UNIVERSITY OF WAIKATO

Hamilton
New Zealand

Motivations to speculate are the driving forces in experimental asset market bubbles

Steven Tucker and Yilong Xu

Working Paper in Economics 2/24

January 2024

Corresponding Author

Steven Tucker
School of Accounting Finance and Economics
Te Raupapa – Waikato Management School
University of Waikato

Email: steven.tucker@waikato.ac.nz

Yilong Xu
Utrecht School of Economics
Utrecht University, The Netherlands

Email: y.xu3@uu.nl

Abstract

Research in Finance has long been intrigued by the causes of price bubbles. It has been argued that investors having doubts about the rationality of others may speculate on future capital gains. However, in an important contribution, Lei et al. (2001, Econometrica) argue that speculation is not the driver of bubbles in the absence of common knowledge of rationality, suggesting a focus on mistakes and confusion. Tucker and Xu (2024) revisit Lei et al.'s (2001) design, confirming the existence of bubbles, but argue that although their design removes the ability to speculate, it potentially introduces unintended design artifacts that may induce bubbles. We design a novel condition that eliminates incentives for speculation without these undesirable effects, which effectively eliminates bubbles even in the presence of confusion and/or lack of common expectations. We conclude that speculation plays a critical role in bubble formation, and thus *does* matter.

JEL Classification

C91, G13

Keywords

speculation

bubbles

cognitive ability

asset market experiment

Acknowledgment

We thank participants at the Experimental Finance Conference 2018, HeiKaMaX workshop 2018, External Validity, Generalizability and Replicability of Economic Experiments workshop 2019 (Barcelona GSE) for helpful comments. We also thank the seminar participants at Erasmus School of Economics (finance group) and Simon Fraser University for their valuable suggestions. We thank Tim Cason, David Freeman, Georg Kirchsteiger, Volodymyr Lugovskyy, Charles Noussair, Joerg Oechssler, Luba Petersen, Daniela Puzzello, Stefan Trautmann for their constructive comments. We gratefully acknowledge financial support from Waikato Management School, University of Waikato. The study has received human ethics approval from the Waikato Management School Human Ethics Committee.

1. Introduction

The history of financial markets is filled with many episodes of bubbles and crashes. Understanding the causes of bubbles is important, for their subsequent crashes often result in severe and long-lasting macroeconomic disruptions, affecting the real economy (see e.g., Brunnermeier and Schnabel 2016 for a comprehensive review, or Shiller, 2015). Studying bubbles using naturally occurring financial data is difficult, as each instance is essentially a one-off event given the heterogeneity of the different bubble environments/institutions and the fundamental values of the assets are often hard to estimate. Smith, Suchanek, and Williams (1988, hereafter SSW) published a seminal paper that initiated research on long-lived asset markets in a controllable setting, where the fundamental value can be pre-defined such that the intrinsic value of the asset is known. The principal result from the considerable research that followed is that markets consistently produce price bubbles.

The SSW paradigm has subsequently triggered a large experimental literature studying factors associated with bubble formation, in a controlled way that is not feasible with observational data (for reviews, see Plott and Smith 2008, Noussair and Tucker 2013, Palan 2013). Both SSW and Plott (1991) conjecture that bubbles occur because common knowledge of rationality cannot be established. That is, in the presence of heterogenous beliefs, agents are more willing to engage in speculative activities. In their seminal paper, Lei, Noussair, and Plott (2001, hereafter LNP) created a clever experimental design that can offer direct evidence on whether speculative behaviors drive bubbles. Their design restricts traders to one market side, eliminating the potential for speculation and making it impossible to buy low and sell high. This design should remove bubbles if speculation is the necessary condition for bubble formation. However, bubbles continue to be observed when the ability to speculate is removed.

In the wake of these results, a literature emerged that suggests decision errors and confusion are the main drivers of bubbles in experimental asset markets (Oechssler 2010; Kirchler et al. 2012; and Bosch-Rosa et al., 2018). Lei and Vesely (2009) and Huber and Kirchler (2012) support this argument by showing that instructions, training and

procedures intended to reduce confusion, reduce bubbles. However, Cheung et al. (2014) show that these methods also lead to common expectations among traders. In other words, bubbles are attenuated if all traders recognize that the dividend process is understood by all traders. However, if interventions reducing decision errors in fact reduce bubbles by establishing common expectations, then the question remains, what is driving bubbles in the absence of common expectations? Speculation would be the most obvious answer, but it is at odds with LNP's results. Tucker and Xu (2024) address these contradicting claims via systematic review and replication of LNP's design to better understand the psychological motives behind bubble formation. They confirm LNP's result that large bubbles still regularly occur even when speculative behavior is prohibited. They conjecture that the observed behavior may be due to the intrusive experimental intervention possibly introducing unintended design artifacts with behavioral implications that lead to bubbles despite prohibiting the ability to speculate.

In this paper, we offer an alternative, non-intrusive experimental condition that fulfils the goal of removing speculative incentives (as LNP's no-speculation condition), while leaving the basic SSW design and market features completely unchanged. This allows us to remove the potential design artifacts in the LNP design that might unintentionally influence behavior. The speculative motive is eliminated by introducing an 100% capital gains tax to the market, which implies that traders' capital gains (and thus the incentives to speculate), within or across periods, will be taxed away.

Our results show that the TAX treatment does significantly reduce mispricing such that bubbles are effectively eliminated in the bubble-prone SSW paradigm, and thus speculation is after all a necessary condition in bubble formation. Note that this result cannot be explained by a mere aversion to tax schemes per se given that bubbles are still frequently observed in other studies that involve taxes (King et al., 1993; Lei et al., 2002). We make use of information on the traders' cognitive ability to further shed light on the underlying mechanism. We find that high ability traders bid more conservatively than low ability traders, but only in the 100% capital gains tax treatment. The results suggest that in the absence of monetary incentives, relatively sophisticated traders who understand the tax are discouraged from engaging in speculative trades. The behavior of

traders who are prepared to buy at any price, e.g. the confused traders, is not affected by the tax. We conclude that speculation must be a key ingredient in the emergence of bubbles. [1]

Our results reconcile the long-standing puzzle that the prevailing results in the experimental literature are at odds to the finance literature that the former suggests that speculation is not a necessary ingredient for bubbles. Rather, mistakes and confusions are the main reasons behind bubbles (Lei et al., 2001; Oechssler 2010; Kirchler et al. 2012; and Bosch-Rosa et al., 2018). Our results show that even if we do not extensively train inexperienced traders, and thus confusion, mistakes, and most importantly the lack of common knowledge of rationality may well be present, bubbles are attenuated when there is no motivation to speculate. Indeed, when there is no motivation to speculate, there is no incentive to take advantage of other people's mistakes. Thus, the most fundamental reason of bubble formation is speculation. This conclusion mirrors Akiyama et al. (2017) who show that bubbles are likely due to strategic responses by more sophisticated traders in the presence of potentially bounded rational traders. Additionally, our results suggest a focus on institutional designs that manage bubble-promoting behaviors, complementing the recent literature of market mechanisms to induce common expectations (Noussair and Tucker, 2006; Noussair et al., 2016; Deck et al., 2020; Guler, et al., 2021).

Importantly, this is an experimental study that directly lends support to theoretical work arguing that the speculative intention of smart investors is critically important for the formation of bubbles. De Long et al. (1990a) argue that sophisticated traders attempt to exploit the less sophisticated traders' actions for greater profits.[2] For instance, the uncertainty about the behavior of irrational noise traders makes it worthwhile for rational traders to ride the bubble. It may even pay for rational traders to push up prices initially to stimulate interest for trend-following noise traders to buy in the next period (De Long

[1] The results in Janssen et al. (2019) also points in the same direction, but they still conclude, as in LNP, that speculation is *not* necessary to cause departures from fundamental values. Contrary to their conclusion, our result shows that when speculation motives are completely removed, bubbles are effectively attenuated.

[2] It has also been shown in experimental markets that sophisticated traders exploit the less sophisticated and achieve greater profits in bubbly markets (e.g., Corgnet et al., 2014; Noussair et al., 2016).

et al., 1990b). Abreu and Brunnermeier (2003) offer an alternative argument for why rational traders ride a bubble instead of attacking it in the presence of boundedly rational traders. In their model, rational traders sequentially are made aware of the fact that "prices are too high", but it is never common knowledge that a bubble exists, making the market correction more difficult. Less sophisticated traders do not realize that the fundamental value does not keep up with the growth in stock price. It is, therefore, reasonable for smart traders to ride the bubble for some time before it bursts, even when they are well aware of the bubble. The model has been experimentally tested and supported by Brunnermeier and Morgan (2010).

The paper is organized as follows. Section 2 presents the experimental design and procedures. The results are reported in section 3. Section 4 probes the underlying mechanism. We then conclude in section 5.

2. Experimental Design and Procedures

In our experiment, subjects participate in an asset market with the opportunity to trade an asset called X. Each market consists of eight subjects.[3] The market is organized as in Smith et al. (1988), using the double auction rules such that all traders are free to place bids and asks at desired prices and can accept other traders' existing offers. The trading platform is computerized using the z-Tree software (Fischbacher, 2007). Each trader receives an endowment of experimental currency, called francs, together with certain units of the asset. The asset has a finite life of 15 periods. Cash balances and inventories of the asset can be carried over from one trading period to the next.

At the end of each period, each unit of the asset *X* pays a random and independently drawn dividend of either 0, 8, 24 or 60 francs with an equal chance. The resulting dividend is the same for all participants. Thus, the expected dividend paid on each unit of *X* is 24 francs per period and 360 francs over the course of a session. As dividends are the only source of value of *X*, the fundamental value is derived from holding a unit of *X* from the current period until the end of the experiment and collecting the stream of

[3] There were two sessions with six and seven traders respectively due to no shows.

expected dividend payments. It is also useful to define the maximum justifiable price of the asset as the maximum possible dividend value multiplied by remaining number of periods in the market. Dividend earnings are saved in a separate account, and thus do not impact the cash to asset ratio in the market. At the end of the experiment, the accumulated cash balance in francs (including those in the dividends account) were converted to NZD at a predetermined exchange rate that was communicated in advance to our subjects.

The Baseline treatment consists of a single market that follows the standard SSW design as described above. Each trader is endowed with 10,000 francs and 10 units of the asset. The data for the baseline treatment wase taken from Tucker and Xu (2024).

Table 1. Treatment Summary

Treatment	Cash	Assets	Dividend	Periods	C/A ratio	# of Obs
Baseline	10,000	10	0,8,28,60	15	2.78	5
NoSpec	10,000/buyer	10/seller	0,8,28,60	15	2.78	9
TMkt/NS	10,000/buyer	10/seller	0,8,28,60	15 (18)	2.78	9
TAX	10,000	10	0,8,28,60	15	2.78	9

The TAX treatment maintains all market and design features of the Baseline except for the introduction of a 100% capital gains tax that is levied on resale profits to eliminate speculative incentives, see Table 1. The tax applies to resale gains both within and across periods, and thus the speculative strategy to buy assets at “low” prices and then sell them at “high” prices is no longer profitable. Therefore, the only incentive to buy an asset is to receive the dividend payments. If traders rationally respond to the tax intervention, overpricing should be reduced, and prices should also not surpass the maximum justifiable value of the asset. If traders are risk neutral or risk averse, then there is no financial incentive to purchase at prices above fundamental value. In contrast to LNP’s design (see below), we address the incentives for speculative behavior as opposed to using an intrusive market mechanism that prohibit speculative behavior, which may introduce unexpected behavioral anomalies as discussed in Xu and Tucker (2024).

Taxes incurred due to resale profits are recorded in a separate tax account that is only settled at the end of the last trading period. Therefore, the cash to asset ratio remains intact throughout all trading periods. Thus, the cash available for purchases will not be artificially reduced by the tax during the experiment. Since the capital gains tax targets only resale earnings, the computer records all purchases made by a trader and sorts purchasing prices from low to high (e.g., $p_1 < p_2 \leq p_3 < p_4 <, ...$). If a sale occurs, regardless of the period in which it takes place, the selling price is compared against the lowest purchase price in the record (p_1 in our example). This price is provided to the subjects on their bidding screen.[4] If the selling price is less than or equal to p_1, no tax is imposed on the seller. If the selling price is greater than p_1, then the entire difference (= selling price $- p_1$) is taxed away, and the seller is notified of the tax. The lowest purchasing price then becomes p_2 and the next sale price is now compared to p_2.

The sole purpose of this design is to create an artificial market structure that eliminates speculative incentives in order to cleanly test the impact of speculative behavior on bubble formation. The design has no intent of testing effective tax rates. It should also be noted that our tax scheme is not the most aggressive one:

1. We do not tax dividend income. Therefore, a trader with the motivation to solely purchase assets to collect dividend payments is not affected by the tax mechanism.
2. The capital gains tax is only levied on resale profit, not against the fundamental value. This means that even if prices are greatly above fundamental value, as long as the resale price is not higher than the purchase price, no tax is imposed on the seller.
3. The tax is not imposed on initially endowed assets. If a trader only acts as a seller in the market, no tax would ever be imposed on her regardless of the selling price. That is, the tax does not prohibit people from trading at prices higher than the fundamental value. Hence, if the tax intervention helps to attenuate bubbles, this is not because it prohibits people from trading at "high" prices or that it eliminates all reasons to buy the asset.

[4] The text provided to subjects on their bidding screen referencing their lowest purchase price (p_1) is as follows, "Because of the constraints on resale earnings, the next unit you sell will be taxed for any price greater than [p_1]."

It is also worth emphasizing that the capital gains tax merely discourages relatively sophisticated traders from engaging in speculative trades. Traders who are prepared to buy at any price, e.g. the confused traders that do not understand the dividends process would not be affected by the tax. In other words, the capital gains tax is not able to prohibit confused traders from trading in the asset market if they exist.[5]

We compare our new 100% capital gains tax treatment (TAX) to the two main treatments in LNP that feature the "no-speculation" intervention, i.e. No Speculation (NoSpec) and Two Market No Speculation (TMkt/NS). The no-speculation treatments' data is taken from Tucker and Xu (2024). The design of those markets is as follows. The NoSpec condition consists of a single asset market with restrictions on trader roles. More specifically, the ability of traders to speculate in the asset market is removed: subjects are randomly assigned to either the role of buyers or sellers, and resale or repurchase of the asset is prohibited. Thus, there is no possibility of realizing capital gains. Therefore, the only source of value from holding the asset is its expected cumulative dividends. Sellers are of course allowed to sell assets at prices above the fundamental values if buyers are willing to pay those prices. The TMkt/NS condition has a goods market operating concurrently with an asset market that is identical to NoSpec (the goods are referred to as *Y*, in distinction to the dividend paying asset *X*).[6] The goods market *Y* is open for three periods before the opening of the asset market. More specifically, the market for asset *X* opens in period 4 and runs concurrently with the goods market *Y* for periods 4 – 18.

In TMkt/NS, the commodity *Y* has a life of one period, and it is treated as a good or service as in Smith (1962). *Y* does not pay dividends in any period, but it has redemption values for agents who consume it at the end of each period. Buyers are endowed with

---

[5] A capital gains tax may have a behavioral consequence as certainly some people may have an aversion to taxes generally, and thus the existence of a tax alone may have a dampening effect on prices. However, there is no support of this in the existing literature. King et al. (1993) introduce a Tobin tax with mixed effects and Lei et al. (2002) implement a 50% capital gains tax with no effects. Therefore, aversion to a tax is not likely to be the driving factor behind the dissipation of bubbles observed in our TAX treatment.

[6] Note, the market for good Y does not use "cash" to facilitate transactions and thus no impact on the C/A ratio. More specifically, just as in LNP, the goods market is conducted similarly to Smith (1962) in which earnings from transactions are simply calculated as the difference between the transaction price and induced values to buyers/sellers.

diminishing personal values for consuming each unit of *Y* (creating a demand schedule). Sellers are assigned increasing private costs for each unit of *Y* they sell (creating a supply schedule). The market for *Y* repeats itself every period, with a market clearing price and quantity found from intersection of traders' submitted bid and ask schedules. Inventories of *Y* are reinitialized after each period and goods cannot be carried over from one period to the next. The goods market *Y* opens three periods prior to the asset market for the traders to be familiar with it, which is why the TMkt/NS treatment has three periods more than the other treatments. Traders can freely access both markets trading *X* and *Y* when the market for *X* opens after the third period.

As can be seen in Table 1, the LNP no-speculation conditions implemented extreme asymmetric initial endowments. In the NoSpec treatment, buyers were endowed with an initial cash balance of 10,000 francs and no assets, and sellers were endowed with 10 units of *X* but no cash. In the TMkt/NS treatment, buyers were endowed with 10,000 francs, but had no endowment of either *X* or *Y*. Sellers in TMkt/NS were endowed with 10 units of *X* and 10 units of *Y*, and zero cash. In the TAX treatment, we keep endowments the same as in the Baseline condition.

A total of 253 subjects participated in our experiment. Each treatment comprised of nine markets (except for the standard SSW baseline, which has five markets) for a total of 32 markets conducted (see Table1), which were all conducted in the Waikato Experimental Economics Laboratory in Hamilton, New Zealand. Trade took place across a series of three-minute periods. The trader composition of the market, period length and number of periods were all made common knowledge to subjects. Each session lasted approximately 100 minutes and subjects earned on average 36 NZD approximately. The experimenter read aloud the instructions for the market experiment, followed by a quiz and private Q&A. Once everyone successfully answered the comprehension questions in the quiz, a practice period was conducted. Profits or losses made in this period did not count toward the final earnings, and both the cash balance and asset inventories were reinitialized before the start of the first trading period.

3. Results

To quantify the magnitude of mispricing and facilitate comparisons, we employ three commonly used bubble measures in the experimental finance literature, Relative Absolute Deviation (RAD), Relative Deviation (RD) and Turnover (Van Boening et al., 1993; Stöckl et al., 2010). RAD is defined as RAD = $\{\sum_t |P_t - FV_t| / (\sum_t (FV_t) / T)\} / T$, where t refers to a specific period and T is the total number of periods in a market session. FV_t is the fundamental value in period t and the term P_t denotes the average price in period t. RAD measures how closely prices track fundamental value. The measure RD is defined as $RD = \{\sum_t (P_t - FV_t) / (\sum_t (FV_t) / T)\} / T$, which indicates whether prices are on average above (RD > 0) or below (RD < 0) fundamental value. We also report Geometric Absolute Deviation (GAD) and Geometric Deviation (GD) introduced by Powell (2016). The interpretation of GAD and GD is the same as RAD and RD but these measures satisfy numeraire independence. GAD is defined as $GAD = \exp\left\{\frac{1}{T}\sum_t \left|\ln\left(\frac{P_t}{FV_t}\right)\right|\right\} - 1$. GD is calculated as $GD = \Pi_t \left(\frac{P_t}{FV_t}\right)^{1/T} - 1$. Turnover is the total number of transactions in a market session, normalized by the total units of asset available in the market. It is defined as $(\sum_t q_t)/TSU$, where q_t is the quantity of units of the asset exchanged in period *t* and *TSU* denotes the total stock of units. In words, it is the total number of transactions over the life of the asset, normalized by the total stock of units in the market. A high Turnover indicates a high volume of trade, which is typically associated with mispricing in experimental markets of the type studied here.

Figure 1 depicts the time series of average prices for all treatments.[7] We added two reference lines for the maximum justifiable value of the asset (long dashed line) and the fundamental value (dash-dotted line). Prices in Baseline are consistently above fundamental values throughout the entire lifespan of the asset, and in the last third of the market above the maximally justifiable prices, which is a typical price path frequently observed in the literature (see Palan, 2013). Importantly, prices in both NoSpec and

[7] Plots of individual sessions are reported in the online appendix.

TMkt/NS lie consistently above prices found in the Baseline except in the second to last period and these prices are for the most part greater than the maximum justifiable prices. This is despite Baseline design features already being highly bubble prone. Lastly, the time series of the TAX treatment tracks the fundamental value closely throughout the entire life of the asset. Importantly, there is no incidence where the treatment average prices rise above the *maximum* justifiable prices.

Figure 1. Time series of treatment average prices

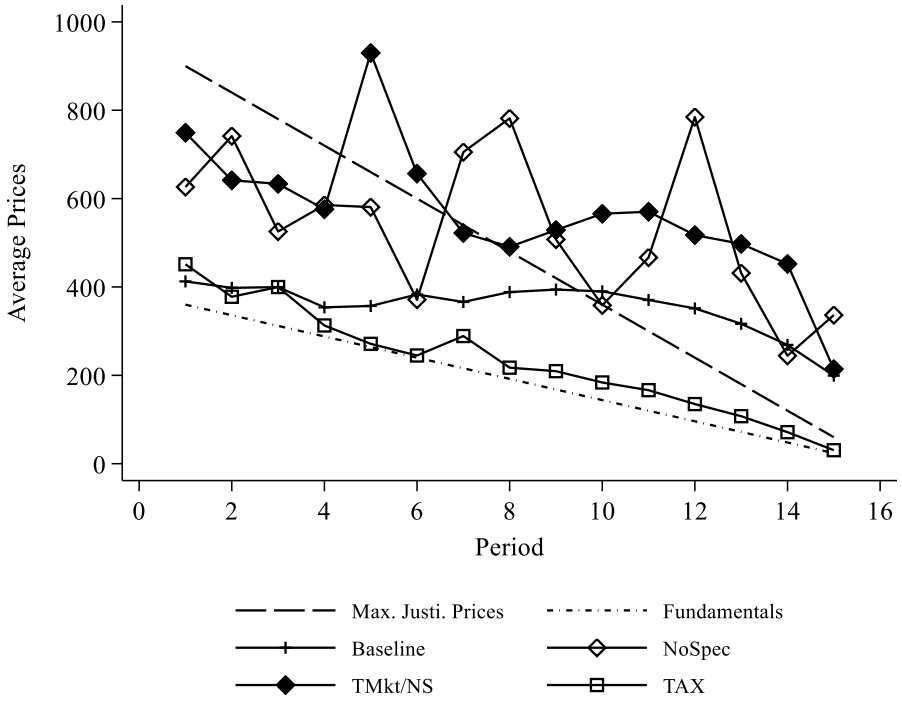

Table 2. Treatment median bubble measures

	TAX	Baseline	NoSpec	TMkt/NS
RAD	0.24	0.80**	0.96***	2.10***
RD	0.23	0.70**	0.96***	2.10***
GAD	0.32	1.09***	1.47***	1.78***
GD	0.17	0.95***	1.32***	1.72***
Turnover[8]	2.23	4.12**	0.98 [na]	0.73 [na]

Notes: ***, **, * indicate significant difference in bubble measures between the LNP replication treatments and the TAX treatment at the 1%, 5%, and 10% levels respectively, Mann-Whitney U exact test

Table 2 presents the bubble measures for all four treatments. First, it should be noted that inclusion of a no-speculation condition induces larger bubbles as illustrated by the greater bubbles measures of NoSpec and TMkt/NS as compared to the Baseline condition. Both RAD and RD in the NoSpec treatments are significantly greater than the respective measures in the Baseline treatment at 5% significance level. Second, price deviations are substantially and significantly smaller in the TAX condition than in the Baseline condition and the no-speculation treatments ($p<0.05$).

One may argue that although there is no pattern of bubble and crash in the TAX treatment as represented in Figure 1, prices appear to still be above the fundamental value on average. However, the RD bubble measure for TAX is quite small (0.25) and not significantly different than 0 at any conventional significance level (Wilcoxon Signed-rank exact test). Therefore, there is no significant deviation in price from fundamental value.

[8] It is not informative to test for differences in Turnover between treatments involving LNP's no-speculation condition because, by design, the LNP no-speculation paradigm has a maximum turnover of 1. A superscript [na] is used to indicate the test is not applicable.

We conclude that when the incentives for speculation are eliminated, bubbles do not occur even in the presence of confusion and/or lack of common expectations. This provides direct evidence that bubbles are predominantly speculative in nature.

4. Probing the underlying mechanism

4.1 Measuring cognitive ability

At the start of each session, we measured subjects' cognitive ability using the Raven's Advanced Progressive Matrices (APM, Raven et al., 1998). The APM test can be considered as a test on fluid intelligence that predicts the ability to solve problems in a novel environment (Mackintosh, 2011), such as a fast-changing asset market. We hypothesize that those who score high on the APM test would also perform well in the market. We employ a short form of the APM test, containing 12 selected items from the original set (Bors and Stokes, 1998). The subjects had 10 minutes to complete the task. We measure the number of questions they answer correctly and loosely refer to this as the IQ score hereafter. The APM test is incentivized such that (1) a higher score yields a higher chance to win a prize of $10, and (2) subjects could never identify their number of correct answers exactly (see Kocher et al, 2019). Also, they are not informed of their earnings for this task until the end of the market experiment.

4.2 Bidding strategy and cognitive ability

Since there are no gains from speculating in the presence of the tax, we argue that sophisticated traders will bid more conservatively than less sophisticated traders in the TAX treatment. However, this relationship may not be present in the no-speculation treatments due to behavioral issues induced by the LNP design that may even affect the bidding behavior of those who clearly understand the market features, as argued by Tucker and Xu (2024). We construct two variables measuring bidding behavior using buyer proposed bids in the market. These proposed bids are not necessarily accepted by other traders if they are not high enough. We are interested in both the difference between the proposed bids and the fundamental values of the asset and the proposed bids relative to maximum possible value of the asset, namely ($Bids - FVs$) and ($Bids - MaxValues$)

respectively. If traders are risk-seeking, they might be willing to pay more than the fundamental values ($Bids - FVs$). This measure may thus be influenced by differences in risk attitude for people of different IQ (Kocher et al., 2019). However, since capital gains are made impossible, there is no valid financial reason to pay more than the sum of the maximum possible dividends ($Bids - MaxValues$). Thus, it is more unlikely for more sophisticated traders to bid above maximum value, though they may still bid above the fundamental value in the hope of lucky dividends draw. We test if sophisticated traders post lower bids because there are no incentives or behavioral motives to do so in the TAX treatment. Traders are considered to be relatively (un)sophisticated if they scored higher than (25%) 75% of the traders in their session on the IQ test.

Table 3 reports regression results where the differences between buyer-proposed bids and fundamentals (maximally justifiable values, respectively) are regressed on the treatment dummy, the bidder's sophistication dummy, period in which the bids took place, and the interaction between treatment dummy and the indicator for sophisticated trader. The treatment dummy D_TAX=1 if a bid occurs in the TAX condition, and it is 0 otherwise. We use data from the two no-speculation treatments and the TAX treatment.[9]

The first regression examines buyer proposed bids relative to the *fundamentals*. It shows that in LNP replication conditions, more sophisticated traders do not bid differently from the less sophisticated. Bids in the TAX treatment are lower on average but insignificant. The interaction term is negative and significant, indicating that sophisticated traders in the TAX treatment bid lower than the less sophisticated traders. Such an effect does not appear in LNP's no speculation treatments.

The second regression considers buyer-proposed bids relative to the *maximally* justifiable values of the asset. The estimated coefficients are largely the same as the previous regression. Bids relative to the maximally justifiable value in the TAX treatment are lower on average though the effect is insignificant. The interaction term is negative and substantially larger than the main effect of sophistication, indicating that

[9] Results are qualitatively the same if we also include the Baseline treatment or using a Probit regression to test the likelihood of proposing a high bid, defined as $Bids - FVs$ or $Bids - MaxValues$ >0.

sophisticated traders in TAX bid substantially lower than the less sophisticated traders. That is, sophisticated bidders show strongly different behavior in TAX versus the no-speculation treatments. These results show that the TAX treatment effectively discourages those who are most likely to understand the speculative strategy, which is the key channel to attenuate bubbles. In contrast, even the smarter traders substantially overbid in the no-speculation condition.

Table 3. Regression analysis of traders' sophistication and bidding intensity

	Bids relative to FVs	Bids relative to max. values
Sophisticated = 1	9.00 (42.60)	9.00 (42.60)
D_TAX = 1	-167.39 (178.20)	-167.39 (178.00)
Sophisticated & D_TAX = 1	-102.15 (49.71)**	-102.15 (26.38)**
Period	7.64 (3.07)**	43.64 (3.09)***
Constant	158.58 (178.64)	-417.42 (178.64)**
# obs	953	953
# clusters	100	135
R^2	0.40	0.57

Notes: Results show coefficients from random effect panel regressions with session fixed effects. Robust standard errors, clustering at the subject level, are reported in the parentheses. *, ** and *** indicate significance at the 10%, 5% and 1 % significance level, respectively.

4.3 Overpricing in the absence of speculative incentives

Although the TAX treatment significantly mitigates overpricing, there are still a few sessions that exhibit mild overpricing, especially at the beginning and the end of the market (see Figure A4). This is not surprising given that we do not tax the sale of the endowed assets. This means that if some traders are willing to purchase the asset at elevated prices (say higher than the fundamentals or even the maximum justified value), it is profitable to fulfill that order. Out of the nine sessions with the capital gains tax, four

exhibit larger overpricing than the rest and we investigate whether cognitive ability can explain the trading behavior in the presence of capital gains tax.

As argued above, since capital gains are impossible, there is no valid financial reason to purchase the asset at prices higher than the sum of the maximum possible dividends. Thus, we expect the less sophisticated traders to make more such mistakes and drive the prices up. We calculate for each trader the net number of "mistakes" she makes as the difference between the total number of shares she purchased and sold at the prices higher than the maximum justified values. If the difference is positive, we consider her to be prone to make decision errors. We find that people who are prone to make decision errors scored lower in the Raven's tests (5 vs. 7, $p<0.05$, Mann-Whitney U test).

Moreover, we find that the total number of shares purchased at prices higher than the maximum justified values is significantly and negatively related to individuals' cognitive ability in these four sessions with higher mispricing (N=32, Spearman's correlation coefficient is -0.43, $p<0.05$). Less sophisticated traders are also more likely to purchase at prices higher than the fundamentals (N=32, Spearman's correlation coefficient is -0.32, $p<0.1$).

Our evidence suggests that decision errors are responsible for some of the mispricing seen in the TAX treatment. Individuals with lower cognitive ability are more likely to be purchase shares at prices higher than the fundamentals or even the maximum justified prices.

5. Conclusion

Economic bubbles are a major destabilizing factor for the economy and often lead to severe consequences (see e.g., Brunnermeier and Schnabel 2016 for a comprehensive review). Economists have long been fascinated by the causes of bubbles. Research in finance in the past decades has shown significant progress. For instance, Brunnermeier and Oehmke (2013) offer a broad survey on various reasons for bubble formation, such as rational bubbles, limits of arbitrage and heterogeneous information, etc. In the experimental finance literature, the conventional wisdom has suggested that bubbles are often caused by speculative activities, which result from the lack of common knowledge

of rationality (Smith et al., 1988; Plott, 1991). This is analogous to heterogeneity in beliefs in the field due to uncertainty in the intrinsic value of the asset. This interpretation has been challenged by Lei et al.'s (2001) results, which suggest that speculation is not a key ingredient to bubbles. Tucker and Xu (2023) argue that these results may be attributed to design features in LNP that replaced speculative motives by other motives to buy assets at elevated prices. To overcome these issues, we introduce a condition with a 100% capital gains tax on traders, meaning that all resale earnings will be completely taxed away. Thus, any financial incentive to engage in speculative behavior is removed while all other aspects of the basic SSW asset market are retained. We find that prices track fundamental value very well, suggesting that speculation is in fact a critical factor for bubble formation. Analyses of the bidding behavior of traders shows that the TAX treatment discourages relatively more sophisticated traders to engage in speculative activities, while they still make high bids in the LNP no-speculation paradigm.

We contribute to the literature by reconciling a long-standing puzzle that the prevailing results in the experimental literature are at odds to the finance literature that the former suggests that speculation is not a necessary ingredient for bubbles. Rather, mistakes and confusions are the main reasons behind bubbles. This paper has shown that even if we do not extensively train these inexperienced traders, and thus confusion, mistakes and the lack of common knowledge of rationality may well be present, bubbles are attenuated when there is no motivation to speculate. Indeed, when there is no motivation to speculate, there is no incentives to take advantage of other people's mistakes. Thus, the most fundamental reason of bubble formation is speculation.

References

Abreu, D., & Brunnermeier, M. K. (2003). Bubbles and Crashes. *Econometrica*, *71*(1), 173–204.

Akiyama, E., Hanaki, N., & Ishikawa, R. (2017). It is Not Just Confusion! Strategic Uncertainty in An Experimental Asset Market. *Economic Journal*, *127*(605), F563–F580.

Bors, D. A., & Stokes, T. L. (1998). Raven's Advanced Progressive Matrices: Norms for first-year university students and the development of a short form. *Educational and Psychological Measurement*, *58*(3), 382-398.

Bosch-Rosa, C., Meissner, T., & Bosch-Domènech, A. (2018). Cognitive bubbles. *Experimental Economics*, *21*(1), 132–153.

Brunnermeier, M. K., & Morgan, J. (2010). Clock games: Theory and experiments. *Games and Economic Behavior*, *68*, 532–550.

Brunnermeier, M. K., & Oehmke, M. (2013). Bubbles, Financial Crises, and Systemic Risk. In *Handbook of the Economics of Finance*. Amsterdam: Elsevier.

Brunnermeier, M. K., & Schnabel, I. (2016). Bubbles and Central Banks: Historical Perspectives. In *Central Banks at a Crossroads: What Can We Learn from History?* Cambridge, UK: Cambridge University Press.

Cheung, S. L., Hedegaard, M., & Palan, S. (2014). To see is to believe: Common expectations in experimental asset markets. *European Economic Review*, *66*, 84–96.

Corgnet, B., Hernán-González, R., Kujal, P., & Porter, D. (2014). The Effect of Earned Versus House Money on Price Bubble Formation in Experimental Asset Markets. *Review of Finance*, *19*(4), 1455–1488.

Deck, C., Servatka, M., & Tucker, S. (2020) Designing Call Auction Institutions to Eliminate Price Bubbles: Is English Dutch the Best? *American Economic Review: Insights, 2*(2), 225-36.

De Long, J., Shleifer, A., Summers, L., & Waldmann, R. (1990a). Noise Trader Risk in Financial Markets. *Journal of Political Economy*, *98*(4), 703-738.

De Long, J. B., Shleifer, A., Summers, L. H., & Waldmann, R. J. (1990b). Positive Feedback Investment Strategies and Destabilizing Rational Speculation. *Journal of Finance*, *45*(2), 379–395.

Fischbacher, U. (2007). z-Tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics*, *10*(2), 171–178.

Guler, B., Lugovskyy, V., Puzzello, D. & Tucker, S. (2021). Trading Institutions in Experimental Asset Markets: Theory and Evidence. Working Paper, SSRN Electronic Journal.

Huber, J., & Kirchler, M. (2012). The impact of instructions and procedure on reducing confusion and bubbles in experimental asset markets. *Experimental Economics*, *15*(1), 89–105.

Janssen, D. J., Füllbrunn, S., & Weitzel, U. (2019). Individual speculative behavior and overpricing in experimental asset markets. *Experimental Economics, 22*(3), 653-675.

King, R. R., Smith, V. L., Williams, A. W., & Van Boening, M. (1993). The robustness of bubbles and crashes in experimental stock markets. *Nonlinear dynamics and evolutionary economics*, 183-200.

Kirchler, M., Huber, J., & Stöckl, T. (2012). Thar She Bursts: Reducing Confusion Reduces Bubbles. *American Economic Review*, *102*(2), 865–883.

Kocher, M. G., Schindler, D., Trautmann, S. T., & Xu, Y. (2019). Risk, time pressure, and selection effects. *Experimental Economics*, *22*(1), 216–246.

Lei, V., Noussair, C., & Plott, C. (2001). Nonspeculative Bubbles in Experimental Asset Markets: Lack of Common Knowledge of Rationality vs. Actual Irrationality. *Econometrica, 69*(4), 831-859.

Lei, V., Noussair, C., & Plott, C. (2002). Asset Bubbles and Rationality: Additional Evidence from Capital Gains Tax Experiments. California Institute of Technology Working Paper.

Lei, V., & Vesely, F. (2009). Market Efficiency: Evidence from a No-Bubble Asset Market Experiment. *Pacific Economic Review*, *14*(2), 246–258.

Mackintosh, N. J. (2011). History of theories and measurement of intelligence. *The Cambridge handbook of intelligence*, R. J. Sternberg and S. B. Kaufman, eds., 3–19. Cambridge, UK: Cambridge University Press.

Noussair, C. N., & Tucker, S. (2013). Experimental Research on Asset Pricing. *Journal of Economic Surveys*, *27*(3), 554–569.

Noussair, C., & Tucker, S. (2006). Futures markets and bubble formation in experimental asset markets. *Pacific Economic Review*, *11*(2), 167-184.

Noussair, C. N., Tucker, S., & Xu, Y. (2016). Futures markets, cognitive ability, and mispricing in experimental asset markets. *Journal of Economic Behavior & Organization*, *130*, 166-179

Oechssler, J. (2010). Searching beyond the lamppost: Let's focus on economically relevant questions. *Journal of Economic Behavior & Organization*, *73*(1), 65-67,

Palan, S. (2013). A Review of Bubbles and Crashes in Experimental Asset Markets. *Journal of Economic Surveys*, *27*(3), 570–588.

Plott, C. (1991). Will Economics Become an Experimental Science? *Southern Economic Journal*, *57*(4), 901-919.

Plott, C., & Smith, V. (2008). *Handbook of Experimental Economics Results*. (Vol. 1). Elsevier.

Powell, O. (2016). Numeraire Independence and the Measurement of Mispricing in Experimental Asset Markets. *Journal of Behavioral and Experimental Finance*, *9*, 56-62.

Raven, J., Raven, J. C., & Court, J. H. (1998). *Manual for Raven's Progressive Matrices and Vocabulary Scales*. Section 4: The Advanced Progressive Matrices. San Antonio, TX: Harcourt Assessment.

Shiller, R. J. (2015). Irrational exuberance. In *Irrational exuberance*. Princeton university press.

Smith, V. (1962). An Experimental Study of Competitive Market Behavior. *The Journal of Political Economy*, *70*(2), 111–137.

Smith, V. L., Suchanek, G. L., & Williams, A. W. (1988). Bubbles, Crashes, and Endogenous Expectations in Experimental Spot Asset Markets. *Econometrica*, *56*(5), 1119–1151.

Stöckl, T., Huber, J., & Kirchler, M. (2010). Bubble measures in experimental asset markets. *Experimental Economics*, *13*(3), 284–298.

Tucker, S. & Xu, Y. (2024). Nonspeculative Bubbles Revisited. Working Papers in Economics 24/01, University of Waikato.

Van Boening, M.V., Williams, A.W., & LaMaster, S. (1993). Price bubbles and crashes in experimental call markets? *Economics Letters*, *41*(2), 179–185.

Online Appendix: Time series of transaction prices by treatment

Figure A1. Time series of transaction prices: Baseline

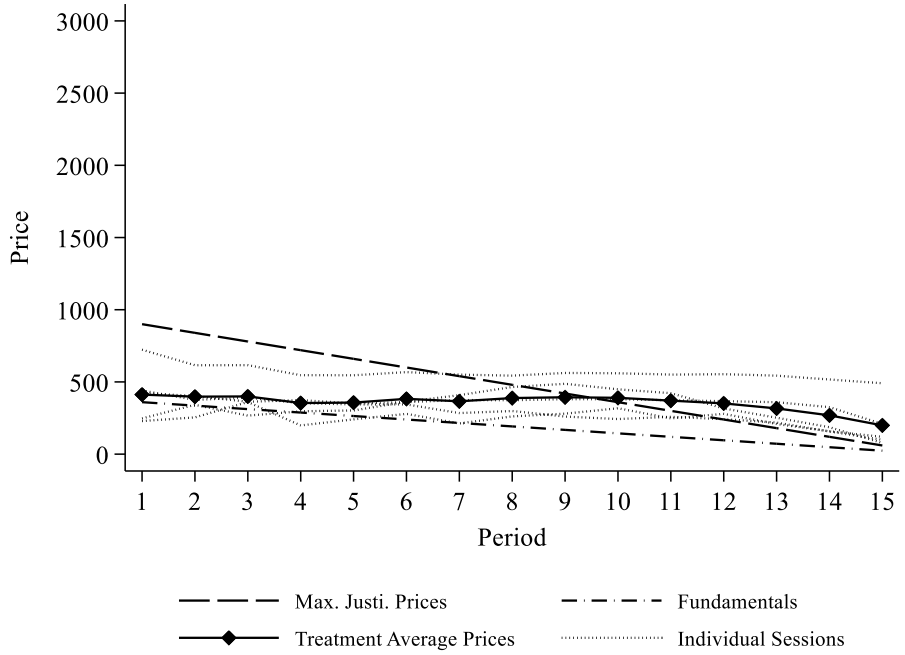

Figure A2. Time series of transaction prices: NoSpec

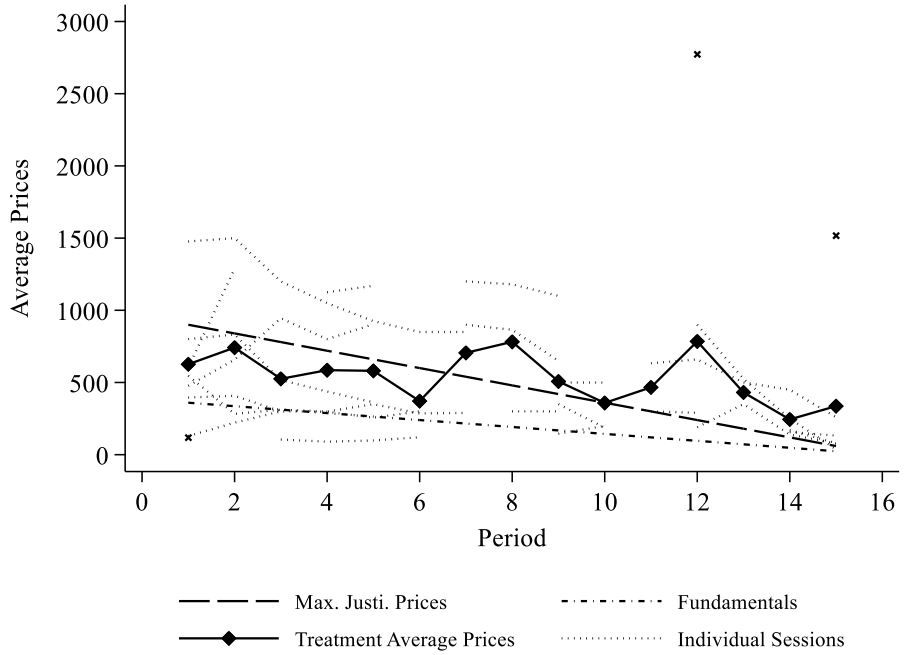

Figure A3. Time series of transaction prices: TMkt/NS

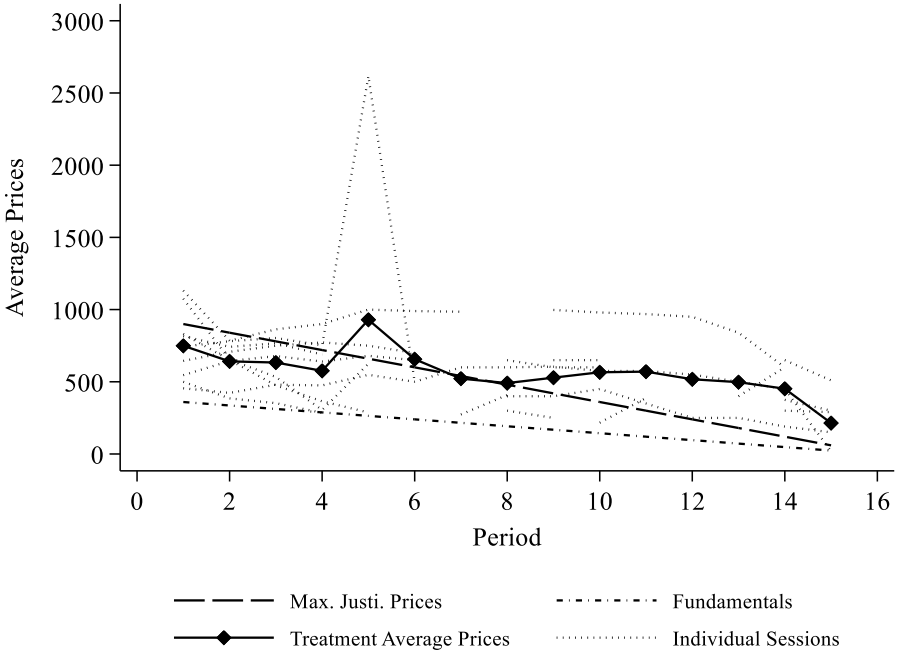

Figure A4. Time series of transaction prices: TAX