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The Bubble Game: A classroom experiment

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Abstract

We propose a simple classroom experiment on speculative bubbles: the Bubble Game. This game is useful to discuss about market efficiency and trading strategies in a financial economics course, and about behavioral aspects in a game theory course, at all levels. The Bubble Game can be played with any number of students, as long as this number is strictly greater than one. Students sequentially trade an asset which is publicly known to have a fundamental value of zero. If there is no cap on asset prices, speculative bubbles can arise at the Nash equilibrium because no trader is ever sure to be last in the market sequence. Otherwise, the Nash equilibrium involves no trade. Bubbles usually occur with or without a cap on prices. Traders who are less likely to be last and have less steps of reasoning to perform to reach equilibrium are in general more likely to speculate.

Keywords: financial markets, speculation, bubbles

1 Introduction

Financial markets are often viewed as going through speculative bubbles and crashes. Shiller (2000), for example, emphasizes irrational exuberance as a driver of booms and bursts. History, with the South Sea bubble or the Mississippi bubble, and more recent episodes such as the dot-com bubble suggest that these events are not rare.

However, to the extent that fundamental values are not observed ex-ante in the field, it is very difficult to empirically identify speculative bubbles. Any price sequence can be rationalized ex-post by changes in beliefs or risk aversion. To overcome this difficulty and study bubble phenomena, economists have relied on the experimental methodology: in an experiment, fundamental values are controlled by the experimenter and can thus be compared to asset prices.

We propose a classroom game on speculative bubbles, the Bubble Game, that is derived from Moinas and Pouget (2013). This game complements the ones proposed by Ball and Holt (1998) and Bostian and Holt (2009) based on Smith, Suchanek, and Williams (1988) (see also Holt (2007)). The Bubble Game is simple enough to be have predictions for individual speculative behavior. Moreover, it enables one to control for the number of trading opportunities, thus easing the interpretation of experimental data. A simple (behavioral) game theory interpretation of the results is offered but is not necessary to interpret the results.

The Bubble Game can be fruitfully used for all class levels in the context of financial economics courses on investments, corporate finance, behavioral finance, or trading. It indeed enables to discuss topics such as market efficiency, speculative bubbles, and investment strategies.

The Bubble Game can also be used in game theory courses. It proposes an interesting setup in which one can solve for a Nash equilibrium in which all players rationally speculate (as is shown below, this is the case when there is no cap on transaction prices). This paradoxical result is a reminiscence of the envelop paradox discussed by Nalebuff (1989) and, especially, Geanakoplos (1992). The Bubble Game can also be useful to apply various concepts of behavioral game theory (see, for example, Camerer (2003)) in a simple yet relevant economic context. When there is a cap on transaction prices, behavioral game theory fits the data better than traditional game theory because it incorporates investors' bounded rationality.

The Bubble Game features a valueless financial asset that can be traded in a sequential market. Traders are ex-ante equally likely to be in each position in the market sequence. Traders have the choice between buying or not buying at the proposed price. If a trader declines the offer, the game ends and the current owner is stuck with the asset. If a trader buys and is able to resell, he makes a profit. The game can be played with any number of students. We focus here on the case illustrated in Figure 1 in which there are three traders in each market (there can be several markets in the same classroom).

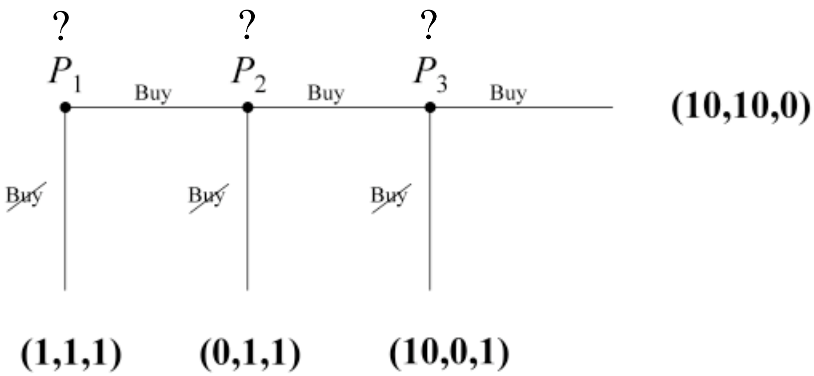


Figure 1: Timing of the Bubble Game.
The Bubble Game features a sequential market. Question marks emphasize the fact that traders are ex-ante equally likely to be first, second or third, and to be offered to buy at prices P_1, P_2, or P_3, respectively. This figure displays traders' payoff only. In case of successful speculation, the payoff is 10 because prices are set as powers of 10 and traders invest one unit of capital with limited liability. Outside financiers' payoffs are omitted.

Prices are exogenous. The first trader is offered a price 10^n, where n is random and follows a geometric distribution: the first price is 1 with probability $\frac{1}{2}$, 10 with probability $\frac{1}{4}$, 100 with probability $\frac{1}{8}$, etc. If a trader decides to buy, he proposes to resell at a price that is 10 times higher than the price at which he bought.

Students are endowed with 1 unit of the Experimental Currency Unit (ECU). Additional capital may be required so as to buy the asset at price $P > 1$. This additional capital (that is, $P - 1$) is provided by an outside financier. The instructor plays the role of the outside financier for all players. Payoffs are divided between the trader and the financier in proportion to the capital initially invested: a fraction $\frac{1}{P}$ for the trader and a fraction $\frac{P-1}{P}$ for the financier.

Consider a trader who decides to buy the asset at price P. When he is unable to resell, his final wealth is 0, which corresponds to the fundamental value of the asset. The outside financier also ends up with 0. When the trader is able to resell the asset, he gets $\frac{1}{P}$ percent of the proceed, that is, $10 \times P$, and thus ends up with a final wealth of 10. The outside financier ends up with $10 \times P - 10$.

When there is no cap on the first price, no trader is ever sure to be last in the market sequence despite prices revealing some information regarding traders' position.[1] Bubbles can arise at the Nash equilibrium.

In contrast, when there is a price cap, only irrational bubbles can form: upon receiving the highest potential price, a trader realizes that he is last in the market sequence and, if he is rational, he refuses to buy. Even if he is not sure to be last in the market sequence, the previous trader, if he is rational, also refuses to

[1]In a market with three students, Bayes' rule indicates that the probability to be last is zero conditional on observing a price $P = 1$ or $P = 10$, and $\frac{4}{7}$ conditional on $P \geq 100$.

buy because he anticipates that the next trader will know he is last and refuse to trade. This backward induction argument rules out the existence of bubbles when there is a price cap if all traders are rational and rationality is common knowledge.

2 Procedure

Pre-printed decision sheets and envelops can be used to collect the students' decisions quickly and privately. The game, including discussion of the results, can fit in a one hour and fifteen minute class session but it can also occupy a two hours and a half class session if one extends the discussion to include examples from actual markets and behavioral issues (see below in the discussion section for suggestions).

The authors have run the Bubble Game several times in their classroom and have often used some kind of incentives to spice up the game. For example, at the London Business School, students in the MBA program received one small box of chocolate per experimental currency unit (a student could thus end up with 0, 1, or 10 boxes of chocolate). At Princeton University, two students among the undergraduate and graduate students who participated in the classroom game were randomly drawn to receive an amazon.com $10-coupon per experimental currency unit (these students could thus end up with $0, $10 or $100 worth of coupons).

In general, the authors implement, in their class, the Bubble Game with a cap on the first price at 10,000. The Nash equilibrium predicts that there is no bubble but, in general, a lot of speculative trades are observed. Also, in this case, it is very unlikely that any student actually receives the maximum price of 1,000,000 and thus students who speculated can always claim (if they did not receive the maximum price) that they were betting on the next trader in the market sequence buying the asset. As we show below, such behavior can be quite rational given the data that we have already collected.

The advance preparation consists in making copies of the instructions provided in the Appendix, and preparing the decision sheets (potentially by using the simple excel spreadsheet we provide as supplemental material).

The instructions - The instructions fit on the front and back sides of a single sheet of paper. A questionnaire can also be distributed in class after reading the instructions. The questionnaire enables the instructor to check that the rules of the game are well understood, and to possibly re-explain them on a face-to-face basis.

The decision sheets - The instructor randomly assigns students to a three-person group (a market) and to a position in the sequence of offers in this market (that is, first, second or third with probability $\frac{1}{3}$). The instructor also randomly draws the first price in each market.

The first price is 10^n, where n is random and follows a geometric distribution: $P(n = i) = \frac{1}{2}^{i+1}$, that is, the first price is 1 with probability $\frac{1}{2}$, 10 with probability $\frac{1}{4}$, 100 with probability $\frac{1}{8}$, etc. If there is a cap K on the first price, then $P(n = K) = 1 - \sum_{i=0}^{K-1} \frac{1}{2}^{i+1}$. The excel spreadsheet provided as supplemental material enables to easily draw the first price and the market positions, and thus to determine the price proposed to all participants.

For each market, the instructor writes down on the decision sheet the price that is or would be proposed to each of the three students. The instructor then slips each decision sheet in an envelop. In the classroom, the instructor shuffles and distributes the envelops. If the number of students is not a multiple of three, the remaining one or two students can team up with some classmates. Students are encouraged to remember their ID number to retrieve their profits when they are displayed by the instructor.

The game - The Bubble Game is designed as a one-shot simultaneous game. Decision sheets are filled by students simultaneously. This prevents students from inferring information on their position based on sequential participation. Students therefore take their decisions *conditional* on a price being proposed. Their decision however only matters for computing their profits if they are first, or if all the previous students have decided to buy.

The outcome - The instructor collects the decision sheets and record the decisions of each student by ID number in the excel spreadsheet. Profits and graphs will be automatically computed and drawn. This enables the instructor to open the floor for discussion right after the experiment.

3 Discussion

The typical results one obtains when organizing the Bubble Game in the classroom are represented in Figure 2. First, bubbles in general arise whether or not there is a cap on prices. Bubbles thus form even if they would be ruled out by backward induction.

These typical results suggest that some people are making mistakes, in particular some participants who buy at the maximum potential price. Trading mistakes have been documented in actual financial markets by various papers. Two cases in which they are pretty clear are offered by Rashes (2001) regarding stock ticker confusion between MCI and MCIC, and by Xiong and Yu (2011) regarding Chinese warrants trades at prices higher than the maximum potential payoff.

Second, the propensity for a subject to enter a bubble in general increases with the distance between the offered price and the maximum price. We refer to this phenomenon as a snowball effect, and show in Moinas and Pouget (2013) that it is related to a higher probability not to be last and to a higher number of steps of iterated reasoning.

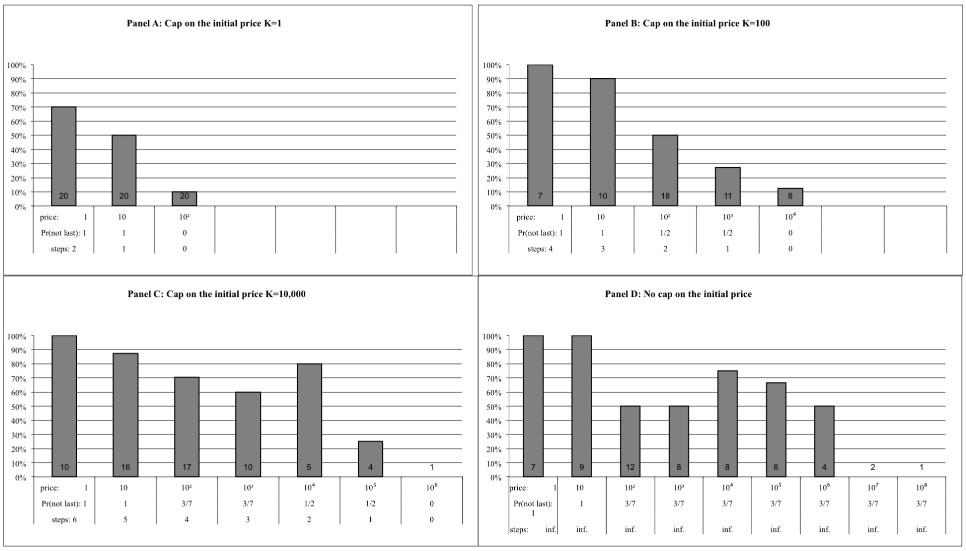


Figure 2: Data from previous sessions.

Data from the experiments reported in Moinas and Pouget (2013) on the probability of a Buy decision, depending on the initial price, the probability not to be last and the number of steps of iterated reasoning. The numbers in the bars indicate the number of players that have been proposed the corresponding price. The excel spreadsheet provided as supplemental material is designed to automatically generate these graphs with the data of the classroom game.

This snowball effect suggests that some participants are actually betting on the fact that others may make mistakes. If one believes that there is a positive probability that a trader will make a mistake and buy the asset at too high a price or that a trader believes other may make mistakes, it may become rational to speculate and ride the bubble. Such a rational speculative trading is consistent with hedge funds' behavior during the dot-com bubble, as documented by Brunnermeier and Nagel (2004), and with London-based bank Hoares trading behavior during the 1720s South Sea bubble, as reported by Temin and Voth (2003).

4 Link with behavioral game theory

Different explanations based on various generalizations of Nash equilibrium can be put forward to explain these results but we focus here on the simplest one based on Quantal Response Equilibrium (QRE) of McKelvey and Palfrey (1995).[2] This

[2]Moinas and Pouget (2013) discuss and estimate additional models that can explain the data. On the one hand, because the Bubble Game involves introspective and iterated reasoning, one could think of the cognitive hierarchy (hereafter CH) model of Camerer, Ho, and Chong (2004). This model considers that players underestimate other agents' sophistication. On the other hand, it might be difficult to form beliefs about the likelihood of speculation at each possible transaction price. Instead, players might simplify the problem by assuming that

equilibrium concept postulates that players do not always choose what is best for them but choose what is better more often. Their payoff responsiveness is not infinite as is the case in the Nash equilibrium but is instead limited. Moreover, players understand that others have a limited payoff responsiveness. This equilibrium concept may thus be viewed as a way to model strategic uncertainty, i.e., a situation in which players are not sure about others' behavior.

Because the Bubble Game requires longer and longer chains of belief formation when a player is farther away from the maximum potential price, one could expect QRE to be relevant. To see this, consider that players are risk neutral and have the same payoff responsiveness λ. For simplicity, we focus on the case in which the first price is capped at 1. Let's compute the probability to buy if players use quantal responses instead of best responses. The player who received a price of 100 is last with probability 1. If he buys, he gets a payoff of 0. If he does not buy, his payoff is 1. For him, the probability to buy is thus:

$$\begin{aligned}\mathbb{P}(Buy|Price = 100) &= \frac{e^{\lambda\times 0}}{e^{\lambda\times 0}+e^{\lambda\times 1}}\\ &= \frac{1}{1+e^{\lambda}}.\end{aligned}$$

A player who is proposed to buy at a price of 10 is sure to be second in the market sequence. Moreover, he anticipates that the last player buys with the probability computed above. His expected profit if he buys is thus $\frac{1}{1+e^{\lambda}}10$, i.e., he gets 10 if the last player decides to buy, otherwise he gets 0. The probability to buy of the second player is thus:

$$\begin{aligned}\mathbb{P}(Buy|Price = 10) &= \frac{e^{\lambda\mathbb{P}(Buy|Price=100)\times 10}}{e^{\lambda\mathbb{P}(Buy|Price=100)\times 10}+e^{\lambda}}\\ &= \frac{1}{1+e^{\lambda(1-\frac{1}{1+e^{\lambda}}10)}},\end{aligned}$$

which is larger than $\mathbb{P}(Buy|Price = 100)$.

Finally, the player who is proposed to buy at a price of 1 is sure to be first in the market sequence. He anticipates that the second player buys with the

this likelihood is the same across various transaction prices. The analogy-based expectation equilibrium (hereafter ABEE) of Jehiel (2005) could thus be pertinent. Moinas and Pouget (2013) theoretically show that each of these models as well as the QRE can account for the main stylized facts from the experiment, namely, (i) the existence of bubbles even when there is a price cap, and (ii) the presence of a snowball effect.

probability $\mathbb{P}(Buy|Price = 10)$, computed above. His probability to buy is thus:

$$\begin{aligned}\mathbb{P}(Buy|Price = 1) &= \frac{e^{\lambda \mathbb{P}(Buy|Price=10)\times 10}}{e^{\lambda \mathbb{P}(Buy|Price=10)\times 10)} + e^{\lambda}} \\ &= \frac{1}{1+e^{\lambda\left(1-\frac{1}{1+e^{\lambda(1-\frac{1}{1+e^{\lambda}}10)}}10\right)}},\end{aligned}$$

which is larger than $\mathbb{P}(Buy|Price = 10)$.

As an example, consider that the payoff responsiveness, λ, equals 0.3 (which is in fact the value of λ that enables the QRE to best fit the data in Moinas and Pouget (2013) according to the maximum likelihood criteria). In this case, the probability to buy is 43% for the third player, 73% for the second player, and 87% for the first player. These probabilities to buy fit Moinas and Pouget (2013)'s data much better than the Nash equilibrium that predicts a probability to buy of zero for each player. They also show that QRE can display a snowball effect: it becomes less and less costly to buy the overvalued asset when a trader is further away from the maximum price.

For the cases in which the cap is higher than one, the predictions of the QRE can be computed similarly by taking into account the probability to be first, second or third conditional on the price being proposed. The predicted probabilities to buy of the QRE with $\lambda = 0.3$ for all the cases considered in Moinas and Pouget (2013) (cap at 1, cap at 100, cap at 1,000, and no cap) are illustrated in Figure 3.

5 Conclusion

Overall, the Bubble Game enables to observe speculation decisions at various places in a speculative episode. It shows that market efficiency, defined as the price of a financial asset being equal to its fundamental value, can be dramatically dampened by speculative bubbles. Also, it may be helpful to demonstrates that speculative bubbles can form even if they are based on a very small probability that some traders may make a mistake.

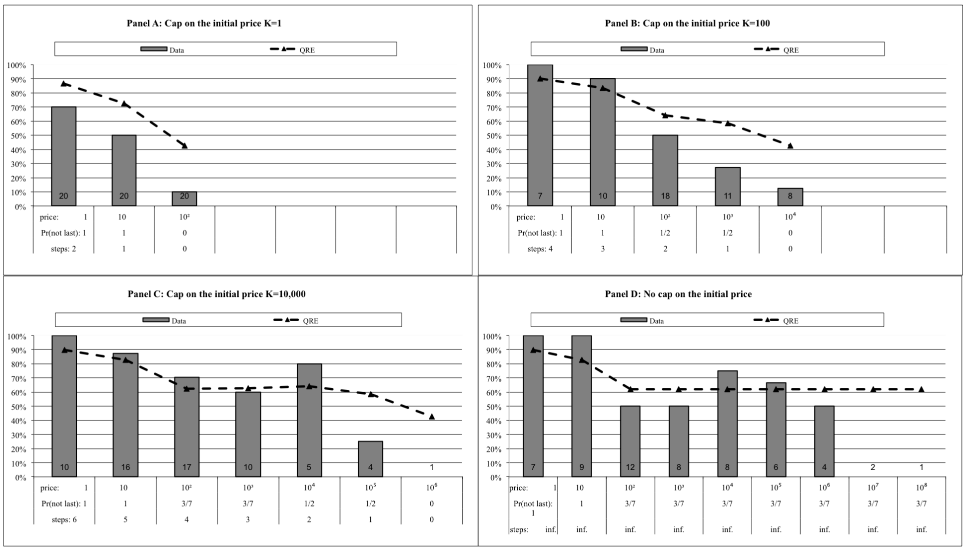


Figure 3: Probability to buy of the QRE with $\lambda = 0.3$.
Predicted probability to buy of the QRE with $\lambda = 0.3$ for the cases in which the cap on the first price is at 1, 100, 1,000, and infinity. The data is taken from Moinas and Pouget (2013).

6 Appendix

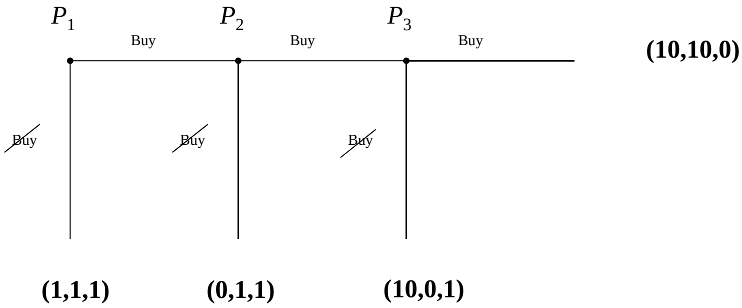
Instructions for the case where $K = 10,000$

Welcome to this market game. Please read carefully the following instructions. They are identical for all participants. Please do not communicate with the other participants, stay quiet, and turn off your mobile phone during the game. If you have questions, please raise your hand. An instructor will come and answer.

As an appreciation for your presence today, you receive a participation fee of 5 euros. In addition to this amount, you can earn money during the game. The game will last approximately half an hour, including the reading of the instructions.

Exchange process

To play this game, we form groups of three players. Each player is endowed with one euro which can be used to buy an asset. Your task during the game is thus to choose whether you want to buy or not the asset. This asset does not generate any dividend. If the asset price exceeds one euro, you can still buy the asset. We indeed consider that a financial partner (who is not part of the game) provides you with the additional capital and shares profits with you according to the respective capital invested. The market proceeds sequentially. The first player is proposed to buy at a price P_1. If he buys, he proposes to sell the asset to the second player at a price which is ten times higher, $P_2 = 10 \times P_1$. If the second player accepts to buy, the first player ends up the game with 10 euros. The second player then proposes to sell the asset to the third trader at a price $P_3 = 10 \times P_2 = 100 \times P_1$. If the third player buys the asset, the second player ends up the game with 10 euros. The third player does not find anybody to whom he can sell the asset. Since this asset does not generate any dividend, he ends up the game with 0 euro. This game is summarized in the following figure.



At the beginning of the game, players do not know their position in the market sequence. Positions are randomly determined with one chance out of three for each player to be first, second or third.

Proposed prices

The price P_1 that is proposed to the first player is random. This price is a power of 10 and is determined as follows:

Price P_1	Probability that this price is realized
1	1/2 (50%)
10	1/4 (25%)
100	1/8 (12.5%)
1,000	1/16 (6.3%)
10,000	1/16 (6.3%)

Players decisions are made simultaneously and privately. For example, if the first price $P_1 = 1$ has been drawn, the prices that are simultaneously proposed to the three players are: $P_1 = 1$ for the first player, $P_2 = 10$ for the second player, and $P_3 = 100$ for the third player. Identically, if the first price $P_1 = 10,000$ has been drawn, the prices that are simultaneously proposed to the three players are: $P_1 = 10,000$ for the first player, $P_2 = 100,000$ for the second player, and $P_3 = 1,000,000$ for the third player.

The prices that you are been proposed can give you the following information regarding your position in the market sequence:

- if you are proposed to buy at a price of 1, you are sure to be first;

- if you are proposed to buy at a price of 10, you have one chance out of three to be first and two chances out of three to be second in the market sequence;

- if you are proposed to buy at a price of 100 or 1,000, you have one chance out of seven to be first, two chances out of seven to be second, and four chances out seven to be last in the market sequence;

- if you are proposed to buy at a price of 10,000, you have one chance out of four to be first, one chance out of four to be second, and two chances out four to be last.

- if you are proposed to buy at a price of 100,000, you have one chance out of two to be second, and one chance out of two to be third.

- if you are proposed to buy at a price of 1,000,000, you are sure to be last.

In order to preserve anonymity, a number will be assigned to each player. Once decision will be made, we will tell you (anonymously) the group to which you belong, your position in the market sequence, if you are proposed to buy, and your final gain.

Do you have any question?

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