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

JEL codes: A20, G1, D7

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). The Bubble Game can be fruitfully used for all class levels in the context of financial economics courses on asset pricing, 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 at the same time in the same classroom).

INSERT FIGURE 1

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.[1]

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 a zero final wealth, i.e., he loses $P-1$ that he invested to finance the purchase of the asset. 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 $10 \times P - 10$. The game has thus three potential outcomes for a trader: 1 if the trader refuses to buy, 10 if the trader buys and is able to resell, and 0 if he buys but cannot resell (either because he is last or because the next trader refuses to buy).

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. Bubbles can arise at the Nash equilibrium. If all traders anticipate that others buy the asset, his or her best response is to also buy the asset if he is not too risk averse. 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 constant at $\frac{4}{7}$ conditional on $P \geq 100$. If a trader buys the asset and anticipates that others also do so, either he is sure to resell or he has three chances out of seven to be able to resell and to earn a return that is tenfold larger than the amount invested.

In contrast, when there is a price cap, only irrational bubbles can form: at equilibrium, there is no bubble because all traders refuse to buy. To show this, we cannot rely on backward induction. Indeed, in a given realization of n, the price cap might not be reached. For example, if the cap on the first price is set at 100 and a player sees a price of 1, he knows that no player in his group will see the maximum price of 10,000 (he knows they will see prices of 10 and 100) and thus no player in his group will know with certainty that he is last. With this particular realization of n, backward induction cannot start.

An infection argument à la Morris and Shin (1995) applies though. Consider again that the cap on the first price is set at 100. The information sets of traders in this case are represented in Figure 2. This figure shows that there are three potential games that can be played depending on the price that is proposed to the first trader: Game 1 is played if the first price is 1, Game 2 if it is 10, and Game 3 if it is 100. The reasoning for the infection argument goes backward. Whatever the price they are proposed, traders, if they are rational and if rationality is common knowledge, anticipate the following behavior from traders at the various positions in the market sequence.

The trader who would be proposed the highest possible price of 10,000 would be sure to be last. It would thus be a dominant strategy for him to refuse to buy. The trader who would receive the second highest price of 1,000 would not know whether he is penultimate or last in the trading sequence. However, in both cases, he would not want to buy: even if he were penultimate, he would anticipate that the subsequent trader would know he is last and would refuse to trade. Thus, whatever his position in the market sequence, the trader who is proposed a price of 1,000 would not be able to resell after buying. As a result, he would be better off not buying.

Consider now the trader who would be proposed a price of 100 and who could thus be first, second or third in the market sequence. If he were last, he would not want to buy. If he were first or second in the market sequence, he would anticipate that the next trader at a price of 1,000 would refuse to trade and thus he would also refuse to trade. Likewise, the trader who would be proposed a price of 10 could be first or second in the market sequence and anticipates that the subsequent trader at a price of 100 refuses to trade. He is thus better off not buying. Finally, the same logic applies to the trader who would receive a price of 1: even if he is sure to be first in the market sequence, he is better off not buying because he anticipates that the subsequent trader at a price of 10 refuses to trade.

Overall, even if the price offered to the first trader is 1 and thus if no trader in the game can be sure that he is last, there is no bubble at equilibrium when there is a finite cap on the price of the asset.

INSERT FIGURE 2

The Bubble Game complements the asset market classroom games proposed by Ball and Holt (1998) and Bostian and Holt (2009) based on Smith, Suchanek, and

Williams (1988) (see also Holt 2007). The contributions of the Bubble Game compared to these classroom games are fourfold. First, the Bubble Game is simple enough to allow theoretical predictions for individual speculative behavior. One reason for this is that our experimental design enables one to control for the number of trading opportunities (it does not feature continuous trading, for example). This eases the interpretation of the experimental data gathered in the classroom. Second, the Bubble Game does not involve fundamental risk and thus bubbles can be defined: even if some subjects are risk-lovers, we can unambiguously identify bubbles. Third, the Bubble Game can offer the opportunity to observe and discuss rational bubbles. The last contribution is more practical. The Bubble Game does not require any team to register transactions, compute profits and losses, or prepare document for the debriefing, nor does it require the use of internet. It is thus much simpler and faster to implement.

2. PROCEDURE

Pre-printed decision sheets and envelopes can be used to collect the students' decisions quickly and privately. The game itself lasts around fifteen minutes. Including the presentation of the game and the discussion of the results, the game session can fit in a one hour and fifteen minute class. The game 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).

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.

ADVANCE PREPARATION - 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. A powerpoint presentation of the instructions and a word version of the questionnaire are provided as supplemental material.

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 in advance the price that will be proposed to all participants.

For each market and each of the three students, the instructor writes down on the decision sheet the price that is or would be proposed to the student. 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 or write down 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 records the decisions of each student by ID number in the excel spreadsheet. For a classroom of thirty students, this does not take more than a couple of minutes and could be done during a break. Profits and graphs are automatically computed and drawn in the excel spreadsheet. This enables the instructor to open the floor for discussion right after the experiment.

INCENTIVES - 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 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).

3. DISCUSSION

The typical results one obtains when organizing the Bubble Game in the classroom are represented in Figure 3. 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.

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 Hoare's trading behavior during the 1720's South Sea bubble, as reported by Temin and Voth (2003).

INSERT FIGURE 3

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 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:

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

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:

$$\begin{aligned}\mathbb{P}(Buy|Price=10) &= \frac{e^{\lambda\mathbb{P}(Buy|Price=100)\times 10}}{e^{\lambda\mathbb{P}(Buy|Price=100)\times 10}+e^{\lambda}} \\ &= \frac{1}{1+e^{\lambda(1-\frac{1}{1+e^{\lambda}}10)}},\end{aligned} \tag{2}$$

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

$$\begin{aligned}\mathbb{P}(Buy|Price=1) &= \frac{e^{\lambda\mathbb{P}(Buy|Price=10)\times 10}}{e^{\lambda\mathbb{P}(Buy|Price=10)\times 10}+e^{\lambda}} \\ &= \frac{1}{1+e^{\lambda\left(1-\frac{1}{1+e^{\lambda(1-\frac{1}{1+e^{\lambda}}10)}}10\right)}},\end{aligned} \tag{3}$$

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

Notice that when λ goes to infinity, the traders are perfectly rational and the probability to buy at each of the three prices of 1, 10, and 100, converges to zero, which is the Nash equilibrium.

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. 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 4. The excel file provided in the supplemental material enables to automatically estimate the value of λ by maximum likelihood, and to draw a figure similar to one of the panels in Figure 4.

INSERT FIGURE 4

5. CONCLUSION

The Bubble Game is a very simple classroom experiment that enables to observe speculation decisions at various phases of 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 demonstrate that speculative bubbles can form even if they are based on a very small probability that some traders may make a mistake.

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NOTES

[1]These features (exogenous and random prices, trading sequences, limited number of traders) are useful to set up a practically simple but conceptually rich game. They should not be taken literally. They are best viewed as a metaphor of actual financial markets in which one can trade at several points in time and, when surfing a bubble, wonders whether he is more likely to be at the beginning or at the end of the speculative episode. Our experience with organizing and analyzing the game in the classroom is that students who participated in the game can feel the close link between the game and trading in a bubbly financial market. The Bubble Game is in fact very close to the metaphor used by Chuck Prince, former CEO of Citigroup, to describe the behavior of his institution during the buy-out boom in 2007: "When the music stops, in terms of liquidity, things will be complicated. But as long as the music is playing, you've got to get up and dance. We're still dancing" (*Financial Times*, July, 9th, 2007). Our game is in the spirit of the musical chairs: there are three players but only two can end up with a profit when the game ends: the last one to buy (or to sit as in the musical chairs) ends up with a loss.

[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 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 reselling at each possible transaction price. Instead, players might simplify the problem by assuming that this likelihood is the same across various transaction prices. The analogy-based expectation equilibrium 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.

6. FIGURES

Figure 1: Timing of the Bubble Game with three players.

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.

Figure 2: Potential games when the cap on the first price is 100.

This figure shows the three potential games that traders might be playing depending on the price that is proposed to the first trader in the market sequence when the cap on the first price is 100. Game 1 occurs if the first price is 1, i.e., if the price offered to the first trader in the trading sequence is 1; Game 2 if the first price is 10; Game 3 if the first price is 100. The oval sets indicate the information known to the traders who are proposed the various prices. For example, the trader who receives a price of 100 may be playing Game 1 (and be last in the trading sequence), Game 2 (and be penultimate), or Game 3 (and be second-to-last). Notice that a trader who is proposed a price of 1 is sure to be playing Game 1 and thus to be first in the trading sequence. Also, a trader who is proposed a price of 10,000 is sure to be playing Game 3 and thus to be last.

Figure 3: 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.

Figure 4: 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).

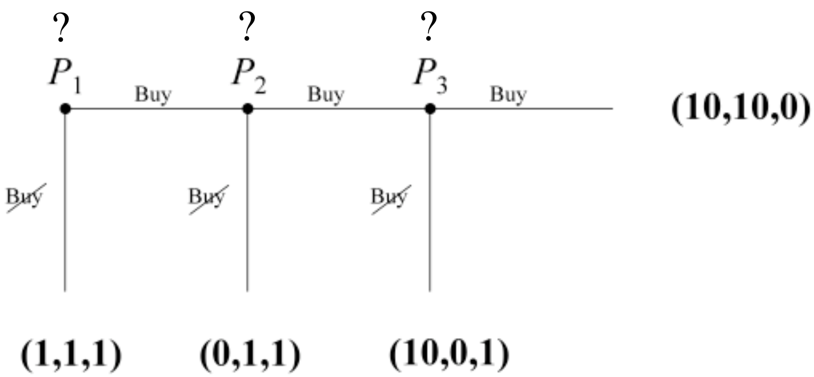
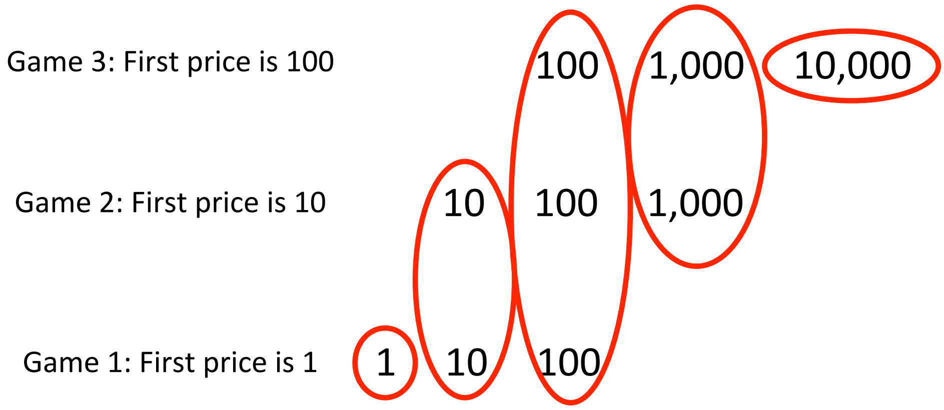


Figure 1



Game 3: First price is 100
100
1,000
10,000
Game 2: First price is 10
10
100
1,000
Game 1: First price is 1
1
10
100

Figure 2

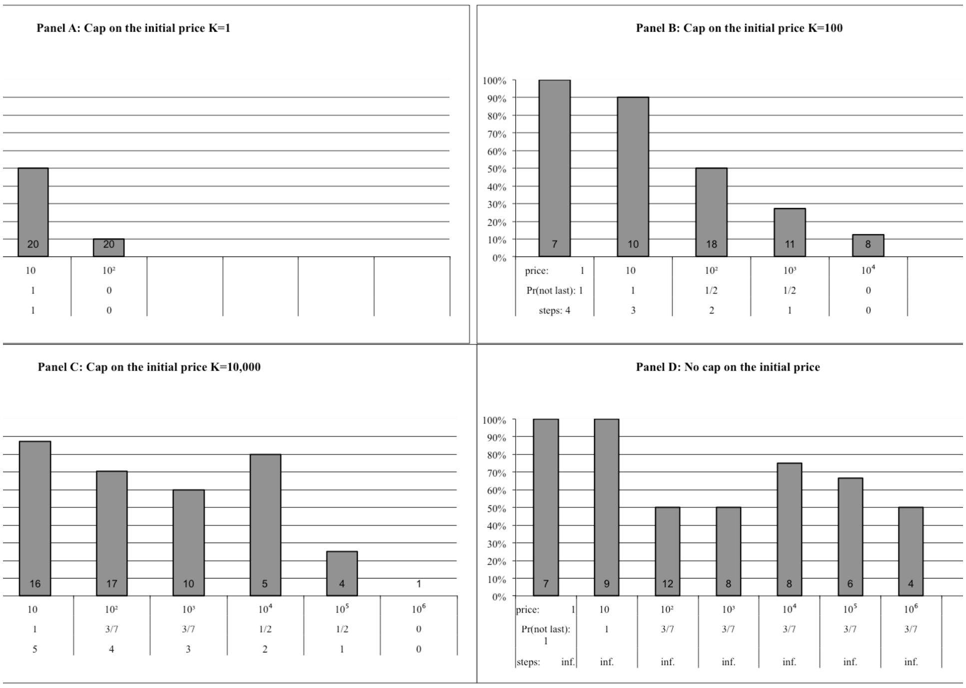

Panel A: Cap on the initial price K=1
Panel B: Cap on the initial price K=100
Panel C: Cap on the initial price K=10,000
Panel D: No cap on the initial price
price:
Pr(not last):
steps:

Figure 3

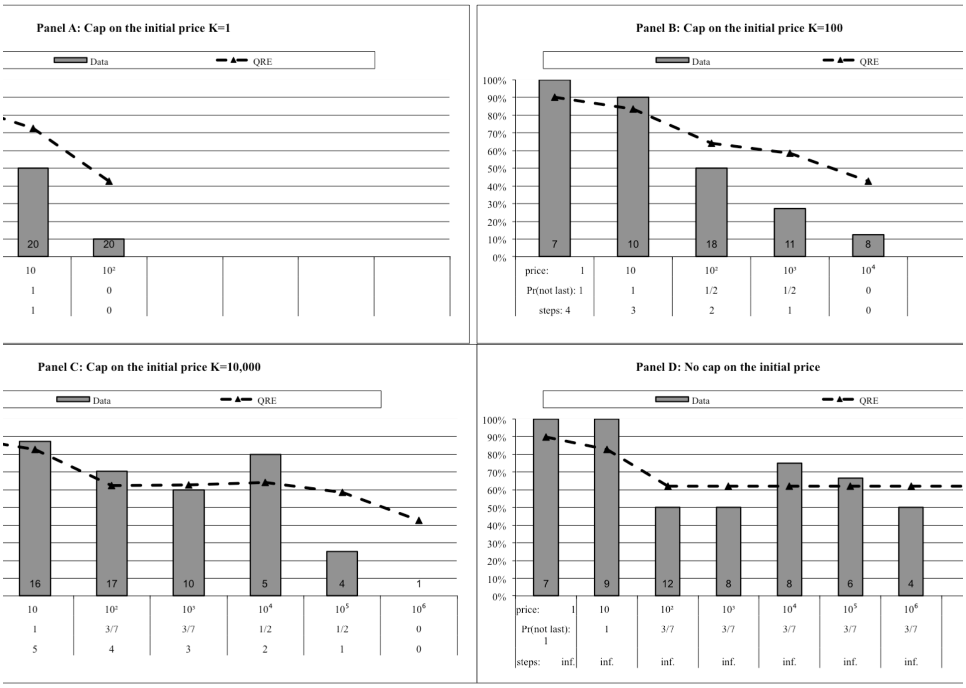

Panel A: Cap on the initial price K=1
Data
QRE
Panel B: Cap on the initial price K=100
Panel C: Cap on the initial price K=10,000
Panel D: No cap on the initial price
price:
Pr(not last):
steps:
inf.

Figure 4

7. APPENDIX

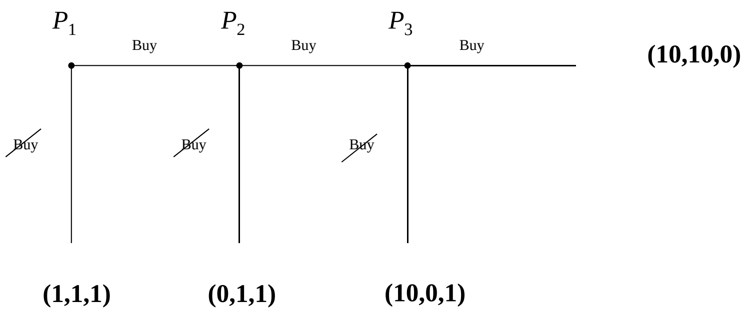
INSTRUCTIONS FOR THE CASE WHERE $K = 10,000$

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?