Role of Information Asymmetry in a Public Goods Game for Climate Change

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ABSTRACT: *Atmospheric carbon-dioxide concentration and global temperatures are increasing at an alarming rate. Global cooperation is much needed; however, little is currently known on how information asymmetry among world players influences emergence of cooperation. In this paper, we study the role of information asymmetry about monetary investments among human players using a modified form of a repeated public goods game for Earth's climate (called, "climate game"). In the climate game, a group of four human players (representing different world economies) play repeatedly against each other where in each round a player decides how much money to contribute to a green fund (the money not invested in the green fund accrues interest as private investment for a player). In an experiment, 6 groups participated in the game across two between-subjects conditions: Info-NoInfo and NoInfo-Info. In Info-NoInfo condition, 3 groups first played the climate game for 50 rounds where information on opponents' contribution to green fund was known to all players. This play was followed by a game where information on opponents' contribution to green fund was not known to players. This information presentation was reversed in the NoInfo-Info condition. Results reveal that contribution to the green fund decreased rapidly when players had information on their opponents' monetary contributions compared to when players did not possess this information. Also, experiencing information in the first game decreased players' contributions to the green fund in the subsequent game. We discuss implications of our findings for emergence of cooperation against climate change.*

1. INTRODUCTION

Climate change has currently become a worldwide phenomenon with disastrous consequences like melting of ice-caps and sea-level rise (Pachauri, 2007). Each year, all countries meet in the Conference of Parties (COP) meetings to discuss and negotiate monetary investments against climate change (UNFCCC, 2014). Although the COPs are a regular event, these negotiations have not resulted in concrete measures against climate change. For example, at COPs there is always speculation among negotiating parties on how much a country or a block of countries is willing to contribute in public funds to avert climate change (Dutt, 2014; 2015). An important aspect of this speculation is how much information a country has about the binding promises of monetary contribution of other countries to public

funds (Dutt, 2014). According to Dutt (2014), sometimes, countries know about the promises of their opponents in advance and sometimes these promises are speculative and hidden from the public.

Although negotiations are an important part of COPs in the real world, very little research has taken place to understand the resulting negotiation behavior in the controlled laboratory environment. Furthermore, prior research has seldom investigated how information asymmetries about contributions made among players influences cooperation against climate change. In this paper, we use a modified form of the classic public goods game (Axelrod, 1997), called "climate game", in order to study these two goals.

In the climate game, just like in the public goods game, players play a game with each other by making yearly monetary investments to a private (personal) fund and a public (green) fund. The end point of the game is not known to the players. The money put in green fund is multiplied by a factor and the return generated is equally divided among all players. In contrast, the money not invested in the green fund is put in a private fund and it earns interest at a constant rate of return. The game takes into account four players, which represent four economic blocks in the world namely high income, middle income, upper-middle income and low income economies. The goal of each player in the game is to earn as much money as possible by making investments in the private and green funds.

Information asymmetries can be created in the climate game by manipulating the information available to players about investments made by their opponents in each round. For example, Tavoni et al. (2011) have manipulated information in a public goods game for climate change, where players decided whether to contribute €0, €2, or €4 to a climate account (a form or green fund) in each of the 10 rounds. After each round, a player was provided information on individual contributions made by other players as well as the aggregate contribution of the group. In the information manipulation condition it was found that contributions decline in presence of availability of other player's contribution as compared to the absence of information.

Similarly, Gonzalez et al. (2014) have reported influence of information asymmetry in decisions making in the Prisoner's Dilemma (PD) game (Rapoport & Chammah, 1965). In this study, as information about opponent actions increased in a repeated PD game, the amount of cooperation across repetitions of play increased as well.

Although prior research has manipulated information availability in abstract 2x2 games (Gonzalez et al., 2014), research that manipulates information availability in an applied domain (e.g., a climate context) is scarce. In this paper, we overcome this scarcity by evaluating the effects of information manipulation in an applied climate-change context using the climate game. For this purpose, we designed the climate game for two scenarios: One with information about monetary contributions is available to opponents and the other, where such information is not available to opponents. We use these two scenarios in a human experiment reported ahead in this paper.

In what follows, first we illustrate the model that is used for developing the climate game. Next, we report an experiment where we manipulated information asymmetry among human players playing the climate game. We report the results from our experiment and highlight the implications of our findings for negotiation behavior against climate change.

2. A MODEL FOR CLIMATE CHANGE

The climate game contains four players, which represent four economic blocks, namely, high income, middle income, upper-middle income and low income economies. This classification of economic blocks into four categories is based upon World Bank data (World Bank, 2015). The payoff for each of these players is defined by the following equation:

$$\pi_i = \sum_{t=1}^{50} \sum_{i=1}^{4} k_i^t (e_t - C_i) + \frac{1}{4}[k_1 * C_1 + k_2 * C_2 + k_3 * C_3 + k_4 * C_4] \quad \ldots(1)$$

where i = 1, 2, 3 and 4 for the four different economic blocks respectively; t = rounds from 1 to 50; e_t is yearly endowment (income) given in form of

GDP; C_1, C_2, C_3 and C_4 are contributions of 4 players to their respective green fund in each round *t*; k_1, k_2, k_3 and k_4 are the return on investments on the amounts contributed to green fund by players 1, 2, 3 and 4; k'_1 is the investment contributed to private fund by different players; and, π_i is the payoff for different players.

Table1. *Values of return on investments on the amounts contributed to the green fund by respective players and investment contributed to private fund by high, upper middle, middle and low income economies respectively*.

Coefficients for the return amounts contributed to green fund	Values of the return amounts contributed to green fund	Coefficients for the amount contributed to private fund	Values of the amount contributed to private fund
k_1	2	k'_1	1.05
k_2	1	k'_2	1.02
k_3	0.8	k'_3	1.06
k_4	0.2	k'_4	1.03

The different k values contributed to green fund is derived based on social dilemma condition (Hoven, 2013)

$$1 < \frac{\sum_{i=1}^{4} k_i}{k_i'} < 4 (2)$$

The different k' values are obtained from the saving bank interest rates of four economies is based on World Bank data (World Bank, 2015). Social dilemmas are situations in which an individual profits from selfishness unless everyone chooses the selfish alternative, in which case the whole group loses. It is a challenging situation as acting in one's immediate self-interest is tempting to everyone involved, even though everybody benefits from acting in the longer-term collective interest.

3. HYPOTHESIS

In the information condition (Info), players are aware of the contributions made by their opponents to the green fund after each round of play. While in the no information condition (NoInfo), players do not know about their opponents' contributions to the green fund. Logically, hypothesis H1 states that in the Info condition, players' contribution will be less than that in the NoInfo condition. This happens because in the Info condition, participants can see how much others are contributing to the green fund and this knowledge causes them to stop or reduce their contribution to the green fund, overtime; however, such knowledge is not there for the participants in the NoInfo condition and thus they do not decrease their contribution to green fund as in the information condition do. Also, this expectation is supported by the results by Tavoni et al. (2011). Hypothesis H2 states that a first exposure to the Info condition will decrease participants' contributions to green fund in a subsequent condition more than a first exposure to the NoInfo condition. This expectation is due to the presence of information in the Info condition and that people show learning effects. In general, Info condition causes people to stop contributing over rounds of play as compared to NoInfo condition. Thus, when people have a prior exposure to NoInfo condition, they tend not to decrease their contribution rapidly; rather, the contribution (though less) remains constant across rounds. Furthermore, when people have prior exposure to the Info condition, they tend to sharply decrease their contributions due to the presence of information.

4. METHOD

***Experimental design*:** In the experiment, 24 participants were divided into 6 groups, where each group consisted of 4 participants. The climate game was played across two between-subjects scenarios: Info-NoInfo and NoInfo-Info. Out of 6 groups, 3randomly selected groups played Info-NoInfo scenario in which the Info condition was played first and it was followed by play in the NoInfo condition. In the Info condition, contributions to the green fund were known to all players in each round; whereas, in NoInfo condition, contributions to the green fund were not known to players across all rounds. Similarly, three randomly selected groups played NoInfo-Info scenario, where the order of presentation of the Info and NoInfo conditions was reversed. As shown in Figure 1, in all conditions, players received certain yearly income and they had to decide as to

how much of that income players want to invest in the green fund for averting climate change. The amount not invested in the green fund is players' private income. This private income could be invested in a bank account and this income may accrue certain simple interest.

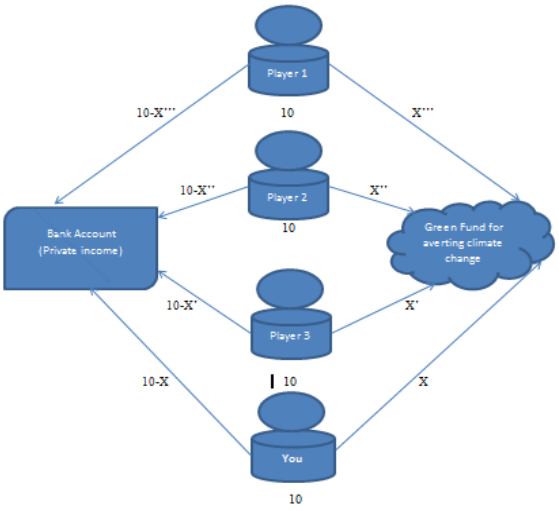

Figure1. *The game uses a fictitious currency EC. Each player gets yearly income of 10 million EC. All players decide to invest a part of this income (X, X', X'', or X''' million EC) in a green fund for averting climate change. The remaining money is stored in a bank account and it accrues a simple interest. The money contributed by all players in the green fund is multiplied by certain multipliers and then summed together. This sum is then equally divided among all players. Each player payoff at the end of a round is the sum of the return on investments obtains from the bank and the green fund.*

Total payoff at the end of each round is the sum of return on investments from the green fund and that from the money invested in private fund. The goal is to maximize total payoff in the climate game by making investments in the green and private funds. Both Info and NoInfo conditions of climate game in each of the two scenarios were run for 50 rounds.

Participants: Twenty-four graduate and undergraduate students from diverse fields of study participated in this experiment, comprising 14 females and 10 males. Ages of the participants range from 18 to 44 years. In self-reports, 56% of participants indicated having heard of public goods game through television, websites, newspapers, magazines or some other means. Also, 90% of participants reported they either completed or are currently pursuing degrees in science, technology, engineering, and management (STEM).All participants received a base pay of Rs 10. The participants could earn an additional maximum bonus of Rs 20, based on their performance in the climate game. Players received base pay of Rs 10 for participating in the experiment and players total payoff at the end of the game was be converted into real money in the following ratio: 1,000 million EC payoff in the game = 10 INR in real money. At the end of the experiment, players' total payoff in million EC in both scenarios was converted into INR and this money was paid to players in addition to the base payment.

Procedure: Participants were given instructions before they were made to play the climate game. The instructions were given online before the study began. Each participant filled their consent form, demographics information and then went through the online instructions. As part of the instructions, participants were shown an image of what would happen in climate game (Figure 1) and how they may contribute to the two funds from the endowments they received in each round. Once participants acknowledged that they understood the game and the task requirements, they were allowed to interact with the climate game on computer terminals.

5. RESULTS

5.1 Payoff differences between Information and No-Information Conditions (H1)

First, we tested hypothesis H1. Figure 2 shows average contribution to the green fund across 50 rounds in both versions of game, Info and NoInfo. The lines for each condition in Figure 2 are averaged across 24 participants across both scenarios. In both conditions, contribution to the green fund reduced rapidly. Although the contributions to the green fund were higher in the Info condition compared to the NoInfo condition, this pattern reversed with increasing number of rounds. The average contribution in Info condition was lower than that in the NoInfo condition between rounds 25 and 50 (NoInfo = 2.84 > Info = 2.50). These results support hypothesis H1.

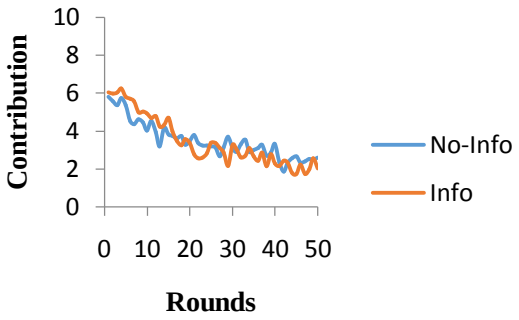

Figure2. *Average contributions to the green fund in information and no-information condition across 50 rounds.*

5.2 Learning Effects of Information and No-Information Conditions (H2)

Next, we tested hypothesis H2. For this purpose, we compared average contributions to the green fund in the NoInfo condition played before and after the Info condition (i.e., effect of information; see Figure 3).Also, we compared the average contribution to the green fund in Info condition played before and after the NoInfo condition (i.e., effect of no-information; see Figure 4).

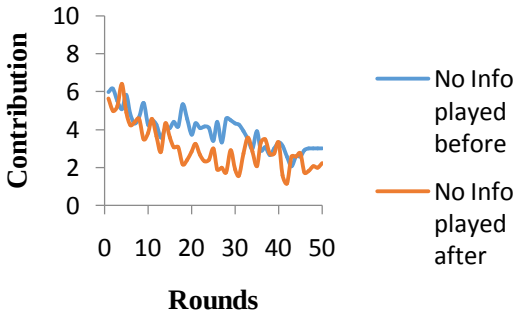

Figure3. *Average contributions to the green fund in no-information condition played before and after information condition across 50 rounds.*

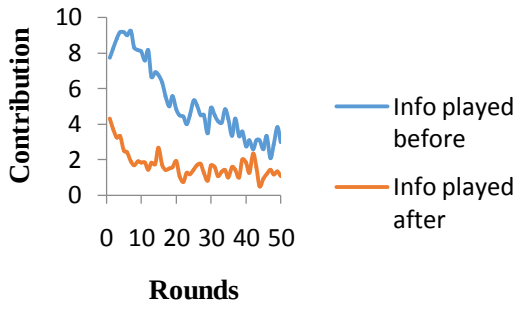

Figure4. *Average contributions to the green fund in information condition played before and after the no-information condition across 50 rounds.*

As shown in Figure 3, playing Info condition first had an impact on participants' performances in the subsequent NoInfo condition, namely, a decrease in contributions to the public fund. As shown in figure, contribution to green fund reduced rapidly for the participants who played Info condition before the NoInfo condition. Thus, when people have prior exposure to the Info condition, they tend to decrease their contribution to the green fund sharply in the subsequent NoInfo condition. However, the effect reverses if participants play the NoInfo condition first. As shown in Figure4, the contribution to the green fund was not reduced rapidly in the subsequent Info condition when participants played NoInfo condition first. Thus, when people have no prior exposure to opponent information, they tend not to decrease their contribution to the green fund across rounds in the information condition. Furthermore, Figure 4 also shows that participants who played NoInfo condition first contribute lesser amounts to the green fund in the subsequent Info condition compared to participants who did not play the NoInfo condition first. This latter effect is attributed to the absence of information about opponent contributions in the NoInfo condition.

6. DISCUSSION AND CONCLUSION

Our study used an experiment with human players to test investment decisions towards averting climate change in the presence and absence of information about opponent contributions. At first we tested average contribution to the green fund across 50 rounds in both versions of game i.e. information and no information. In both conditions, contribution to

the green fund reduced rapidly. Although the contributions to the green fund were higher in the information condition compared to the no information condition, this pattern reversed with increasing number of rounds. Then, we tested average contributions to the green fund in no information condition, which was played before and after the information conditions across 50 rounds (i.e., the effect of information). It was observed that when people have a prior exposure to opponent payoff information, they tend to decrease their contribution rapidly. Finally, we tested the average contributions to the green fund in information condition played before and after the no-information condition across 50 rounds (i.e., the effect of information).Thus, when people have no prior exposure to opponent information, they tend not to decrease their contribution to the green fund sharply in the following information condition.

In the information condition, participants can see how much others are contributing to the green fund and this knowledge causes them to stop or reduce their contribution to the green fund, overtime; however, such knowledge is not there for the participants in the no information condition and thus they do not decrease their contribution to the green fund as in the information condition. As a result, the no-information condition produces higher payoffs to the green fund compared to the information condition. Thus, results, in particular after the 25^{th} round, are as per our expectation in H1. Results before the 25^{th}round could be attributed to participants learning the game dynamics.

Furthermore, according to our hypothesis H2 we find that people show learning effects. In general, information condition causes people to stop contributing over rounds of play and no information condition does not. Thus, when people have no prior exposure to information, they tend not to decrease their contribution rapidly; rather, the contribution (through less) remains constant across rounds. Furthermore, when people have prior exposure to information, they tend to more sharply decrease their contributions due to the presence of information itself.

This study is the start of a large research program that investigates how public contributions for averting climate change is influenced by a number of ecologically valid factors. In the immediate future, we would like to extend this game by including stochastic losses due to climate change as part of a player's payoff.

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