An Investigation of Video Experiment on Dynamic Bargaining Game

Wanbo Lu, Zhenxin Li, and Huihui Li

***Abstract*—Experimental economics has been became one of the most active areas in economics nowadays. Based on the data and copy from a video experiment on the dynamic bargaining game conducted at Sichuan University recently, this paper studies the factors influencing negotiating behavior, the hypothesis of rational economic man in the dynamic bargaining game experiment. Our experiment simulates the non-cooperative two-person characteristic function game. We find that the fairness and patience do impact the bargaining behavior in the experiment and the hypothesis of rational economic man is threatened to some extent. At most of time, economic man is bounded rationality, resulting in a deviation from the optimum strategy, challenging the classical game theory in a sense.**

***Index Terms*—Bounded rationality, characteristic function, fairness, nonparametric test.**

I. Introduction

For a long time, economics is considered as a social science which must depend on observing the world, rather than natural science (such as physics, chemistry) relying on experiment method. With the extension of the research areas of economics, experimental economics has become one of the most active areas nowadays. The 2002 Noble Prize in Economics was awarded to Smith who studies experimental economics [1] and Kahneman who studies psychological economics [2]. Video experiment method is used widely in the researches, see e.g. Greiner, Güth and Zultan [3] and Hennig-Schmidt, Walkowitz and Geng [4].

A complete video experiment includes the following elements: 1) Experimental design consists of experimental purposes, incentive medium, choice of the participants and so on, is the first step and also the most important step. 2) Preparing experimental equipment and recruiting the participants. Participants should sign the agreement and agree that the video tapes and sound image can be used and only for academic research. 3) The procedures of experiment mainly includes the role assignment, introducing the experimental rules, recording the decision-making process, paying for experiment when finishing, etc. 4) Saving and coping the video, then collecting the data. 5) Analyzing the data and the copy, then reporting the outcomes. This is the final but the most difficult step. Hennig-Schmidt has introduced the method of video experiment in detail in the book [5].

In literature, experiment economics is bound together with the development of economics. Roth has pointed out that the existing literatures of experimental economics can trace back to the 1930s-1960s when there were three thoughts, one of which appeared with the development of game theory [6]. The bargaining game is that two players (or more) negotiate on the allocation of a sum of profits, if conflict, the negotiation fails to reach an agreement. The earlier researches on bargaining is cooperative game theory, which has been quite mature, see e.g. Bruce and Clark [7] and Zhao *et al*. [8]. In contrast, the non-cooperative game theory, see e.g. Frechette, Kagel, and Morelli [9] and Kultti and Vartiainen [10], are continuously developed. One of the basic models of structural bargaining in static situation is ultimatum game. The earliest results of simulation experiment of which reported by Güth *et al*. [11]. Then, the development of the authoritarian bargaining game, see Desal, Olofsgard and Yousef [12], the obedient game, the gift exchange game in one static stage and the trust game and so on play a great role to promote economic theory to a large extent. The dynamic bargaining game has many rounds to complete negotiation for both sides, they can bargain repeatedly until to reach an agreement, otherwise the negotiation breaks down. Now it mainly focus on two rounds, the earliest result of which reported by Binmore, Shaked and Sutton [13], we must acknowledge that the field of three or more rounds is immature.

On the other hand, it is much meaningful to reveal the general laws of humans in the bargaining in a deeper level from the empirical point of view, due to the fact that the research on the dynamic bargaining game is complex and pioneering. In this paper, with the method of video experiment, we will focus on some interesting problems. We hope to draw some meaningful conclusions with the technology of video experiment.

II. Experimental Design and Model

Dynamic bargaining is common in the international and domestic commercial trade. What we will conduct is infinite bargaining game so we can observe their decision making process, this model is based on the distribution of a sum of profits between two asymmetric-power companies or enterprises. Two sides in the video experiment make corresponding decision due to the other's decision written in text transmitted by experimenter and don't talk to each other until the experiment is over. Here, participants who are selected randomly can get some cash as an incentive, and the

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payoff depends on the behavior. We make sure they can receive some cash if the negotiation breaks down with determining the payoff in advance. The amount of payoff is as many as they can get from part-time job in per hour. After two sides reached the isolated experimental sites on time, we began to draw lots randomly to assign the roles, strong group and weak group. If the negotiation breaks down, the payment paid to the strong group is four times as much as the weak. Many researches have shown that three participants are enough ([14], [15]), so we decide that each group consists of three people. The rule of the minority obeying the majority helps to solve the dispute. The video experiment began if there is no question. Organizers must interrupt negotiation and told them only 20min remained when negotiation exceeded the time limit. If they still could not reach an agreement in the remaining time, the negotiation is forced to break. So we know that either experiment ends with an agreement or the negotiation break down.

Our experiment simulates the non-cooperative two-person characteristic function game (Selten, [6]). Supposing that the set of players is $N=\{1, 2, \ldots, n\}$, the subsets of N are alliances of players. For any $C \subset N$, defining a mapping v: $C \rightarrow N$, then, v is the characteristic function, as for $\varphi \subset N$, defining $v(\varphi)=0$, the characteristic function of an alliance can be considered as the total amounts of cash to be allocated to the players included in the subset C after reaching an agreement. The basic idea, framework and procedures of the bargaining game model are shown in Fig. 1. We give the explanation of the game and procedures as follows:

1) Initial sending groups. Sending group in the first round is determined randomly (rectangular 1), they must decide whether to distribute the alliance profit (rhombus 2) or not. If they don't, the negotiation breaks down; if they do, the distribution scheme will be submitted to the other side, then, the former become new receiving group.
2) Distribution of alliance profit. It is put forward by sending group (rectangular 3), the total alliance profit of all players is v_{12}. Supposing that initial endowment of the strong group is v_1, the weak group is v_2, and $v_1>v_2$, $v_1+v_2< v_{12}$, $v_1+v_2=\frac{1}{2}v_{12}$, q_s is the profit distributing to the strong group, q_w is the profit distributing to the weak group. There are five fair and reasonable solutions for distribution of the alliance profit:

- ES (Equal Split): $q_s=q_w=\frac{1}{2}v_{12}$, $q_s+q_w=v_{12}$
- PS (Proportional Split): $q_s=2v_1$, $q_w=2v_2$, $q_s+q_w=v_{12}$
- SD (Split the Difference): $q_s=v_1+\frac{1}{4}v_{12}$, $q_w=v_2+\frac{1}{4}v_{12}$
- MEPS (Mean of ES and PS, equal to SD):

$$q_s=\frac{ES+PS}{2}=\left(\frac{1}{2}v_{12}+2v_1\right)\Big/2=v_1+\frac{1}{4}v_{12}$$

$$q_w=\frac{ES+PS}{2}=\left(\frac{1}{2}v_{12}+2v_2\right)\Big/2=v_2+\frac{1}{4}v_{12}$$

- MESSD (Mean of ES and SD):

$$q_s=\frac{ES+SD}{2}=\left(\frac{1}{2}v_{12}+v_1+\frac{1}{4}v_{12}\right)\Big/2=\frac{1}{2}v_1+\frac{3}{8}v_{12}$$

$$q_w=\frac{ES+SD}{2}=\left(\frac{1}{2}v_{12}+v_2+\frac{1}{4}v_{12}\right)\Big/2=\frac{1}{2}v_2+\frac{3}{8}v_{12}$$

In the five solutions above, only ES distributes the same amount of profit between two sides, the others all are $q_s>q_w$.

1) Receiving group. It is a group which can accept or reject the distribution solution put forward by the sending group (rhombus 4). The receiving group in the first round is determined randomly. If they agree with the solution, two sides reach an agreement, or they become a new sending group (rectangle 6) on the condition that it spent less than the maximum time determined previously. The role of receiving group alternates between two sides constantly too.
2) Interruption of the negotiation. Generally speaking, three hours is a maximum time, avoiding that players are too tired to affect the experimental result. Our experiment is no exception. During the maximum time, we set up a breakpoint (rhombus 5). When the breakpoint is up, organizers will interrupt the experiment. At this time, two sides still have 20min to negotiate.
3) End of the game. They may either reach an agreement (rectangle 8) or break the negotiation (rectangle 7). Whatever the result is, the experiment is done.

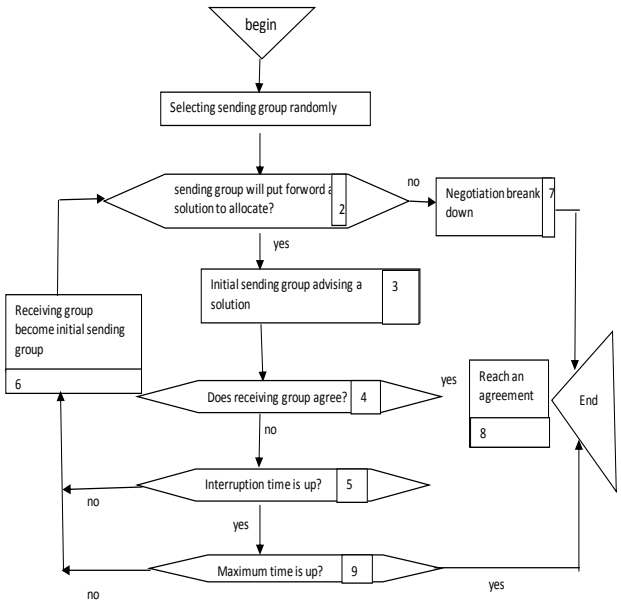

Fig. 1. The flow chart of game process.

From all above, we know that the decision motives and negotiation strategies between the strong and weak group are different and the point is that the former has more endowment. Essentially, this is twice cooperative game. Firstly, intra-group (three people) arrives at a consensus decision cooperatively, and secondly, inter-groups negotiate to reach an agreement cooperatively too.

III. Analysis of the Experimental Result

Recently, we have conducted a video experiment in Sichuan University. There are nine groups of participants in three days experiment. In the experiment, the initial endowment of the strong and weak group is v_1=128 and v_2=32, respectively. The ratio of v_1: v_2=4:1. The total alliance profit of players was 320 points. There were seven groups reaching an agreement, the others failed. We totally recruited 54 participants. They came from department of mathematics (26 persons), economics (25 persons), art design (one person), life sciences (one person) and computer science (one person), respectively. In the end, we got a video lasting 30 hours and organized text materials which had about 800 pages. Both of them provide us important reference to analyze motivation, behaviors, emotion of the participants. We mainly discuss this experiment from following two aspects.

A. Analysis for the Factors Influencing Bargaining Behaviors

Decision-making in bargaining may be influenced by many factors. Here, we mainly investigate the influence of their fairness psychology, patience and the asymmetric incentive on the bargaining and then make a reasonable explanation.

In recent years, more and more evidence have proved that economic men are altruism now. Therefore, the fairness psychology has become a main variable to explain why bargaining behavior deviate from the rational expectations. Here, we discuss the existence of the fairness psychology and its influence on the negotiation.

The players could identify solutions presented in the Section two, and discussed which solution was fair. We made a comparison using the initial expectation level and found that strong groups allocated themselves 262 averagely in the first round, weak groups only 177.67. We made a Mann-Whitney nonparametric test on the points that two sides gave to strong group and find that there were significant difference (p=0.010).

We notice that all the players had realized that ES is a sensitive solution. Though strong group realized ES may be fair for the weak group, they show disgust obviously (Mann-Whitney, p=0.020). All strong groups want to get more points than ES. But, weak group don't show disgust obviously (Mann-Whitney, p=0.058). The payoffs of all the weak groups less than or equal to the mean value (160 points) have a share of 50.3% in average. So we believe that strong groups show obvious disgust for the fairness, the weak groups don't. As seen from above, the influence of fairness increases the possibility of failing to reach an agreement.

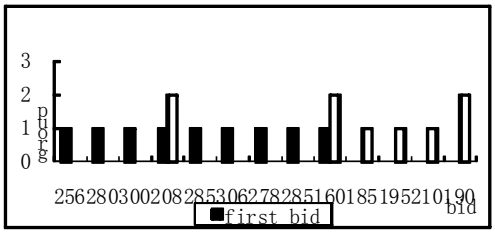

Fig. 2. The bid distribution of strong groups.

As shown in Fig. 2 and Fig. 3, players' final bid differ greatly from the initial bid. There is significant difference (Mann-Whitney, p=0.007 for strong group and p=0.002 for weak group). That is to say, the expectation level is adjustable. We made a nonparametric test for the final bid of strong group and weak groups, for the average initial bid for both groups. There were not obvious significant difference (p value is 0.121, 0.042, respectively), indicating that expectation level is affected by the psychology of fairness, then tends to a certain principle of fairness in the end or is adjusted to a level between the initial expectation levels of strong group and weak group. As seen from Table I, most payoffs adjusted to between MESSD and SD. So we think that the existence of much fairness psychology is an important factor to collapse the negotiation, but at the same time, expectation levels are adjusted by the effects of fairness psychology so that the negotiation can reach an agreement.

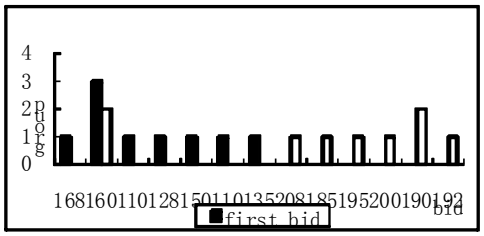

Fig. 3. The bid distribution of weak groups.

TABLE I: The Distribution of the Allocation

Solution	ES	PS	SD	between SD and MESSD	MESSD
Strong group	2	0	2	5	0
Weak group	2	0	1	6	0

During the negotiation, the patience is also an important factor. In our experiment, there are no groups terminating the negotiation initiatively. Among them, 5 groups exceeded the time limit. The average negotiation time of the 9 groups is 177.7 minutes. The average times of quoting were 106.6. By observing the video copy, we find that the players use 13 different words to describe the interruption, but only one word really meant termination. We constructed a simple indicator to depict the degree of patience, $T_i = 1 - \frac{J_i}{R_i}$. For the i-th group, R_i is the quotation times, J_i is the adjustment times, and T_i is the degree of patience. Particularly, when $R_i = 1$, we have $J_i = 1$, $T_i = 0$; when $R_i = J_i \neq 1$, we still have $T_i = 0$, which shows that the player have no patience at all to participate in the negotiation. In contrast, when $J_i = 0$, we have $T_i = 1$, suggesting that the players have enough patience to participate in negotiation. More nearer this indicator is approaching to 1, the greater the degree of patience. More nearer this indicator is approaching to 0, the smaller the degree of the patience. Since the players are divided into strong group and weak group, we measure each group using maximum degree of the patience $T_{mi} = \max(T_{si}, T_{wi})$, where T_{si}, T_{wi} are degree of patience of strong group and weak group, respectively. By calculating, the average of maximum degree of the patience

for all groups is $T_m = \frac{1}{9}\sum_{i=1}^{9} T_{mi} = 56.06\%$. There are no obvious significant difference for degree of patience between the strong and weak groups (Mann-Whitney, p=0.930). It shows that both strong and weak groups had great patience in the negotiation. Besides, Pearson correlation test for degree of patience and final payoffs are made respectively for strong and weak groups, both of them had a positive correlation (p is 0.007,0.014, respectively). It shows that the greater degree of the patience, the more rounds they will negotiate, the longer they will spend and the higher of payoff for final distribution they will expect. At this time, they don't want to terminate the negotiation initiatively or break down the negotiation.

According to the concept of Nash bargaining solution [17], bargainers' final payoffs should reflect power differences, so they should come to an agreement on SD. According to the views of the Binmore, *et al*. ([18], [19]), the experimental result cannot explain the asymmetry in power, and the players should come to an agreement on ES unless payoffs get from this division less than conflict payoffs. In the experiment, we still use expectation level to measure the feeling of the asymmetric power. We define the maximum expectation level to be the points that the players think they deserve and ought to appear in the payoffs. We made the Mann - Whitney nonparametric test for the maximum expectation levels of the strong group and weak group (p=0.004), suggesting that both groups feel the difference in their power comparing with the other group under asymmetric incentive, and admitted asymmetric mechanism given by the experiment setup. By analyzing the experiment copy, we have verified the phenomena reflected by the expectation levels. Both sides have taken conflict payoff into consideration when calculating the profit. At the same time, they calculate the degree of deviation from SD. The mean of final expectation levels of strong groups and weak groups are 189.56 and 133.33 respectively, which is between MESSD and SD. This suggests that players prefer the solution of MESSD, but in fact, there is a little deviation due to the fairness psychology of the players when negotiating.

B. Hypothesis of Rational Economic Man in the Dynamic Bargaining Game

The classical game theory is premised on the hypothesis of rational economic man which assumes that economic man has complete knowledge and enough ability to make a logical analysis to achieve maximization. It builds a rigorous theoretical framework and introduce analysis method of mathematical model which have high logical, providing a strong support for mainstream economics. On this basis, the rational expectation theory pushes the behavior rationality of economic man to the peak. However, the research shows that there is obvious limitation when people are thinking and cognizing. Simon is first to make a contribution to the pioneering development of economic man hypothesis [20]. He holds that rationality embodies in substantive rationality and procedural rationality, and traditional economics only use the essential rationality, so he further put forward the concept of bounded rationality. Recently, Tversky and Kahneman have observed that people tend to be biased, imagine the big from the small, only pay attention to subjective condition probability and neglect the prior probability in the real economy and life [21]. They discovered most individuals are not rational and don't avoid risk, in most cases they are irrational and have anomalous preference when facing uncertainty.

Under the hypothesis of complete rationality, the players accept any payoff higher than collision payoff, preferring a higher and rejecting a lower. It is irrational to break negotiation so they can reach an agreement. Here, rationality has two meanings: one is individual rationality, that is, a rational player will not accept any payoff lower than conflict payoff. The other one is joint rationality, that is, that both sides reach an agreement about distribution of profit will bring each other more payoff than conflict payoff. However, an irrational phenomenon that violates rational expectation happened in our experiment. In one session, under the situation that weak group asked 120 points 5 times continuously, the strong group made concessions constantly, from 230 down to 210, finally, it chose to give up negotiation. In another session, strong group made concession from asking 288 to 208, but the weak group asked 192 in continuous 7 times, finally, the negotiation broke down. In Section 3, we have analyzed that expectation level of players was affected by various psychologies of fairness, increasing the possibility of breaking the negotiation. Therefore, we believe that the rational hypothesis of economic man would be affected by the psychology of fairness, so that they change the preference and then make a decision against rationally. We also find that there is no obvious evidence proving that bargainers use the optimization method to obtain maximum profit. From the perspective of rational man，the players should make corresponding strategy according to the opponents' strategy, bargainers tend to rely on their own expectation, but the expectation adjusts constantly with the repetition of behavior process. Based on the above discussion on expectation level, we know that players' expectation adjusts due to the fairness psychology. Therefore, we think that the rationality of the rational economic man will be affected by whether the behavior is repeated, resulting in that the preference between initial interest and long-term interest transfers.

The above mentioned phenomena violating the classical rational hypothesis have aroused our attention to fairness and altruism. When people make a decision, they choose the strategy satisfying themselves rather than the optimal strategy to obtain maximum benefit. Meanwhile we notice that individual has a certain degree of psychological tendency and cannot be aware of the inherent psychological deviation so as to fix the decision-making behavior, so people's irrational subjective strategy result in some irrational negotiation outcomes.

IV. Summary and Conclusion

To sum up, there is no definite conclusion on the accuracy of non-cooperative game theory. But in any case, dynamic bargaining game plays an important role to promote and deepen this important theory research on bargaining behavior. It mainly reveals a general law of human bargaining behavior

in a deeper level from the experiment (empirical) view now. In this paper, we focus on the influence of fairness, degree of patience and incentive mechanism on the behavior of players and some interesting problems in a specific experiment of dynamic bargaining game.

At the same time, to put the irrational emotional factors into the research of experimental economics faces a difficult problem, which is how to measure or compare the magnitude. In this paper, we try to make a quantitative analysis and draw some meaningful conclusions. However, as for the experiment research on the dynamic bargaining game, we should make a further discussion on the difference of individuals bargaining behavior under different cultural background and also a further discussion on the strategy and the process of learning in the bargaining, etc. Thus we can more close to the person's real nature of psychology, build more accurate theory model and revel the general law of human bargaining in a deeper level, thereby, form scientific theory of bargaining behavior.

REFERENCES

[1] V. L. Smith, "Method in experiment: Rhetoric and reality," *Experimental Economics*, vol. 5, pp. 91-110, Oct. 2002.

[2] D. Kahneman, "Maps of bounded rationality: A perspective on intuitive judgment and choice," presented the Nobel Prize lecture at Aula Magna, Stockholm University, December 8, 2002.

[3] B. Greiner, W. Güth, and R. Zultan, "Social communication and discrimination: A video experiment," *Experimental Economics*, vol. 15, pp. 298-417, Sep. 2012.

[4] H. H. Schmidt, G. Walkowitz, and H. Geng, "On the nature of fairness in bargaining-experimental evidence from Germany and PR China," Beiträge zur Jahrestagung des Vereins für Socialpolitik 2010: Ökonomie der Familie - Session: Cultural Influences on Economic Behaviour, No. C13-V3, 2010.

[5] H. H. Schmidt, "Bargaining in a video experiment-determinants of boundedly rational behavior," *Leture Notes in Economics and Mathematics Systems*, Springer Verlag, Berlin, Heidelberg, New York, London, Paris, Tokyo *et al*., vol. 467, 1999.

[6] A. E. Roth, "On the early history of experimental economics," *Journal of the History of Economic Thought*, vol. 15, pp. 184-209, 1993.

[7] C. Bruce and J. Clark, "The impact of entitlements and equity on cooperative bargaining: an experiment," *Economic Inquiry*, vol. 50, pp. 867-879, Oct. 2012.

[8] Y. X. Zhao, S. Y. Wang, T. C. E. Cheng, X. Q. Yang, and Z. M. Huang, "Coordination of supply chains by option contracts: A cooperative game theory approach," *European Journal of Operational Research*, vol. 207, pp. 668-675, Dec. 2010.

[9] G. R. Frechette, J. H. Kagel, and M. Morelli, "Gamson's law versus non-cooperative bargaining theory," *Games and Economic Behavior*, vol. 51, pp. 365-390, May 2005.

[10] K. Kultti and H. Vartiainen, "Multilateral non-cooperative bargaining in a general utility space," *International Journal of Game Theory*, vol. 39, pp. 677-689, Oct. 2010.

[11] W. Güth, R. Schmittberger, and B. Schwarze, "An experimental analysis of utimatum bargaining experiments," *Games and Economic Behavior*, vol. 3, pp. 367-388, Dec. 1982.

[12] R. M. Desal, A. Olofsgard, and T. M. Yousef, "The logic of authoritarian bargains," *Economics and Politics*, vol. 21, pp. 193-125, Mar. 2009.

[13] K. Binmore, A. Shaked, and J. Sutton, "Testing non-cooperative bargaining theory: A preliminary study," *American Economic Review*, vol. 75, pp. 1178-1180, Dec. 1985.

[14] C. R. Plott, "Industrial organization theory and experimental economics," *Journal of Economic Literature*, vol. 20, pp. 1485-1527, Dec. 1982.

[15] V. L. Smith, "Markets as economizers of information: Experimental examination of the hayek hypothesis," *Economic Inquiry*, vol. 20, pp. 165-179, Apr. 1982

[16] R. A. Selten, "No-cooperative model of characteristic-function bargaining," in *Game Theory and Mathematical Economics*, R. J. Aumann, Ed., Bibliographisches Institute AG, Mannheim, Wien, Zürich, 1981, pp. 131-151.

[17] J. Nash, "The bargaining problem," *Econometrica*, vol. 18, pp. 155-162, Apr. 1950.

[18] K. Binmore, A. Shaked, and J. Sutton, "An outside option experiment," *The Quarterly Journal of Economics*, vol. 104, pp. 753-770, Nov. 1989.

[19] K. Binmore, P. Morgan, A. Shaked, and J. Sutton, "Do people exploit their bargaining power? An experimental study," *Games and Economic Behavior*, vol. 3, pp. 295-322, Mar. 1991.

[20] H. Simon, "From substantive to procedural rationality," in *Method and Appraisal in Economics*, S. Latsis, Ed., 1976, pp. 129-148.

[21] A. Tversky and D. Kahneman, "Rational choice and the framing of decisions," *The Journal of Business*, vol. 59, pp. 251-278, Oct. 1986.

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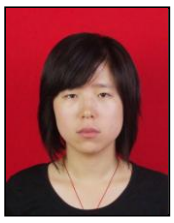

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