

**Understanding inequality in the public goods game: effects of heterogeneous endowment
and heterogeneous punishment on cooperation**

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ABSTRACT

In the experiments presented, we look at the effects of heterogeneous endowment and heterogeneous punishment on cooperation as measured by percent contribution in a modified standard public goods game. We model inequality using Gini-coefficients and provide a systematic method for calculating Gini coefficients for heterogeneous endowment public goods games. Across 10 conditions of inequality ranging in Gini coefficient value from 0.02 to 0.80, we found that endowment level and inequality have a negative effect on cooperation. We also present a forthcoming experiment that investigates how absolute vs proportional punishment effects cooperation and predict that absolute punishment will have little effect at high inequality but that proportional punishment will increase cooperation. Together these findings will clarify the role of inequality in cooperation and provide a better understanding how to effectively sanction in the presence of inequality.

INTRODUCTION

Studying cooperative behaviour in the presence of social dilemmas is most frequently studied using the public goods game (pgg), and most often involves homogenous endowment and homogeneous punishment conditions. For these cases, the literature is quite exhaustive (e.g., Chaudhuri, 2011). However, while cooperative contributions to a public pool may lead to increases in overall wealth of a group, this cooperation can still lead to increases in inequality; further mechanism for promoting cooperation, such as sanctioning, do not seem to decrease increases in inequality (Gächter et al, 2017). This leaves open the question of how inequality arises, and what mechanisms are effective in promoting the wealth of the group while mitigating or even decreasing inequality. We aim to contribute to this body of literature by first investigating the effects of

inequality across a range of inequality levels and by investigating if inequality can be mitigated or reduced when all members of a public goods game can use heavy-handed punishment, not just those who have high endowments.

Inequality in public goods games, heterogeneous endowment, is modelled by assigning each participant unequal initial endowments. While this is a relatively common practice, there is no standard method for modeling inequality in a public goods game. In some studies, Gini coefficients have been used with to create clear inequality levels (e.g., Nishi et al, 2015). However, to our knowledge, heterogeneous inequality has not been measured across a full range of Gini coefficient demarcated inequality values. Typically, the Gini coefficient is used to quantify country's level of income inequality, the degree which a country's wealth is unequally distributed. The Gini coefficient has a minimum value of 0 (perfect equality) and a maximum value of 1.0 (perfect inequality). The World Bank (2018) gives the Gini coefficient values for 64 countries with a mean Gini value of $M = 0.355$ ($SD = 0.075$, $Mdn = 0.349$). To give a sense of the range of world Gini coefficients, Finland has one of the lowest Gini coefficient values at 0.273, Spain with a Gini coefficient of 0.347, and Brazil with the highest Gini coefficient at 0.539.

Although the public goods game is an abstraction from real world dynamics, in conjunction with the Gini coefficient, it can be used to create a range of heterogeneous endowment conditions that represent inequality in the various countries around the world. As discussed, inequality can be operationalized as heterogeneous endowment using public goods games. To calculate Gini coefficients for heterogeneous endowment conditions, where there are discrete levels of income distribution, the discrete Lorenz transform can be used. However, the Lorenz curve can take many shapes, and there are theoretically an infinite number of solutions for any given Gini coefficient value. Interestingly, a country's level of economic inequality tends to follow a Lorenz curve

distributed as log-normal (Aitchison, 1957). The Lorenz equation can be given by equations: (1) $L(p) = \Phi(\Phi^{-1}(p) - \sigma)$, and (2) $\sigma = \sqrt{2} \Phi^{-1}\left(\frac{1+G}{2}\right)$ where p is the population percentile, G is the Gini coefficient, and Φ is the cumulative distribution of the standard normal equation, and cumulative income range is given by $0 \leq L(p) \leq 1$ (Aitchison, 1957; Földvári, 2009). To use this equation, all that is needed is the desired Gini coefficient value, and the number of players in the public goods game in question. For example, if we wanted to create a specific case of inequality to represent, say Finland, in a 3-player public goods game, we would use $Gini = 0.273$, and for player A: $p = 0.33$, player B: $p = 0.67$, and player C: $p = 1.0$.

The log-normal equation is a continuous function, however, and when used in a discrete application, results in Gini values that are slightly below expected. Because of this, these values then need to be modified. It is not possible to simply subtract the same amount from each endowment level value until the desired Gini coefficient is achieved, instead we need some value that systematically changes the endowment across all conditions. To do this, we use instantaneous rate of change of the original log-normal Lorenz curve at each value of p . We can then subtract $xL'(p)$ where x is an arbitrary modifier variable. This gives the endowment equation $e(p, x) = L(p) - xL'(p)$. For example, to approximate endowment levels for Brazil, we use $G = 0.54$ to get the initial approximate endowment level values for a 4-person public goods game, we then calculate the actual Gini coefficient and find that is it 0.48 not 0.54, we then choose a modifier value of $x = 0.06$ which shifts all endowment level values systematically to achieve a Gini coefficient of 0.54. This method allows for standardized heterogeneous endowment levels for the public goods game that uses equations that are known to approximate real-world inequality levels.

Hauser (2019) puts forth a mathematical model for addressing stable cooperation as a function of inequality in productivity, endowment, and payoff functional form (linear/non-linear), and it predicts that cooperation stability is depended on these three heterogeneous components. This model of cooperative reciprocity suggests that if endowment inequality exists, and when inequality becomes too extreme, inequality will increase over the evolution of repeated interactions and cooperation will be unfeasible (Hauser et al, 2019). However, empirical findings are mixed as to whether inequality in strategy public goods games leads to cooperation. For example, Colasante et al (2017) show in dynamic public goods game with initial heterogeneous endowment, inequality leads to lowered contributions, while Chan et al (1999) find that endowment heterogeneity has a small but significant positive effect on contributions. Together, these theoretical and empirical findings suggest that the effect of inequality may have a local maxima, where there is an optimal level of inequality for cooperative outcomes.

Other studies show that high income earners tend to be less generous when there is high income inequality salience, but this does not hold when income inequality salience is low (Cote et al, 2015). Low-income earners express egalitarian motives by incurring personal costs to increase income of other low earners and decrease income of high-income earners (Fowler et al, 2007). When individuals are only aware of the absolute contribution of others, on average, they punish those who contribute less and reward those who contribute more, yet when they are aware of the relative percent contribution, individuals reward and punish indiscriminately, reducing earnings of those who contribute less and rewarding those who contribute more (Hauser et al, 2019).

Gächter et al, 2017 find that while public wealth increases for repeated public goods games with punishment, inequality increases significantly in both punishment and no-punishment conditions. This seems to suggest that punishment, while improving public wealth, still leads to

the wealth being concentrated at the top. Nishi et al 2015 used a public goods game to explore the mechanism that sustain inequality within social networks. To better model approximate real world social networks, the heterogeneous endowments used Gini values of 0.2 and 0.4, which roughly approximate countries with low and medium levels of inequality. In social networks of participants with cooperative agency, they found that inequality tends to persist when visible, yet when invisible, inequality tends to decrease (Nishi, 2015).

In our first experiment, we use a public goods game to model Gini-based wealth inequality as heterogeneous endowment. We investigate how inequality level and endowment levels of participants effects percent contribution in public goods games. Wealth is operationalized as player's initial endowment (from 0 to 10,000), inequality is operationalized as heterogeneous endowment points, and cooperation as participant's percent contribution. We predict that at low levels of inequality, egalitarian motives will maintain cooperative behaviour, yet as inequality increases, cooperation will decrease due to increased selfish feelings and motives. Similarly, as endowment increases, we expect cooperation to decrease. We vary endowment inequality and hold inequalities of productivity and payoff linearity constant. Specifically, we use a 5-player public goods game with 10-levels of inequality that equate to Gini coefficients, spaced equally, from 0.02 to 0.80. Each round is a "one-shot" round meaning it is independent from the previous one. We hypothesize that both increases in endowment level and inequality level will cause a decrease in participants' percent contribution.

The second experiment is still under development and continues with Gini-based inequality conditions. While the purpose of the first experiment was aimed at gaining a clear picture of the effects of inequality across a very wide range of Gini values, this second experiment aims at understanding the effects of heterogeneous punishment on cooperation. We will use a 4-player

public goods game with high ($Gini = 0.75$) and low inequality ($Gini = 0.02$) with an absolute punishment condition and a proportional punishment condition, for a total of 4 conditions. We hypothesize that in the presence of absolute punishment, percent contribution will increase, and inequality will increase. For the proportional punishment condition, we hypothesize that percent contribution will increase and that inequality will decrease.

EXPERIMENT 1: GINI INEQUALITY

In our first experiment we examined the effects of heterogeneous endowment across 10 conditions ranging in gini coefficient inequality from 0.02 to 0.80. This was done using a non-real-time, one-shot, 5-person public goods game with deception, played by participants on Mturk in the United States.

PARTICIPANTS AND DESIGN

We recruited 1010 United States participants using Amazon MTurk platform, after excluding participants who indicated they wished their data to be left unanalyzed, we had a final sample of 1,006 participants ($M_{age} = 38.63$, $SD = 12.98$; 50% female, 49% male, 1% other; 74% Caucasian, 9% African American, 9% Asian, 5% Hispanic, 3% other). Participants received USD\$1.50 as a base rate for participation plus a bonus payment between USD\$0.00 and USD\$3.50, which was calculated using one of the ten public goods game rounds each participant played.

PROCEDURE

Participants completed a Qualtrics based experiment using their phone or web browser. Before beginning the public goods game, participants completed a comprehension check and only data from participants who correctly answered the comprehension questions on the first try was used.

The methods for this experiment were approved by the University of British Columbia Ethics Board.

PUBLIC GOODS GAME (PGG)

The PGG was designed to have ten levels of inequality each with five SES levels. The PGG had a total pool of 10,000 points and these were distributed between the five SES levels unequally to produce varying Gini coefficients. Each level of inequality was designed to have SES levels that produced Gini coefficient-based inequality levels increasing in equal increments from 0.02 to 0.80. Participants were told that they would be playing with 4 other players, but that they and the other participants would remain anonymous. Participants did not in reality play against other players, yet for paying the participant out, one of their rounds was retro-actively matched with 4 other participants. For example, if the payout round selected for the participant had an SES level of one, they would be matched with participants who played SES levels two, three, four, and five, and all from the same Gini coefficient-based inequality level. The contribution from each player was summed, multiplied by 1.3, and divided by 5. The final redistributed value (between zero to ten thousand points) was then translated into a US dollar amount at a conversion rate of 30 points = USD\$0.01 and paid to the participants within 3-days of completing the experiment. Importantly, inequality visibility is apparent through proportionally representing each of the 5 player's endowments in a bar graph. The experimental setup controls for social norm enhancement motives by maintaining player anonymity and independence of rounds (Folwer, et al, 2007). This effectively isolates for egalitarian motives in the PGG.

EXPERIMENTAL CONDITIONS

Participants played ten rounds of an online non-real-time PGG. For each round, participants were randomly assigned to one of the fifty conditions (i.e., one of the 10-levels of inequality and one of

the corresponding 5-levels of SES) with replacement. In each round, participants were presented with a bar graph to visually represent their endowment and the endowments of the other players and were asked “how much do you want to contribute to the pool?”. After entering an amount and clicking “enter”, the participant was shown their remaining endowment and could click “next” to proceed to the next round or adjust their contribution amount.

RESULTS

Across all levels of inequality, participants mean percent contribution was $M = 44.54\%$ ($SD = 35.59\%$). We modeled percent contribution using multilevel modelling techniques. We tested a fixed intercept only model, and three fixed slope random intercept models (endowment, gini level, or both as predictors), for a total of 4 models. The intercept-only model (model 1) showed significant variation in the intercepts ($ICC = 0.65$; $p < .001$; $AIC = 61804$, $BIC = 61824$). The fixed slope random intercept model, with endowment as a predictor (model 2), was significant ($\beta_1 = -1.38$ $p < .001$, $AIC = 61754$, $BIC = 61781$). The fixed slope random intercept model, with Gini level as a predictor (model 3), was significant ($\beta_1 = -0.24$ $p < .001$, $AIC = 61799$, $BIC = 61826$). The fixed slope model, with Gini level and endowment as predictors (model 4), showed a significant effect of endowment and a significant effect of Gini level ($\beta_1 = -1.37$, $p < .001$, $\beta_2 = -0.22$, $p < .05$, $AIC = 61732$, $BIC = 61774$) where β_1 is the fixed slope term for endowment across all clusters and β_2 is the fixed slope term for Gini level across all clusters.

DISCUSSION

The intercept only model (model 1) tells us that 65% of the variation in percent contribution is attributable to between-cluster differences. Random slopes were left out of all models due to singularities. The fixed effects random intercept model, with endowment as a predictor (model 2),

shows that the marginal expected value of percent contribution, across all levels of inequality, decreases by 1.38 when moving up one endowment level (i.e., SES level). The fixed effects random intercept model, with Gini as a predictor (model 2), shows that the marginal expected value of percent contribution, across all levels of endowment, decreases by 0.24 when moving up one inequality level. The fixed effects random intercept model, with endowment and Gini level as predictors (model 4), shows that the marginal expected value of percent contribution decreases by 1.37 for each inequality level increase, when controlling for endowment level, and that the marginal expected value of percent contribution decreases by 0.22 for each endowment level increase, when controlling for inequality level. Looking at the AIC and BIC values across all models, we see that model 4 provides the lowest values, and thus the best fit to the data.

There are mixed findings on whether heterogeneous initial endowment leads to increases or decreases in contributions in the public goods game. These findings support the view that inequality leads to decreases in contributions. To our knowledge, it is the first study to test the effects of inequality and endowment in public goods games across the full range of economic inequality (i.e., $Gini = 0.02$ to $Gini = 0.80$), and the first to model heterogeneous endowment using a modified discrete log-normal Lorenz distribution; a model that has been shown to accurately describe economic inequality distribution within countries.

The MLM analysis was delimited to linear effects without consideration of possible interaction effects. As such, it possible (and actually true), that further analysis would reveal more nuanced statistical insight into the nature of contributions with changing endowment and inequality levels.

One limitation of this study is that simulated trust games, such as the one in this study, have been shown to reduce participant trust levels when compared to real-time games; however, a review of literature finds that the results are mixed, and in no study is this effect strong enough to significantly impact the detection of an effect (Casari & Carson, 2009; Brandts & Charness, 2011). It is possible that the simulated nature of the experiment, with no feedback to support person-to-person interaction, decreased trust. If this were true, we would expect a smaller effect of percent contribution overall. It is our contention that this effect would likely be very small.

EXPERIMENT 2: HETEROGENEOUS PUNISHMENT

The second experiment is forthcoming and is in the process of being developed. We will be using a modified public goods game with punishment. In addition, we have made this second experiment a real-time game rather than a simulated public goods game. Adding the real-time component addresses the strategy game limitation of the first experiment. While the first experiment addresses the effects of heterogeneous endowment across varying Gini level conditions, this second experiment is intended to investigate the effects of heterogeneous punishment effectiveness on cooperation. We will investigate how percent contribution depends on the participants ability to effectively punish, and will manipulate how the effectiveness of participants ability to reduce the earnings of others.

PARTICIPANTS AND DESIGN

We will recruit participants from the United States using Amazon MTurk platform, after excluding participants and expect similar demographics to experiment one (e.g., $M_{age} = 38.63$, $SD = 12.98$; 50% female, 49% male, 1% other; 74% Caucasian, 9% African American, 9% Asian, 5% Hispanic, 3% other). Participants will be paid using the same scheme as before and will receive USD\$1.50

as a base rate for participation plus a bonus payment between USD\$0.00 and USD\$3.50, calculated based on the performance of one of the ten public goods game rounds each participant plays.

PROCEDURE

Participants will complete a Qualtrics based experiment using their phone or web browser. Before beginning the public goods game, participants will complete a comprehension check and only data from participants who correctly answered the comprehension questions on the first try was used. The methods for this experiment will first need to be approved by the University of British Columbia Ethics Board.

PUBLIC GOODS GAME WITH PUNISHMENT

Participants will play 10 rounds of a one-shot public goods game in groups of four. Participants will be randomly assigned to the same endowment level for all 10 rounds, and in each round, participants will be randomly placed in either a high or low inequality condition. For example, if playing the high inequality condition (Gini = .60, endowment levels: 237, 642, 1008, 8113), a participant randomly assigned as “player C” would receive 1008 units and a player assigned to “player a” would receive 237 units. Participant’s contributions will be summed, multiplied by 1.3, and redistributed evenly amongst all players. After the initial round, participants will see everyone’s contributions and will have the option to punish by reducing other’s earnings. Each round, participants will either complete a proportional punishment condition or an absolute punishment condition. In the absolute punishment condition (i.e., homogeneous punishment, for every 1-unit participants spend, they will reduce their targets earnings by 3 units. In the proportional punishment condition, participants will be able to spend 1% of their earnings to reduce their target’s earnings by 1%. The details of the proportional punishment scheme are still a

work in progress. Participants will be blind to who has punished them and will only see the total amount they have been punished. For each new round, participants begin in their assigned endowment level the whole group completes either the high or low inequality condition.

GENERAL DISCUSSION

This research examines the effects of heterogeneous endowment and heterogeneous punishment on cooperation. We found that both endowment level and inequality level have negative effect on participants percent contribution. Which suggests that inequality tends to decrease cooperation. While the analysis was limited to linear fixed slope models without interactions, further analyses is needed, and we expect (know) that the effects of inequality on percent contribution will be highest when inequality is high. The present analysis cannot account for any local maxima that would support the view that inequality may have an optimal level that enhances cooperation. Further analyses using non-linear MLM is needed to reveal a significant curvilinear relationship to support this. In addition to this, we have not yet analysed the Gini coefficients of the outcome endowment distribution. It could be interesting to see if there is an effect of initial inequality on final inequality for this public goods game setup.

At low levels of inequality, the effects of egalitarian motives and social norm adherence are likely to be stronger and thus lead to high levels of percent contribution. Yet as inequality rises, selfish motives are more likely to increase and those with more are likely to act selfishly. Perhaps participants with more see decreasing utility in giving to participants with less because the marginal utility curve of gains flattens out. On the other hand, perhaps it is simply that in society, it is often not expected that an individual contributes most of their wealth to those with less.

In the second experiment we expect to find that absolute punishment will have little effect on cooperation at high levels of inequality but will be effective at improving cooperation at low levels of inequality. We also expect that absolute punishment at low levels of inequality will lead still lead to increases in inequality. At high levels of inequality, we expect cooperation to decrease, as percent contribution will be lower but inequality should also decrease since those at the top already have so much that giving basically any amount should decrease overall inequality. We expect proportional punishment to lead to higher levels of cooperation and lower levels of inequality across all conditions of inequality. In these conditions, participants with less endowment amounts will still have the power to punish those at the top, regardless of their wealth.

Overall these findings suggest as inequality increases, people tend to contribute less proportionality to the group. Generally, it would seem prudent for countries pay attention to the management of inequality. Maintaining low-income inequality as measured by the Gini coefficient may lead to more cooperative behaviour between persons within a country. Further, as Gini level inequality rises the punishment effectiveness of absolute punishment, as an aid in decreasing inequality, is likely to become increasingly unrealistic.

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