A Game Theoretic Approach to Model Financial Markets: Guessing Game

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ABSTRACT

How deep our reasoning is and how strategic we think are crucial in making financial investment decisions because we need to guess how other people will behave. This paper studies Guessing Game (Beauty contest game) that helps us understand how people make decisions in environments where depth of reasoning plays a key role. We mainly summarize the findings of experimental studies focusing on this game and then link these findings to financial markets, especially to stock market players' behavior. We also offer some extensions that may further contribute to produce better and more realistic models of financial markets.

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1. Introduction

A financial market is a mechanism or a medium in which people buy and sell financial instruments and commodities. Financial markets basically match the ones who own capital to the ones who need them. In other words, it allocates available savings in the most productive way by eliminating informational frictions between borrowers and lenders of fungible items such as stocks, bonds, agricultural goods and oil. By nature, financial markets are the fundamental channels that transmit changes in one part of the economy to other parts since transactions can occur instantly as opposed to other markets in which transactions may take a long time to occur.

A broad look at the structure of financial markets indicates the following ingredients: traders as players, strategies of traders, and outcomes and implied payoffs for each trader determined by their collective strategies under some trading rules. Since any situation that involves parties with possibly conflicting interests, their strategies and payoffs emerging from joint strategies can be named as a *game*, this essentially brings us to a point where we see a financial market as a game. Then, in order to understand and investigate this very complex game, we can utilize the tools of *Game Theory*.

Game theory, a branch of applied mathematics, is simply a science of decision making in strategic environments. It primarily tries to understand and model the behavior of agents who interact in different strategic situations. It has numerous applications in economics and finance as well as in other sciences such as biology, political science, international relations and computer science. Game theory generates predictions on how a certain game should be played under some rationality and informational assumptions. Since we are interested in financial markets and try to understand their dynamics, we need a simple model that will give insights about how people behave in financial markets. At this point, Keynes gives us a clue in understanding the dynamics of financial markets, more broadly of any investment decision[3] by making an analogy between a professional investment and a newspaper contest:

"*...professional investment may be likened to those newspaper competitions in which the competitors have to pick out the six prettiest faces from a hundred photographs, the prize being awarded to the competitor whose choice most nearly corresponds to the average preferences of the competitors as a whole; so that each competitor has to pick, not those faces which he himself finds prettiest, but those which he thinks likeliest to catch the fancy of the other competitors, all of whom are looking at the problem from the same point of view. It is not a case of choosing those which, to the best of one's judgment, are really the prettiest, nor even those which average opinion genuinely thinks the prettiest. We have reached the third degree where we devote our intelligences to anticipating what average opinion expects the average opinion to be. And there are some, I believe, who practice the fourth, fifth and higher degrees.*[4]"

[3] Colin Camerer, Behavioral Game Theory, Princeton University Press, 2003, p.16
[4] John Maynard Keynes, The General Theory of Employment, Interest and Money, London: MacMillan, 1947, p.156

This implies that in any investment decision[5], it is important what you believe about what other people will do and to act in accordance with these beliefs. Moreover, as mentioned, it is not enough to form beliefs about what others will do, it is also crucial to consider what others think about what others will do. Perfectly rational players must consider this recursively and act accordingly. However in real life, most people do not take this consideration into account and they fail to make a profit out of their investments.

Inspiring from this quote, a game called guessing game (also known as p-beauty contest game) is introduced. The guessing game incorporates the mentioned reasoning in a very simple game format. When we employ game theoretical tools to predict the outcome of this game, it gives a unique and trivial solution. However, since there is no clear cut answer of whether human decisions occur in the same way as game theory predicts[6] and since there is a vast amount of evidence that there are significant differences between traditional game theoretical results and the actual behavior of people, we need to test the theory's predictions. The most apparent and directly informative method to test predictions of game theory is to conduct experiments in controlled environments.

It turns out that guessing game is a striking example because although it is very simple and understandable by everyone, experimental results clearly show that people do not employ such reasoning in their decision making process and that standard theory's predictions simply fail. The aim of this paper is to analyze experimental studies on guessing game that is an extremely simple model of financial markets.

To fix the ideas, we give a real life example from stock traders' behavior. Especially inexperienced traders make decisions cursorily and use some rule of thumbs. One example of this "irrational" behavior is selling winning investments too early and selling losing investments too late. The reason for this behavior is the lack of recursive thinking in the sense that one should sell a winning stock whenever he thinks that other traders thinks that others will sell it, not at the time that he thinks that others will sell it (This is only the third level of thinking and actually it should proceed further, if necessary). There is a fairly recently emerging field called "behavioral finance" investigating the interaction of psychological characteristics people have with the financial decision making processes (for an extensive survey of Behavioral finance see Thaler and Barberis, 2002; Olsen, 1998; and Shleifer, 2000). One of the main reasons of the observed anomalies in financial markets, especially in stock markets is the mentioned lack of reasoning. This paper aims to increase awareness of this phenomenon that has attracted academic and professional attention recently by focusing on the guessing game which intuitively reflects this lack of reasoning.

The remainder of the paper is organized as follows. Section 2 introduces the guessing game and theoretical solution of its basic version. Section 3 presents the

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[5] This can be thought as any investment opportunity that one encounters such as investing in a land, a real estate, a stock and so on. Even an academician, who believes a specific area will become popular soon and invests his/her time and effort to that area, can be considered as an investor

[6] Colin Camerer, Behavioral Game Theory, Princeton University Press, 2003, p.20

experimental studies with their contributions and critiques to the theory. Section 4 presents some extensions and Section 5 concludes with a brief discussion.

2. Guessing Game and Its Game Theoretical Solution

In this section, the logic and basic structure of the guessing game and its game theoretical solution will be presented. In a typical guessing game, there are N $(N \geq 2, N \neq \infty)$ players and each of them chooses simultaneously a number *(n_i, i = 1, 2, 3, …, N)* from a closed interval, frequently [0, 100]. The winner of a fixed and known prize is the player whose number is close to the target number *(T)* that is calculated as follows:

$$T = [(\sum_{i=1}^{N} n_i / N) + d] * p$$

where d is a constant. In its simplest form[7] $0 < p < 1$ and d is zero. p and d are common knowledge. In case of a tie, prize it is divided among the players who guess the target number. Other players receive nothing. In words, players guess a number from a certain interval and the one whose guess is the closest to a certain fraction (p) of the average number wins.

Guessing game has been mainly used to analyze the players' reasoning process and the availability of boundedly rational behavior (see Güth, Kocher and Sutter, 2002, p. 219). In other words, it can be said that *"The structure of the game is favorable for investigating whether and how a player's mental process incorporates the behavior of the other players in conscious reasoning.[8]"*

We now consider a strategic game of N $(N \geq 2)$ players where each player chooses a number between 0 and X $(X \neq \infty, X \in R^{+})$, [0, X]. For simplicity, we assume that $d = 0$ and 0<p<1. If one thinks that others will choose the highest mean, $(X * N)/N$ which is simply X, then this person will choose T such that $T_0 = X * p$. Thus, the numbers between X and T_0 will be dominated by the choices which are below or equal to T_0. If one thinks one step further (meaning that everybody can perceive this, so nobody will choose numbers between X and T_0; the new boundary is not X but it is T_0), then the new T will be $T_1 = X * p^2$. This process goes infinitely up until only "zero" survives which is the unique Nash equilibrium that is obtained by the iteration process called Iterative Elimination of Weakly Dominated Strategies (IEWDS), which is $T_\infty = X * p^\infty = 0$. This solution is an approximation because it neglects the effect of player itself[9].

A Numerical Example: Let N be the number of players (N>2), $p = 2/3$, X=100, M be the mean of the chosen numbers, T be the target number and it is defined

[7] In the case where p=1, all numbers can be the equilibrium. This kind of game is called "coordination game".
[8] Rosemarie Nagel, "Unraveling in guessing games: an experimental study", *American Economic Review* 85, 1995, p.1313
[9] For a detailed solution see (Ohtsuba and Rapoport, 2006)

as $T = M * p$. If one has a belief as a rational player that others will choose the highest mean, then by making one iteration, she should choose the number; T_0 = 100*2/3=66,6. The numbers above 66,6 will be strictly dominated. If one has a second depth of reasoning[10] and thinks that others are one level players, then she must choose T_1 = 100*2/3*2.3 = 44,4. This iterative process necessitates that all numbers strictly larger than zero are strictly dominated. Thus, a perfectly rational player must choose zero (if all other players are perfectly rational as well).

One point that has to be emphasized is the assumption of rationality and common knowledge of rationality[11]. In game theory, the standard practice is to construct the equilibrium concepts based on the rationality and common knowledge of rationality assumptions. In this game, rationality requires to follow the elimination process mentioned above. However, the elimination process should only be employed if it is known that other players are rational as well and if all players' rationality is common knowledge. Otherwise, it does not make sense to guess zero in this game. In other words, even if a player is rational but believes that the other players do not follow the elimination reasoning, then it is rational not to guess zero. Thus, what a player should play depends not only on the rationality assumption but also on the beliefs about the other players and higher order beliefs[12]. Moreover, the absolute distance between a player's guess and the equilibrium value can be considered as a proxy of the belief of a player about the rationality of other players, and about the distribution of the higher order beliefs about rationality in the population.

3. Experimental Studies on Guessing Games

The pioneer of experimental guessing game[13] is Rosemarie Nagel and in this section, we will explain her first experiment in detail as a benchmark. Then, all the published experimental studies until now about guessing games that are grouped[14] based on their focus will be explained briefly.

3.1. First Study on Guessing Games

[10] This term is used in the literature to indicate the iteration steps.

[11] This assumption means that every player knows that every player is rational; every player knows that every player knows that every player is rational, and so on. In other words, common knowledge of a rule or a situation can be achieved by making a public announcement of that rule or situation.

[12] After the Asian crisis, some of the investors withdrew their capital from Brazil. The reason was not that they overestimated the economic linkages between Asia and Brazil but that they thought other investors might do so. It is reported that apparently irrelevant news about the economy leads some firms to reduce their investments, not because they think that the news is relevant, but because they think others may believe so. Moreover, some investors pay inflated prices for internet stocks not because they believe that their future dividends will be high, but because they believe that others may think so (Dasgupta, 2010). A single bouncing check, even if it is a mistake, can be the beginning of the end of a very strong firm that lacks liquidity quickly due to rejections of its checks that is caused by the spread rumor about its financial state. This is not because people believe that the firm is in a bad financial condition but because they believe that others may think so and do not accept the firm's checks.

[13] Hervé Moulin (1986) is actually the first person who theoretically mentioned this game. In his textbook, he calls the game "Guess the average".

[14] This categorization is formed by the authors according to the similarities of the papers.

In 1995, Rosemarie Nagel conducted the first experiment in the University of Pompeu Fabra. It was a "classroom experiment[15]" with about 18 subjects. The subjects are given instructions, one response card for each period[16] and an explanation sheet in which subjects were asked to give written explanations of their choices after each period. The structure of the game was the same as the basic form explained in previous sections; Subjects pick a number between 0 and 100. Target number (T) is calculated as $T = [(\sum_{i=1}^{N} n_i)/N)]*p$, where N is the total number of subjects, n_i is the chosen number by subject i.

There were three different treatments[17] in this experiment where only p was changed (p values were 2/3, 1/2 and 4/3) by holding everything else the same. Subject who picked the number closest to the target number earned 20DM (26 TL) at each period. All subjects were paid an extra 5DM in the experiment as a show up fee regardless of their decisions in the game. At the end of each period, subjects were informed about the choices of other participants, the average, the target number, and the winning choice(s).

Nagel analyzed the data in two main parts. First, the 1st period's choices were examined where subjects had no information about others' choices and could pick a number based only on their n^{th} order beliefs. Second, the latter periods' choices were analyzed where subjects could see how far their choices were from the group decision and also from the target number.

In the first period, none of the subjects chose 0 in the p=2/3 and p=1/3 sessions and only 6 percent chose below 10. In p=4/3 sessions, only 10 percent chose 99 or 100. Different parameters did not affect the frequencies of the equilibrium strategies but when p was increased, the mean of chosen numbers was higher[18]. The mean and the median of the first round for p=2/3, 1/2, 4/3 were respectively 36.73, 27.05, 60.12 and 33, 17, 66. She concluded that many players did not choose numbers randomly but they were influenced by the parameter p. She also checked whether they have zero, first,... n^{th} order beliefs. Chosen numbers of the first period showed that many of the subjects had second order beliefs, which means that they did only two iterations.

In the latter periods, most subjects decreased their choices over time in all sessions. In the $p = 4/3$ session, they increased their choices. These results showed that there was a gradual convergence to the equilibrium. This was also tested by using

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15 For almost more than 7 years computers are used to design experiments that are called "laboratory experiments" where subjects can make their decisions through a software program.

16 There were 3 sessions with p=1/2, 4 sessions with p=2/3 and 3 sessions with p=4/3. Each session is a sum of 4 periods. And each subject can only participate in one session.

17 Treatment means (in experimental economics) "Specific combination of economic agents, environment, and institutions." A treatment is an environment where the instructor can test a specific hypothesis.

18 Nagel statistically reject that the choices from the p=1/2 and p=2/3 sessions were coming from the same distribution, likewise the sessions p=2/3 and p=4/3. Mann-Whitney U test is used to test these hypothesis.

simple learning-direction theory[19] to see whether learning was possible during the last three periods and the results showed that subjects tend to decrease (or increase upon *p*) their choices.

3.2. Contributions and Critiques

There are twenty one[20] papers listed either as a refereed paper or working paper on this topic. While nineteen of them mainly test different hypothesis, the other two papers criticize some of the existing papers.

3.2.1. Contributions to the Literature by Testing Different Hypothesis

Learning: In guessing games, one of the main questions is "Do people learn during the decision process?" After Nagel (1995), Stahl (1996) finds that subjects learn according to rule learning. The results of Camerer et al. (1998) are similar to what Nagel found. Weber (2003) addresses the question whether learning can occur even though there is no feedback[21] about the previous periods' results of the game. In order to answer this question, he uses two treatments. In one of them, feedback is provided but in the other, there is no feedback. He finds that both in feedback and no feedback treatments, there is convergence towards the equilibrium but convergence is slower in the latter. This shows that playing the game repeatedly is also a way of learning via experience.

Group Size (Individuals versus Groups): In business life, strategic decisions are commonly taken in small groups. Sutter (2005) asks about the effective group size. He compares the results of 4 subject groups with that of 2 subject groups and individuals. He finds that while groups of 4 subjects are earning more than groups of 2 subjects and individuals, there is no significant evidence showing that the behavior of 2 subject groups differs from that of individuals. He concludes that group size is important but only if the size is big enough. However, this paper does not explain the reasons of being in a group from the individuals' perspective. Kocher et al. (2006) analyze: *i)* how many players choose to be in a group, *ii)* the reason to be in a group, and *iii)* whether groups earn more than individuals. The results of the experiment showed that more than 60% of the individuals chose to be in a group simply because of high expected payoff and groups earn almost as twice as individuals.

Effect of Information (Historical Data versus Advice): Weber (2003) shows the importance of feedback. In addition, Kocher et al. (2007) investigate how the history of the game results and advices on decisions can affect the players' choices. They find that subjects who are provided either advice or historical data information earn more in the first period than their group members who are not provided any advice or

[19] "*...In words, if he observed that his chosen number was above p-times the mean in the previous period (i.e., his adjustment factor was higher than the optimal adjustment factor), then he/she should decrease his rate; if his number was below p times the mean (i.e., his adjustment factor was lower than the optimal adjustment factor), he should increase his adjustment factor.*" (Nagel, 1995)

[20] There are 2 more papers studied the similar topic in a different way, which we do not include.

[21] In this experiment, the word 'feedback' refers to an information set containing "actions of other players and/or subject's own payoff"

information. However, in the long run (all periods in total), surprisingly, only advice leads subjects to earn more than their uninformed group members while historical data has no impact on the results on average. Apart from the effect of history or/and advice, Patrizia (2008) studies the information effect in a different set up by simply announcing the identity of the winner at the end of each period. She shows that non-winners simply imitate those who won in earlier periods. Even more sophisticated players change their decisions in the latter periods by following the winners. Sonnemans and Tuinstra (2008) investigate the effect of positive feedbacks in financial market experiments. Their findings suggest that although providing more information to the participants or changing the incentive structure[22] do not affect the convergence rate, decreasing the feedback does. On the other hand, when they change the incentive scheme to a quadratic error rule and use interior equilibria, a faster convergence rate is obtained.

Effect of Complexity: Güth et al. (2002) address the following question: "If individuals play guessing game in a heterogeneous group, how can this affect their decisions?" They divide subjects into two groups where all subjects have the same *p* value in homogenous groups and have different *p* values, i.e. 2/3 or 1/3, in the heterogeneous groups. They find that heterogeneous groups earn less than homogenous groups while they spent more time on making decisions. Kovac et al. (2007) test the same question with mathematically talented subjects and show that it is important to have some mathematical abilities to be successful in heterogeneous groups.

Large Subject Pools: Nagel et al. (2001) study the guessing game through 3 newspapers in Spain, UK and Germany (one in each) to see the decisions in large groups. Totally 7,900 people participated the experiments. They find stable patterns across the countries and have also the same results of 1-3 levels of iteration steps as the ones in laboratory experiments. The same game was played through the Danish newspaper Politiken in 2005 by the supervisory of Jean-Robert Tyran. There were 19,196 participants and 5 of them shared the 5,000DKK (approximately $800) prize as winners. Politiken example gives almost the same results of Nagel et al. (2001).

"**Sleepy" guesses**: Dickinson and McElroy (2009) question whether sleepiness has any effect on guesses of the people in a guessing game. While they measure the sleepiness of the subject through a survey, they also ask the subjects to guess a number between 0 and 1,000; winner takes $50. They find that the guesses of the people who sleep less than 6 hours the day before are farther from the equilibrium.

Framing: Framing[23] is a way to present the same situation in different formats. Duffy and Nagel (1997) use framing by simply changing the mean in the calculation of target number by median or maximum choice. They find that although in all cases equilibrium points are the same (zero), subjects' depth of reasoning are higher in the median game than in the others. Thus, framing affects the reasoning process.

[22] In positive feedback experiments, incentive mechanism is based on the accuracy of the predictions. This means that as you get closer to the winning number, you earn more. The authors replaced this mechanism with the one in guessing game i.e. winner-takes-all.
[23] See for details Kahneman & Tversky, 1986.

Experience: Slonim (2005) studies the effect of experience. He runs an experiment with experienced players i.e. who play the same game just before they play it against inexperienced players. He shows that experienced players earn more than inexperienced ones and that inexperienced ones behave the same against both inexperienced and experienced players. Another interesting result is that if any new subjects are added into the game, experienced players stop to take decisions towards equilibrium.

Time effect: According to the psychology literature (Woodworth, 1899), time pressure has a significant effect on individuals' decision making and many decisions involve time pressure. Kocher and Matthias (2006) address this issue by incorporating time into the payoff function. That is, quicker decisions as well as correct decisions lead to earn more. They find that time pressure has a negative effect on the earned payoffs and speed of convergence. However, using a time dependent payoff function leads to significantly quicker decision-making with no effect on the quality of decisions.

Individual effect: Grosskopf and Nagel (2008) study the same "basic" form of the game with pairs (N=2) in which iterative reasoning is not necessary to win the game. In this game, the subject who chooses zero (actually, the smaller value) can simply win the game. Thus, more subjects are expected to choose zero. However, the results showed that individuals exclude their effects on calculating the winning number even in the experienced and the most sophisticated subject pools (i.e. game theorists). They did the experiment in two subject pools: students and professionals i.e. academics. Only 9.85% of the students and 36.92% of professionals chose zero. They explain this situation by comparing it to congestion where a driver is not thinking of her own effect on the congestion if she drives in the same road.

3.2.2. Critiques to the Literature

There are 2 papers in the literature in which some of the prior studies are tested. Morone and Morone (2006) test whether the results of Güth et al. (2002) are compatible with the theory of boundedly rational theory by Nagel (1995). They find that neither Güth et al.'s interior equilibrium[24] nor Nagel's boundedly rational behavior is verified with their model's parameterization and conclude that specific parameterization of Güth et al. (2002) and Nagel (1995) generates their results.

Chou et al. (2007) conduct several experiments to see which limitations the guessing game experiments have in their design and instructions that affect subjects to make decisions different than what the theory predicts. Their subjects are students from California Institute of Technology (Caltech) and a local community college. They find that: *i)* the loss of experimental control and the lack of game form recognition[25] lead to the discrepancy between the experimental and theoretical results; *ii)* Improving the instructions of the guessing game significantly avoids the lack of game form recognition. *iii)* While receiving hints has a very strong effect on Caltech students (they

[24] In basic form of the guessing game where d=0, the equilibrium is in the boundary. It is possible to create interior equilibrium by assigning a positive value to d. Camerer and Ho (1998), Güth et al. (2002) and Kocher and Sutter (2006) examined guessing games with interior equilibria ($d > 0$).

[25] It means subjects do not understand how to play the game.

move to the equilibrium easily), it has no significant effect on community college students. They finally emphasize that it is important to make sure that subjects understand the game and to properly control the experiment.

4. What is left? Discussion for the Future Experiments

Although it seems that many critique questions about guessing games have been answered since 1995, there are still some "*blur*" parts that need further research. Some ideas for future experiments are as follows:

Cultural Effect: Kachelmeier and Shehata (1992) study the cultural effects on a market situation where subjects are either buyers or sellers. This effect has never been studied in a guessing game. A possible set up can be as follows: There can be a group of 4 subjects (1 East + 3 West) against a group of 4 subjects (3 East + 1 West). Only the information about the winner's identity and the winning number can be given at the end of each period as in Patrizia (2008). In this kind of setup, it can be investigated whether people follow only the people from their own culture or they do not follow anyone at all when they are not the winner of that period. It is also possible to see whether the source of information (coming from the subjects of their own culture or from others) affects the behavior of subjects.

IQ Level Differences: Some studies show that in heterogeneous groups, mathematically talented subjects converge to the equilibrium faster than others (Kovac et al., 2007). To see the effect of "being smart" can be studied broadly by using subjects of different IQ levels. For a clear overview, it may also be useful to have subjects of different ages. Mainly, there might be 2 different groups: in one group 6-8 years old subjects who have not studied mathematic in a systematic way (i.e. in the school) can play against another subject group which is a group of students at least 16-18 years old who have enough practice of mathematics. Using cross-level[26] setup, it would be possible to see the effect of mathematical practicing and the level of IQ.

Asymmetric Players: In every stock market, there are different types (spectrum) of players in terms of their market power. Strong/big players are the ones who have the financial power to affect the price of an asset more than smaller players whereas small players are the most common players in stock markets. When relatively small players make transactions, in addition to following the market movements, they also follow the big players' or their advisors' moves. Until now, none of the guessing game experiments examined the game from this perspective. In a design where one player has power to choose more than one number, it is easy to mimic the real life in this sense. In this environment, whether big players have a significant effect on relatively small players' choices and being big means always winning can be investigated.

The Power of History: Studies show that announcing relevant information, e.g. the winning number, has an effect on people's guesses. When we closely look at the

[26] 6-8 years old subjects with higher IQ against to the same ages and higher age subjects with lower IQ levels and reverse.

stock market, it is obvious that both the quality and the quantity of information are huge and its update-speed is enormous. Therefore, in a simple guessing game setup, it would be good to engage subjects with full information, i.e. winner's number, target number, guesses of all players in all previous periods, to see whether there is a significant correlation between the quantity of information they get and the quality of guesses they make.

5. Discussion and Conclusion

Guessing game has been extensively studied for more than 10 years by many researchers. This game is very simple in terms of both conducting an experiment and controlling the environment. Moreover, it is very useful to understand the reasoning process of players in financial markets. General findings of the literature are: i) subjects learn by playing repeatedly, ii) the speed of convergence to the equilibrium depends on the information they have and the environment, and iii) Experience has no significant effect on the depth of reasoning level but has a positive effect on earned payoffs.

There is no doubt that the behavior of the players i.e. investors and the mechanism which adjusts prices in stock markets are more complex than in this game. Guessing game is just an attempt to simply model how do players guess how the other players will behave and the interaction between players in stock markets. This model does not incorporate any information related to the stocks or their real value. This game focuses on how people's beliefs and guesses, given the information, range, p values etc., affect the outcome. It is assumed that the prices fully reflect all the relevant information in stock markets in which the information complexity and diversity is so high that both acquiring and processing information is much more difficult than what the guessing game models. While only the person who has the closest guess to the target number is awarded in the game (a discrete type reward scheme), it is enough to guess the direction of the price correctly in stock exchanges and all the ones who guess the direction right are awarded (a continuous type reward structure).[27] In spite of this, the incentives to guess the target / price direction correctly are similar.

The points mentioned above can be seen as a lack of comprehension of the game in modeling real behavior. However, the findings of the research on guessing games somewhat shed light on how prices are formed and trader behavior in stock exchanges. The finding that subjects learn by playing repeatedly implies that as players buy and sell in the stock market and positive and negative payoffs are realized, they may train themselves in terms of rational reasoning. Repeated play helps people comprehend the rationale that the price is a function of all players' actions and that the recursive thinking is critical[28].

[27] Costa-Gomes and Crawford (2006), Güth et al. (2002) and Kocher and Sutter (2006) employed this continuous reward structure such that they reward all participants based upon the absolute distance between their guess and the target number. The experiment conducted by Güth et al. (2002) showed that subjects try to avoid extreme choices and in games with interior equilibria, convergence is faster than in games with boundary equilibria.

[28] Of course, here we assume almost a homogenous distribution of players in terms of size. Relatively big players may engage in speculative behavior. Even in this case, main strategy is still the same and based on how the rest of the players including big ones will behave.

The second finding implies that the information through feedback that the players are given plays a critical role in the speed of convergence to the equilibrium. What this may mean for the stock market is that naive players who do not base their decisions on available information are disadvantageous relative to the ones who seek information on the player structure; the financial status of the public corporation (firm) whose shares you trade, managerial situation and risks of the firm, and who base their trades on the analysis of this kind of information. Nonetheless, the most important factors that should determine how to make trade are the information and beliefs about the other players and about how they take positions. The reason why the information about firm's financial status etc. and analysis of this information are important is that especially the institutional and big investors intensely incorporate this information into their decision making process and this is publicly known.

The last point emphasizes the importance of experience and states that experience has no significant effect on the depth of reasoning level but makes you earn more. There may be different reasons of this result one of which can be that people do not fully understand the strategic motive that lies behind the game they play. The other reason, related but possibly more appealing one, is that people may think that the others do not fully understand the game. Given this, the best response is to behave according to what you believe about how others will behave. Actually, the related result that if any experienced subjects are replaced with the inexperienced ones, experienced players stop to take decisions towards equilibrium is a good indicator of this way of thinking. This is similar to what happens in the stock markets as well. If you think people will behave in a certain way, then it is optimal to behave in that way (e.g., if you believe people think that price a certain stock / index will skyrocket and they will intensively buy it soon, then you should buy it as well).

Consequently, guessing game is not only a very simple, trivial and understandable game but also rich in terms of implications and applications to real life. Its standard version can especially be used to model markets whose players focus more on dividend yield and value stocks[29]. Although it is not being studied as intensive as before, its current results and implications shed light on the mechanisms of decision making in strategic environments and help us understand the behavior of investors in real life.

References

[29] Guessing games conducted in different environments such as median and maximum game as in Duffy and Nagel (1997) can be interpreted as giving more or less weight to fundamental or speculative behavior. For example, the median game environment can be viewed as a game where players focus relatively more on market fundamentals such as the fraction p or the previous period's market average, and are not interested in speculating about the future actions of other players. On the other hand, the maximum game can be considered as a game where players are relatively more concerned with speculating about the future actions of other players who choose high numbers and they do not focus on market fundamentals much.

1. Barberis, Nicholas and Thaler, Richard, "*A survey of behavioral finance in Advances in Behavioral Finance, Volume II*", (Ed.), Barberis, Nicholas and Thaler, Richard, Princeton University Press, 2005, pp. 1-74
2. Bosch-Domènech Antoni, García-Montalvo, Jose, Nagel, Rosemarie and Antoni, Satorra Albert, "One, Two, (Three), Infinity: Newspaper and Lab Beauty-Contest Experiments", The American Economic Review, Vol. 92, No 5, 2002, pp.1687-1701
3. Camerer, Colin F., Behavioral Game Theory, Princeton University Press, 2003
4. Costa-Gomes, M.A. & Crawford, V.P., "*Cognition and behavior in two-person guessing games: An experimental study*", American Economic Review, 96, 2006, pp.1737-1768
5. Chou, Eileen, McConnell, Margaret, Nagel, Rosemarie and Plott, Charles R., "*The Control of Game Form Recognition in Experiment: Understanding Dominant Strategy Failures in a Simple Two Person 'Guessing' Game*", Experimental Economics, 12, 2009, pp.159-179
6. Dasgupta, Amil, "*Order Beliefs in Applied Game Theory*", [Online]; available from http://fmg.lse.ac.uk/~amil/research.html, accessed 03.03.2010
7. Dickinson, David L. and McElroy, Todd, "*Rationality around the clock. Sleep and time-of-day effects on guessing game response*", Working Paper, 2009
8. Duffy, John and Nagel, Rosemarie, "*On the robustness of behavior in experimental 'beauty contest' games*", The Economic Journal, Vol. 107, November 1997, pp.1684-1700
9. Gibbons, Robert, Primer in Game Theory, Prentice Hall, 2002
10. Grosskopf, Brit and Nagel, Rosemarie, "*The Two-Person Beauty Contest*", Games and Economic Behavior, 62 (1), 2008, pp.93-99
11. Grosskopf, Brit and Nagel, Rosemarie, "*Unraveling The Two-Person Beauty Contest*", Working Paper, November 2009
12. Guth, Werner, Kocher, Martin and Sutter, Matthias, "*Experimental 'beauty contests' with homogeneous and heterogeneous players and with interior and boundary equilibria*", Economics Letters, Vol. 74, 2002, pp.219-228
13. Ho, Teck, Camerer, Colin and Keith, Weigelt, "*Iterated Dominance and Iterated Best Response in Experimental 'P-Beauty-contests*", American Economic Review, Vol. 88, 1998, pp.947-969
14. Kachelmeier, J.Steven and Shehata, Mohamed, "*Culture and Competition: A Laboratory Market Comparison Between China and the West*", Journal of Economic Behavior and Organization, Vol. 19, 1992, pp.145-168
15. Kahneman, Daniel and Tversky, Amor, "*Rational Choice and the Framing of Decisions*", Journal of Business, Vol.59, 1986, pp.251-278
16. Keynes, John Maynard, "*The General Theory of Employment, Interest and Money*", London: MacMillan, 1947
17. Kocher, Martin G. and Sutter, Matthias, "*Time is money—Time pressure, incentives, and the quality of decision-making*", Journal of Economic Behavior & Organization, Vol. 61, 2006, pp.375-392
18. Kocher, Martin, Straub, Sabine and Sutter, Matthias, "*Individual or team decision-making - Causes and consequences of self-selection*", Games and Economic Behavior, Vol. 56, 2006, pp.259-270

19. Kocher, Martin, Sutter, Matthias and Wakolbinger, Florian, "*The impact of naive advice and observational learning in beauty-contest games*", Tinbergen Institute Discussion Paper, January 24, 2007
20. Kovac, Eugen, Ortmann, Andreas and Vojtek, Martin, "*Comparing Guessing Games with Homogeneous and Heterogeneous Players: Experimental Results and a CH Explanation*", Economics Institute of the Czech Academy of Sciences Working Paper, March 2007
21. Mas-Colell, Andreu, Whinston, Michael D. And Green, Jerry R., "*Microeconomic Theory*", Oxford University Press, 1995
22. Morone, Andrea and Morone, Piergiuseppe, "*Guessing Games and People Behaviors: What Can We Learn?*" , S.E.R.I.E.S. Working Paper No:15, 2006
23. Moulin, Hervé, "*Game Theory for Social Sciences"*, New York University Press, 1986
24. Nagel, Rosemarie, "*Unraveling in guessing games: an experimental study*", American Economic Review, Vol. 85, 1995, pp.1313-1326
25. Ohtsubo, Yohsuke and Rapoport, Amnon, "*Depth of reasoning in strategic form games",* The Journal of Socio-Economics, Vol. 35, 2006, pp.31-47
26. Olsen, Robert A., "*Behavioral finance and Its Implications for Stock-Price volatility*" , Financial Analysts Journal, Vol. 54, No. 2, March - April, 1998, pp.10-18
27. Sbriglia, Patrizia, "*Revealing the Depth of Reasoning in p-Beauty Contest Games*", Experimental Economics, Volume 11, No.2, 2008, pp.107-121
28. Shleifer, Andrei, "*Inefficient markets: An introduction to behavioral finance*", Oxford University Press, April 2000
29. Slonim, R. L., "*Competing Against Experienced and Inexperienced Players*" Experimental Economics, Vol. 8, 2005, pp.55-75
30. Sonnemans, Joep and Tuinstra, Jan, "*Positive Expectations Feedback Experiments and Number Guessing Games as Models of Financial Markets*", Tinbergen Institute Discussion Paper, August 22, 2008
31. Stahl, Dale O., "*Boundedly Rational Rule Learning in a Guessing Game*", Games and Economic Behavior, Vol. 16, 1996, pp.303-330
32. Sutter, Matthias, "*Are Four Heads Better than Two? An Experimental Beauty-Contest Game with Teams of Different Size*," Economics Letters, Vol. 88 (1), 2005, pp.41-46
33. Tyran, Jean-Robert, "*Unpublished Lecture Notes*", MA Course - Behavioral and Experimental Economics Fall 2006.
34. Weber, Roberto A., "*Learning with no feedback in a competitive guessing g*ame", Games and Economic Behavior, Vol. 44, 2003, pp.131-144
35. Woodworth, R.S., "*Accuracy of voluntary movements"*, Psychological Review, 1899, 3, 1–101.