted with a ratio 1:36 into Euro. That means 36 Taler are worth 1 Euro. In order to be paid, participants will be asked to come to the front desk one by one. There they will be paid anonymously.

In addition to your earnings from the stock market and the other task, you will receive 5 Euro.

#### **2. The Market**

The market consists of 10 trading periods, each period lasting 120 seconds. Your payoff depends on your Taler holdings at the end of the market. You will carry over both cash and stock holdings from one period to the next.

**Initial Endowment:** Each participant receives an initial endowment of 1000 Taler and 5 stocks.

**Dividend:** The stock pays only one random dividend, at the end of the market, after the 10th period ended. Apart from this dividend, the stock is worthless. The dividend is 200 Taler with a probability of 20% and 75 Taler with a dividend of 80%. Therefore, the average dividend payout is 100 Taler. All the stocks in the market pay the same dividend.

**Trade:** Stocks will be traded in the market: participants can both buy and sell stocks. Trade will be settled in Taler. Participants who buy a stock pay it in Taler. Participants who sell a stock receive the price in Taler.

**Loan:** Your initial endowment was financed with a loan. The loan will be paid back by you after the last period of trading. To pay back the loan, your Taler holdings after the dividend payout will be used. The loan amounts to 1200 Taler.

**Market earnings:** At the end of the market, your Taler holdings less the amount of the loan will be paid out. However, your market earnings can't be negative, even if your Taler holdings after paying back the loan are negative. In this case you won't have any earnings from the market.

### **3. Buying and Selling**

To sell stocks, you need enough stocks. Your stock holdings can't become negative. To buy stocks, you need enough Taler, your Taler holdings can't become negative either. Within a trading period, there are four ways to trade stocks.

**Offer to sell:** You can offer to sell as many stocks as you would like. To do so, enter the number of stocks you want to sell in the box 'Quantity', and the price per stock in the box 'Sell-Price'. To confirm the offer, press the button 'SELL'. As soon as your offer is confirmed, it will be added to the list of open sell offers. This list is visible to all market participants. The list is ordered increasingly depending on prices. You can only sell more stocks than you hold.

**Offer to buy:** You can make an offer to buy for as many stocks as you would like. To do so, enter the the number of stocks you want to buy into the box 'Quantity', and the price per stock in the box 'Buy-Price'. To confirm the offer, press the button 'BUY'. As soon as your offer is confirmed, it will be added to the list of open buy offers. This list is visible to all market participants. The list is ordered decreasingly on prices. You can only buy as many stocks as your Taler holdings allow for.

**Multiple Offers:** You can make as many offers to buy and offers to sell as you like. However, the total amount of stocks offered may not be higher than your current stock holdings. Moreover, you can only make as many offers to buy as your Taler-holdings allow for. Confirmed offers cannot be taken back.

**Buy it now:** You can accept open offers to sell. Enter into the box 'Quantity' how many stocks you wish to buy. Then click the button 'BUY' to confirm the sale. Your Taler holdings have to be high enough to make the transaction.

**Sell it now:** You can accept open offers to buy. Enter into the box 'Quantity' how many stocks you wish to sell. Then click the button 'SELL' to confirm the sale. Your stock holdings have to be large enough to make the transaction.

**Overview of Transactions:** You get an overview of all sales and purchases made within one period. This overview will be shown above the trading platform. Additionally, there will be an overview of transaction prices in the lower left part of the screen.

**Practice Market:** To make you familiar with the trading environment, there will be a 3-period practice market. In this practice market, your decisions will not affect your final payoff.

#### **4. Payoffs**

Your payoff depends on your earnings from the stock-market and from the additional task. Your earnings from the stock market are your Taler holdings after dividend payout and after paying back the loan. In case you cannot pay back the loan in full, you will receive no payoff from the stock market. You will still receive your earnings from the additional task, however. Taler holdings from both the stock market and the additional task will be converted at a 1:36 ratio into Euros and will be paid on top of the 5 Euros you receive for your participation in the experiment.

**Example 1:** At the end of the stock market, you have a portfolio of 300 Taler and 10 stocks. The randomly determined dividend is low, so each stock pays out 75 Taler. So, after dividend payout, you have 1050 Taler. Since your loan is higher than your Taler holdings, you will have no earnings from the stock market. Assuming you earned 108 Taler in the additional task, your total payoff will be  $(0+108)/36 + 5 = 8$  Euro.

**Example 2:** At the end of the stock market, you have a portfolio of 300 Taler and 10 stocks. The randomly determined dividend is high, so each stock pays out 200 Taler. So, after dividend payout, you have 2300 Taler. After paying back the loan, your payoff from the stock market is 1100. Assuming you earned 108 Taler in the additional task, your total payoff will be  $(1100+108)/36 + 5 = 38.33$  Euro.

#### **5. Summary**

1. You trade with other participants in a 10-period market.
2. Your initial endowment will consist of 1000 Taler and 5 Stocks. Stocks and Taler will be carried over to the next period.
3. Stocks pay out a dividend after the last period. The dividend is 200 Taler with 20% probability, and 75 Taler with 80% probability. The average dividend payout is 100 Taler.

4. After the experiment, you have to pay back a loan of 1200 Taler.
5. Your payoff depends your Taler holding at the end of the 10th period. Your Taler holdings minus the loan will be converted at a ratio of 1:36 into Euros.
6. If at the end of the stock market, the loan is higher than your Taler holdings after dividend payout, your earnings from the stock market will be zero.
7. In addition to the stock market, there is a further task where you can earn additional money. This task will be described on screen.

## Framing Treatment

### **1. General instructions**

This is an experiment where you trade in a market. At the end of the experiment you will be paid in cash. The payout will be anonymous. Your payoff depends both on your decisions and on the decisions of others. The experiment will take part on the computer where you sit. If you have any questions during the experiment, please raise your hand, an experimenter will come to you and answer the question.

The market is a fictitious stock market, so you will trade stock. Trade will be settled in Taler, a fictitious currency. In the market you will take the role of a portfolio manager. For your work as portfolio manager you will receive a wage of 5 Euro. In addition, you might gain a bonus in case of good performance. The exact payoff modalities will be discussed in part 4.

[...]

### **4. Payoffs**

Your payoff depends on your earnings as a portfolio manager and from the additional task. Your earnings as a portfolio manager consists of your wage of 5 Euro and a bonus. The bonus depends on your Taler-holdings at the end of the stock market. In case your Taler holdings are above 1200, you receive a bonus. For each 36 Taler above 1200, you will receive 1 Euro. Taler holdings from the additional task will be converted at a 1:36 ratio into Euros and added to your wage as a portfolio manager.

### **5. Summary**

4. Your bonus depends on your Taler holdings at the end of the 10th period. You will receive a bonus, if your Taler holdings exceed 1200 Taler. For each 36 Taler above 1200, you will be paid out 1 Euro.



## Constant Capital Ratio

### 2. The Market

**Loan:** Your initial endowment was financed with a loan. The loan will be paid back by you after the last period of trading. To pay back the loan, your Taler holdings after the dividend payout will be used. The loan amounts to 1200 Taler. The loan will be adjusted in the course of trading, see below.

**Portfolio Value:** The value of your portfolio will be determined at the end of each period. The value of the portfolio is determined by your Taler and stock holdings. Stocks will be valued at the average trading price of the last period. In case no trade took place, the average price of the period before last will be taken instead. Hence, the value of your portfolio might vary from period to period. The variation depends both on changes of the average price and on your purchasing and selling behavior.

**Loan Adjustment:** The size of your loan will be adjusted automatically at the end of each period. The loan will always be equal to 80% of the value of your portfolio. That is, if the value of the portfolio changes, you will be credited additional Taler holdings. While your Taler holdings will increase by the amount credited, your loan will also increase by the same amount. Conversely, if the value of your portfolio declines, you will automatically repay part of the loan. The loan adjustment takes place according to the following formula:

$$\text{Loan adjustment} = 4 \cdot \text{Value of Portfolio} - 5 \cdot \text{Loan Amount}$$

**Example 1:** Assume that the value of your portfolio in the previous period was 1000 Taler. Last period's loan was 800 Taler. Your portfolio in the current period consists of 400 Taler and 6 stocks. The average trading price was 105 Taler. Hence, the value of your portfolio is 1030 Taler, before the loan adjustment. You will be credited 120 additional Taler as a new loan. Therefore, your Taler holdings increase from 400 to 520 and the value of your portfolio increases from 1030 to 1150. At the same time the loan increases from 800 to 920.

**Example 2:** Assume that the value of your portfolio in the previous period was 1000 Taler. Last period's loan was 800 Taler. Your portfolio in the current period consists of 400 Taler and 6 stocks. The average trading price in this example was 90 Taler. Hence, the value of your portfolio is 940 Taler, before the loan adjustment. You will pay back 240 Taler of the loan. Therefore, your Taler holdings decrease from 400 to 640 and the value of your portfolio decreases from 940 to 700. At the same time the loan decreases from 800 to 560.

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