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National inequality, social capital, and public goods decision-making

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ABSTRACT

Inequality affects how people make social decisions. Laboratory research has shown that when income inequality is simulated using cooperative economic games, groups with higher inequality often generate less wealth overall, with poorer group members receiving the worst outcomes. This study links these experimental findings to real world inequality and applies a decision model to explain the effects in terms of social decision-making dynamics. Using a pre-existing dataset from 255 groups playing a public goods game in thirteen economically diverse societies, we show that in nations with higher inequality, groups contribute less (Research question (RQ) 1). Further, we find that higher inequality is associated with lower optimism regarding others' contributions at the outset of the game and increased sensitivity to others' contributions, which accelerates the decay of cooperation (RQ2). These effects might be explained by national differences in social capital as expressed by trust and adherence to civic norms (RQ3). Using the European Values Survey, we replicate the negative association between inequality and contributions to a public good by examining national volunteering rates (RQ4).

1. Introduction

People are averse to inequality (Fehr and Schmidt, 1999) and most report being happier in more equal societies (Alesina et al., 2004; see however Starmans et al., 2017). Countries with lower inequality also perform better on a range of outcomes, including reduced health problems and lower crime rates (Wilkinson and Pickett, 2017). This may be because societies which are more equal are better able to increase collective welfare, and to decrease resource conflicts, by more efficiently providing public goods (Bouchey, 2019). At the policy level, countries with lower income inequality are more likely to favor more re-distributive fiscal policies (Lindert, 1996). At the civic level, communities with lower income inequality are more likely to have members who contribute to shared social and economic welfare (Goldin and Katz, 1999; Costa and Kahn, 2003; La Ferrara, 2002).

There is much research aimed at understanding how equality and social welfare are related to the provision of public goods. Most of this work is focused on understanding inequality at the structural or macro-scale level (e.g. Piketty, 2013; Krugman and Venables, 1995; Fligstein and Shin, 2004), however important work has also focused on the social contextual and psychological processes related to inequality. Suggested psychological processes include reduction of cooperation (Cherry, Kroll, and Shogren, 2005; Nishi et al., 2015); stigmatization of poverty (Jachimowicz et al., 2020); and the perception that the social environment is more competitive (Sánchez-Rodriguez, Willis et al., 2019).

The purpose of the present research is to investigate a connection between structural and psychological levels of analysis, by linking income inequality at the national level to public goods decision-making at the individual level. We start by investigating whether national level inequality predicts cooperation in an experimental public goods game (Research Question 1). We then examine how national level inequality is related to individual decision-making to explain why, in cognitive processing terms, people living in more unequal societies might contribute less to the public good in the experimental game (Research Question 2). We then explore which national level social contextual factors can explain the relation between inequality and people's decision-making in the experimental game (Research Question 3). Finally, we generalize our findings to behavior beyond the laboratory, and show how the contextual processes identified in our analysis could also explain the effects of inequality on national level differences in real world public goods behavior (Research Question 4).

To preface our conclusions, we show that in less equal nations, people do cooperate less in the experimental public goods game (RQ1). We use cognitive modeling to show that people in less equal nations are less optimistic about others' contributions at the outset of the game. At the same time, they are more sensitive to others' contribution levels when choosing how much to contribute themselves, which might foster

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a race-to-the-bottom social dynamic in the game (RQ2). We show that the social contextual factors trust and adherence to civic norms are also related to contributions in the game, such that these might explain the relationship between inequality and cooperation (RQ3). We generalize this result by using a different and larger dataset to show that inequality is associated with reduced social volunteering – an in-kind contribution to the social public good (Sugden, 1984) – and that this effect of inequality can also be explained by national differences in social trust (RQ4).

2. Research questions

2.1. Research question 1: does national inequality predict contributions in the public goods game?

Experimental research investigating the relationship between inequality and cooperation has mainly focused on the public goods game. This research has shown reliable effects of experimentally produced inequality on individual behavior in the laboratory. In the public goods game, a group of participants are given a fixed number of tokens, which they may either keep for themselves or contribute to a public good. All contributions to the public good are then multiplied by some factor and redistributed equally to all group members independent of their own contributions. The best outcome occurs for the group if all individuals contribute all their tokens to the public good. If this happens, then the maximum number of tokens will be multiplied and returned to the individuals. However, the best outcome for each individual occurs if all other participants contribute all their tokens, while the individual themselves contributes nothing. The public goods game is thus a canonical example of a social dilemma, where individual and group outcomes are in opposition. In practice, most participants split their tokens and invest about half in the private good and half in the public good, with contributions declining as the game is repeated (Ledyard, 1995; Kopelman et al., 2002; Zelmer, 2003). Explanations for this decline range from intrapersonal mechanisms like reward-based learning about diminishing returns during the game (e.g. Burton-Chellew et al., 2015; Camerer and Ho, 1999), to social processes related to weak-reciprocity and conditional cooperation (e.g. Fischbacher and Gächter, 2010).

Experimental research has shown that individual contributions in the public goods game are influenced by inequality in the distribution of tokens given. Chan et al. (1996) found that individuals who were given more tokens on each round contributed less than they otherwise would have: inequality led people to contribute less than their fair share. Subsequent laboratory research has supported and extended on this finding. Rather than manipulating the number of tokens received on a trial, Andersen et al. (2008) induced inequality between participants by paying different show-up fees. This manipulation induced the same effect as the unequal distribution of tokens, and people contributed less than they otherwise would have (1996). Similar results have been reproduced in a wide range of laboratory settings, using different variants of the experimental public goods game, and different methods for simulating inequality (Tavoni et al., 2011; Schlösser et al., 2020; Burton-Chellew et al., 2013; Hauser et al., 2019). Experimentally induced inequality leads to lower cooperation overall (Anderson et al., 2008; Hauser et al., 2019; Zelmer, 2003).

To address our first research question, we re-analyze open data from an experimental implementation of the public goods game played by groups from a range of economically diverse nations (Herrmann et al., 2008; Herrmann et al., 2017). We correlate the contributions made by each group in the game with the Gini coefficient for the country from which the experimental participants were sampled. The Gini coefficient is a standard measure of inequality. It quantifies the extent to which the distribution of wealth or income in a society departs from perfect equality. We focus on income inequality. Scores can range from zero to one, with zero indicating perfect income equality and one indicating perfect inequality. If national income inequality reduces cooperation in the experimental public goods game, we should observe a negative correlation between national Gini coefficient and contributions made in the experimental public goods game when played in different countries.

2.2. Research question 2: how is national income inequality related to decision-making processes in the public goods game?

Our second research question concerns the nature of the decision-making processes by which inequality might reduce cooperation. Experimental researchers have urged theorists to develop behavioral models to explain empirical departures from game theoretic equilibria in the public goods game (Chan et al, 1996). A range of cognitive/behavioral models of choices in the game now exist for this purpose. These models rely on two major mechanisms thought to be involved public goods decision-making. One is reinforcement learning, whereby people simply update their preferences for contributing a given number of tokens as a result of feedback (e.g. Camerer and Ho, 1999; Erev and Roth, 1998; Roth and Erev, 1995). The second mechanism is social beliefs or expectations, whereby people adjust their own contributions as a function of what they believe others will contribute during the game, depending on their preference for matching or undermatching others' contributions (e.g. Fischbacher and Gächter, 2010; Larrouy and Lecouteux, 2017; Masel, 2007).

To explore how inequality in participants' home country is related to their decision-making in the game, we develop a formal implementation of Fischbacher and Gächter's (2010) conditional cooperation schema. This model includes both social belief and social learning processes (see Masel, 2007; Larrouy and Lecouteux, 2017 for similar models). The model's central assumption is that each individual has preferences for how much to contribute on a round, given what they believe others will contribute. The goal of the model is to infer the effects of social dynamics within the group both on individuals' contribution on each trial, and on their beliefs about others' contributions. Given these beliefs and preferences, the model assumes that contribution amounts are chosen according to the following process.

We begin by modeling the contribution c of individual s in group g on trial t as a draw from a Poisson distribution. The Poisson distribution is an appropriate representation for this process because token contribution is a discrete outcome variable whose variance (or parameter uncertainty) increases with the size of contribution $c_{g,s,t}$:

$$c_{g,s,t} \sim Poisson\left(P_{g,s,t}\right) \tag{1}$$

We interpret the parameter of the Poisson distribution as the individual's latent contribution preference on that trial, denoted $P_{g,s,t}$. We then model contribution preferences $P_{g,s,t}$ as a function of the individual's beliefs about the group contribution on the trial, denoted $Gb_{g,s,t}$:

$$P_{g,s,t} = \rho_{g,s}.Gb_{g,s,t} \tag{2}$$

The parameter $\rho_{g,s}$ is a scaling or contribution matching parameter. It represents the individual's preferences for conditional cooperation (Fischbacher and Gächter, 2010). In this way, equation 2 captures the fact that a more cooperative person may prefer to match what they believe the rest of the group will contribute, whereas a less cooperative person may prefer to under-match, and save more for themselves.

The parameter $\rho_{g,s}$ must be inferred, and is assumed to be between 0 and 1. If $\rho_{g,s}$ is inferred to be equal to 0, then the individual is completely non-cooperative, and will always contribute zero tokens regardless of their belief about the group. If $\rho_{g,s}$ is inferred to be equal to 1, then the individual is completely conditionally cooperative, and will always match what they believe the group will contribute. Values between represent a preference to more or less under-match what the individual believes the group will contribute (Fischbacher and Gächter, 2010).

We then model individuals' belief about the group contribution, $Gb_{g,s,t}$, as the outcome of learning over trials. This belief is updated according to the learning rule

$$Gb_{g,s,t} = (1 - \omega_{g,s}).Gb_{g,s,t-1} + \omega_{g,s}.Ga_{g,s,t-1} \tag{3}$$

where $Gb_{g,s,t-1}$ denotes the individual's belief about the group's contribution on the previous trial, $Ga_{g,s,t-1}$ denotes the average contribution observed on the previous trial, and $\omega_{s,g}$ is a weighting for the influence of the observed contribution, relative to the individual's prior beliefs. In this way, equation 3 captures the fact that a person who is more sensitive to others' contributions may quickly update their beliefs about what the rest of the group will contribute on the following round, whereas a person who is less sensitive to others' contributions may update their beliefs less quickly.

Because the average contribution $Ga_{g,s,t-1}$ is observed, it is included in the model as data. The parameter $\omega_{g,s}$ must be inferred and is assumed to be between 0 and 1. If $\omega_{g,s}$ is inferred to be equal to 0, then the individual is completely insensitive to the group's behavior and will never update their beliefs about what the group will contribute. They will fix a belief at the beginning of the game, and it will not change. If $\omega_{g,s}$ is inferred to be equal to 1, then the individual is maximally sensitive to the group's behavior, and their beliefs about contributions on the next trial will always reflect exactly what they observed on the last trial. Values in between represent more or less sensitivity to others, defined as more or less rapid belief updating (Fishbacher and Gächter, 2010; Masel, 2007).

Finally, we model individuals' initial beliefs – or optimism – about what others will contribute prior to starting the game. Initial beliefs are modeled as part of the Poisson draw on the first trial:

$$Gb_{g,s,1} \sim Poisson(\alpha_{g,s}) \quad (4)$$

Parameter $\alpha_{g,s}$ thus represents participants' initial beliefs about the group contribution. In this way, equation 4 captures the fact that individuals may be more or less optimistic at the outset, assuming that others will give more or less on the first round. A perfectly pessimistic player will believe that others will contribute none of their tokens on the first round, and $\alpha_{g,s}$ will be equal to 0. A perfectly optimistic player will believe that others will contribute all their tokens on the first round, and $\alpha_{g,s}$ will be equal to 20. Values in between represent more or less optimism about the contributions to be offered in the game.

The model therefore has three decision parameters for inference. These are $\rho_{g,s}$, which represents the individual's preference for conditional cooperation or matching to group contributions (Fishbacher and Gächter, 2010); $\omega_{g,s}$ which represents the individual's sensitivity to information about the rest of the group's contributions in updating their beliefs (Masel, 2007); and $\alpha_{g,s}$, which represents the individual's optimism about what the rest of the group will contribute prior to the first trial. Given this model, if national inequality undermines economic cooperation and has stable effects on individuals' decision-making processes, then groups should have identifiable differences in one or more of these decision model parameters, depending on the inequality in their country.

2.3. Research question 3: which national level social contextual factors can explain the relationship between national inequality and public goods decision-making?

Our third research question concerns the social contextual variables that might be associated with inequality, and that might also be related to decision-making in the public goods game. Research suggests two main kinds of contextual factor which might share connections both to national inequality and to public goods game decision-making. The first is the degree to which individuals in a society rely on others versus relying on themselves. It has been shown that in less equal societies, people feel that it is more necessary to be self-reliant to overcome financial hardship (Jachimowcz et al, 2020). People are more likely to endorse norms related to self-enhancement (Sánchez-Rodriguez et al., 2020), possibly as a way of coping with increased threat of relative poverty. This suggests that effects of a nation's level of inequality on public goods decision-making may be explainable by a tendency of that nation's inhabitants towards greater individualism. To investigate this possibility, we include national level measures of trait individualism (Hofstede et al., 2010) in our models.

The second contextual factor which may be related to both inequality and public goods decision-making is the "social capital" available to members of a society. A society has more social capital if there are social ties among its members that make their interactions more honest and effective (Granovetter, 2017). In societies with more social capital, there is less need for formal institutions to regulate cooperation, because cooperation is regulated by interpersonal relationships and norms. Social capital is "capital", then, in the sense that societies with more of it can save resources on administration of sanctions against anti-social behavior.

There is broad agreement that social capital has two main elements. The first is trust. Trust has been defined as the expectation of future reciprocity, or the belief that others will do no harm (Granovetter, 2017). This belief motivates cooperation (Alós-Ferrer and Farolfi, 2019; Ostrom and Walker, 2003; see however Chaudhuri et al., 2002), and research has shown that individuals in more trusting environments are more likely to contribute to a public good, both in the laboratory (e.g. Iacono and Sonmez, 2020) and in natural behavior (e.g. Sønderskov, 2009). It is well known that general trust is lower in unequal environments (Fiske et al., 2012). This suggests that the relationship between national inequality and public goods decision-making may be explainable as effects of the level of generalized trust between people living in that nation (Sønderskov, 2009).

The other main element in social capital is the adherence to civic norms. Adherence to civic norms has been described as a "mirror reflection" of trust (Knack and Keefer, 1997). Whereas trust is defined by a belief that others will not do harm, adherence to civic norms is characterized by a belief that one is worthy of being trusted by others, because one's choices and behavior will reliably follow social expectations for good interactions (Knack and Keefer, 1997; Granovetter, 2017). People in more equal societies are more likely to participate in civic institutions (Costa and Kahn, 2003; Levin-Waldman, 2012; van Holm, 2019), and field research has shown that trustworthiness, separately from trustingness, drives real world public goods contributions (Karlan, 2005). Therefore, any relationship between inequality and public goods decision-making might also be explainable by the general level of adherence to civic norms in a society.

2.4. Research question 4: does our analysis of laboratory results generalize to national level public goods behavior?

Our fourth research question concerns the generalizability of our findings. To answer the first three questions, we focus on a dataset with a limited number of countries that is collected mostly with university students. University students are famously unrepresentative of national populations. Also, these data were collected in cities that vary in how well they represent their national economic and cultural contexts, which causes some uncertainty about our inferences concerning national level variables. It is therefore important, where possible, to assess whether our results generalize to more nationally representative samples. Another concern is that the laboratory version of the public goods game is an artificial situation, with artificial rules explicitly designed to model behavior with respect to theoretically well-defined equilibria. Ideally, we would also like to generalize any patterns found in our analysis to more natural kinds of public goods actions (Levitt and List, 2007). To address these concerns, we apply the same statistical models used to answer RQ1-RQ3 to a different dataset. Here we use the European Values Survey to investigate the effects of inequality and our other national level social contextual variables on national rates of social volunteering, a typical public goods behavior (Sugden, 1984).

To recap, the present study aims to address four main questions. These are:

- RQ1) what is the relationship between national level inequality and contributions in an experimental public goods game?
- RQ2) What are the decision-making mechanisms involved?
- RQ3) What other social contextual processes might explain how inequality is related to public goods decision-making? and
- RQ4) Can any insights we draw from our analysis be generalized to real public goods actions measured in larger nationally representative samples?

3. Method

3.1. Datasets

The experimental data used to answer RQ1, RQ2, and RQ3 were collected by Herrmann and colleagues (2008). The researchers have made this data freely available (Herrmann et al., 2017). Participants in the experiment were asked to play a ten round public goods game in stable groups of four. On each round, participants were allocated 20 tokens to keep or to contribute to the public good. On each round, all of the tokens contributed to the public good were multiplied by a factor of 1.6, and the new total was redistributed to all group members independent of their contributions. Each group played two versions of the game, in counterbalanced order. The first was the standard game. The second was a version in which it was also possible for group members to punish each other. We focus exclusively on data from the standard game. Most participants completed the standard game before the version with punishment (Herrmann et al., 2008). Excluding participants who experienced the punishment version first did not alter the results of any analyses.

280 groups participated in the experiment for a total of 1120 participants. Data were collected from 15 economically and culturally diverse nations. These were Australia, Belarus, China, Denmark, Germany, Greece, South Korea, Oman, Russia, Saudi Arabia, Switzerland, Turkey, the UK, Ukraine, and the USA.

Gini coefficients for the years 2002-2006 were retrieved from the World Bank (n.d) for as many of the participant countries as possible. Gini coefficients were unavailable for Oman and Saudi Arabia, and so data collected from participants in these nations were not included in the analysis. Data from the other 13 countries were included. Only 25 groups were excluded from analysis for this reason. For some countries, Gini data were not available for all years. Averages from the available years were used. The Gini data used are available as Table 1A in Appendix 1.

The experimental data included in the analysis are from 10 groups from Australia, 17 groups from Belarus, 24 groups from China, 17 groups from Denmark, 15 groups from Germany, 11 groups from Greece, 21 groups from Korea, 38 groups from Russia, 47 groups from Switzerland, 16 groups from Turkey, 14 groups from the UK, 11 groups from Ukraine, and 14 groups from the USA.

For remaining national level variables in the analysis of the experimental data, values reported in Herrmann and colleagues (2008) were used. They acquired trait individualism scores from Hofstede and Hofstede (2004), a standard source for national level survey data for cultural traits. For Russia, Belarus, and Ukraine, we added updated scores from the revised edition by Hofstede et al. (2010). Following the methodology established in Knack and Keefer (1997), Hermann and colleagues retrieved national level social capital variables from the World Values Survey (Inglehart et al., 2018). Trust was defined as the national rate of positive answers to the question “Most people can be trusted”, and adherence to civic norms was defined as the national level mean score (out of 10) for responses to questions about the justifiability of falsely claiming welfare entitlements, tax avoidance, and fare evasion on public transport. Greater adherence to civic norms was defined as believing that these trespasses are *less* justifiable (i.e. the items were reverse scored in analysis). See Knack and Keefer (1997), Granovetter (2017), and Herrmann and colleagues (2008) for discussion of this method.

To distinguish between an effect of unequal incomes within countries and an effect of unequal incomes between countries, we included per capita GDP as an additional control. Per capita GDP data from the International Monetary Fund’s World Economic Outlook Database (2007) was used, as reported in Herrmann et al. (2008).

To answer RQ4, we used a separate dataset. This included national level economic indicators and data from the European Values Survey. Values for the variables trust, civic norms, and volunteering rate are calculated from the 2008 – 2010 wave of the survey (EVS/WVS, 2021). This wave was chosen because it included the highest number of countries with responses to all relevant survey questions. Volunteering was defined as social volunteering, which was measured as the percentage of individuals within each country that responded that they had volunteered for one or more of the following types of organization: social welfare, religious, educational or cultural, human rights, environmental conservation, ecology, animal rights, youth work, sports, women’s, peace movement, health, or consumer rights organizations. Volunteering for political parties, political action groups, labor unions, and professional organizations was not counted. Trust and civic norms were defined as for Herrmann et al. (2008), using the corresponding trust and civic norms questions in the European Values Survey. Gini scores for the relevant countries were taken from the 2009 Human Development Report (UNDP, 2009), and per capita GDP was taken from World Bank estimates for 2009 (World Bank, n.d.). Data from 46 countries were included, and the data table is available in Appendix 1.

3.2. Hierarchical model structure and overview of measures

We use Bayesian hierarchical modeling for all inference (Lee and Wagenmakers, 2013; McElreath, 2020; Gelman et al., 2020). Hierarchical modeling is appropriate whenever it is important to account for repeated measures across levels of analysis, or to account for the effects of other kinds of nesting in the data. In the present study, there are four possible levels of analysis, and different variables enter the analysis at different points in the models’ hierarchy. At the bottom is the trial level, or the ten rounds on which participants chose to contribute to the public good. Token contributions are the only data included at this level. Higher up is the participant level, with contributions assumed to be repeated samples from individual participants. Only the cognitive model parameters $\rho_{g,s}$, $\alpha_{g,s}$, and $\omega_{g,s}$ are represented in our analysis at this level. Next is the group level, or the four-person context in which participants play the experimental game in the laboratory. Overall group contributions are analyzed at this level. Individual participant contributions are also assumed to be constrained by the social dynamics in the group, and so individual level cognitive model parameters are assumed to have shared group-level variance. At the top is the national level, with each four-person group assumed to be influenced by the national social context in which they are playing the game. The variables included at this level are GDP, Gini coefficient, individualism, trust, adherence to civic norms, and national rate of social volunteering (depending on the model and the RQ).

We use *Bayesian* hierarchical modeling because it allows us to codify all the necessary assumptions about how measures and model parameters are related across levels, and thus affords more precise estimates of model parameters given the data (Gelman et al., 2020). We can explain each token contribution at the trial level in terms of the cognitive model, whose parameters are then interpretable at the individual level. We can represent the effects of group social dynamics as shared variance in cognitive model parameters between individuals at the group level, and we can make inferences about national level context by modeling the effects of national level measures on national level means of cognitive model parameters. Importantly, we can do this all within the same integrated model (Lee and Wagenmakers, 2013).

The alternative to this fully hierarchical statistical approach is a multi-step approach, in which one first fits models to each participant individually, and then runs regressions on participant level parameter

estimates. The integrated Bayesian hierarchical approach is preferable, because it fully represents shared variance at group and national levels in the analysis, and it makes use of all uncertainty in the data. This ensures improved parameter estimation at all levels of analysis. This is because posterior estimates are regularized by assumptions of shared variance, which greatly increases the precision of the posterior distributions, improving our inferences about the parameters they represent (Ketahira, 2016).

3.3. Statistical analyses

We developed four sets of statistical models: one to represent each of our four research questions. All models are specified here in full. All inference was done using MCMC sampling implemented in JAGS software (Plummer, 2003) via the R2jags R package (Su and Masano, 2012). For all models, we used three chains of 15000 samples, with 5000 samples discarded as burn-in. Code for default JZS priors (used for partial correlation in the regression models, see below) was adapted from the code for the BayesMed package (Nuijten, et al., 2014, Ntzoufras, 2009). We report posterior distributions and/or Bayesian credible intervals for parameters of interest in all models, and these can be interpreted as national level regression coefficients. No major divergences were observed in any of the traceplots for the models' posterior distributions, and convergence diagnostics were acceptable with $\hat{R} < 1.1$ for all parameters. Because our RQs are primarily exploratory, and we are not conducting hypotheses testing relative to point null hypotheses, we do not report Bayes Factors (Gelman and Shalizi, 2013). All predictors were standardized before inclusion in a model.

Our RQ1 is whether national inequality predicts contributions in the public goods game. We used a default Bayesian hierarchical correlation model to represent this question (Wetzels and Wagenmakers, 2012). Data for this model was the overall contribution Y of each group g. This was calculated by adding all contributions on a trial, and then adding across all trials. The prior for contribution Y_g was assumed to be:

$$Y_g \sim Normal\left(\mu_{nation}, \tau\right) \tag{5}$$

Here μ_{nation} represents the expected average contribution for groups in a nation, and τ is the national level precision (inverse of the variance). An uninformative Gamma distribution was used as a prior for τ

$$\tau \sim Gamma(0.01, 0.01) \tag{6}$$

The relation between inequality (the national Gini coefficient) and the national level estimate of group contribution μ_{nation} was modelled as a linear relationship:

$$\mu_{nation} = \beta_0 + \beta_{Gini}.Gini_{nation} \tag{7}$$

Because Gini was standardized before entry into the model, a standard normal distribution was used as the prior for the model intercept β_0. For the model slope, the Jeffreys–Zellner–Siow (JZS) prior was used (Liang et al., 2008, Wetzels and Wagenmakers, 2012). The general form of this is:

$$\beta \sim \ Normal\left(0, \ \frac{g}{\varphi}\left(X^T.X\right)^{-1}\right) \tag{8}$$

where φ is assigned the prior

$$\varphi \sim Gamma(0.01, 0.01) \tag{9}$$

g is assigned the prior

$$g = \frac{n/2^{1/2}}{Gamma\left(\frac{1}{2}\right)} g^{-3/2} e^{-n/(2g)} \tag{10}$$

and n is the number of groups. The parameter of interest for this model is the effect of inequality β_{Gini}. JAGS code for the model is included in Appendix 2.

Our RQ2 concerns how inequality affects decision-making processes used in the public goods game. To represent this question, we used a default correlation model to model the relationship between national level Gini coefficient and national level estimates for each of the parameters in our decision model. We used the same fully hierarchical model to infer decision parameters simultaneously for all participants, in all groups, and within each nation, and then predicted the inferred national level estimates for the decision model parameters from national level Gini coefficients.

The decision model is specified above in Equations 1 to 4. The preference for conditional cooperation parameter $\rho_{g,s}$ and the sensitivity to others' contributions parameter $\omega_{g,s}$ are both bounded by 0 and 1. Therefore, we used beta regression to model effects at the group level. Each subject level parameter (e.g. $\rho_{g,s}$) was modelled using a beta distribution with national level shape parameters

$$\rho_{g,s} \sim Beta\left(\beta shape1^{\rho}_{nation}, \beta shape2^{\rho}_{nation}\right) \tag{11}$$

which were reparameterized in terms of national level mean μ^{ρ}_{nation} and concentration (or precision) σ^{ρ}_{nation}

$$\beta shape1^{\rho}_{nation} = \mu^{\rho}_{nation}.\sigma^{\rho}_{nation} \tag{12}$$

$$\beta shape2^{\rho}_{nation} = (1 - \mu^{\rho}_{nation}).\sigma^{\rho}_{nation} \tag{13}$$

The concentration parameter was assigned a broad uniform prior

$$\sigma^{\rho}_{nation} \sim Uniform(1, 100) \tag{14}$$

and the relationship between the probit transformed national level estimate and national level Gini coefficients was assumed to follow the group level linear model

$$Probit\left(\mu^{\rho}_{nation}\right) = \beta_0 + \beta_{Gini}.Gini_{nation} \tag{15}$$

Because the Gini variable was standardized, the prior for the model intercept β_0 was assumed to be a standard normal distribution. The prior for the regressor β_{Gini} was the same JZS prior that was applied in the contributions model Equations 8 to (10).

The relation between Gini and Learning rate $\omega_{g,s}$ was modelled in the same way as contribution preferences $\rho_{g,s}$, and so the specification is the same.

The optimism or initial beliefs parameter $\alpha_{g,s}$ can range continuously from 0 to 20. The subject level prior for this parameter was therefore assumed to follow a Gamma distribution

$$\alpha_{g,s} \sim Gamma\left(\gamma shape^{\alpha}_{nation}, \gamma rate^{\alpha}_{nation}\right) \tag{16}$$

which was reparameterised in terms of the mode and standard deviation

$$\gamma shape1^{\alpha}_{nation} = 1 + \mu^{\alpha}_{nation}.\gamma rate^{\alpha}_{nation} \tag{17}$$

$$\gamma rate^{\alpha}_{nation} = \mu^{\alpha}_{nation} + \frac{\sqrt{{\mu^{\alpha}_{nation}}^2 + 4.\left(\sigma^{\alpha}_{nation}\right)^2}}{2.\left(\sigma^{\alpha}_{nation}\right)^2} \tag{18}$$

The standard deviation was transformed to precision and assigned an uninformative Gamma prior

$$\sigma^{\alpha}_{nation} = \frac{1}{\sqrt{\tau^{\alpha}_{nation}}} \tag{19}$$

$$\tau^{\alpha}_{nation} \sim Gamma(0.01, 0.01) \tag{20}$$

and the log transformed national level estimate was assumed to have a linear relationship with national level Gini coefficients:

$$log\left(\mu^{\alpha}_{nation}\right) = \beta_0 + \beta_{Gini}.Gini_{nation} \tag{21}$$

The prior for the model intercept β_0 was assumed to be a standard normal distribution. The prior for the regressor β_{Gini} was the same JZS parameter that we applied in the contributions model Equations 8 to (10). JAGS code for the model is included in Appendix 2.

Our RQ3 is whether any effects of inequality can be explained by the national level psychological variables individualism, trust, or adherence to civic norms? Two separate default partial correlation models

were used to represent this RQ. Partial correlations were used to control for effects across regressors, and the results from these models are interpretable as coming from standard multiple regression models.

One model focused on group contributions. This was identical to the model used to correlate Gini and group level contributions Equations 5 to (10), except that the linear equation included all five variables GDP, individualism, trust, adherence to civic norms, and Gini coefficient. For the parameters of the linear equation, the multivariate JZS prior for partial correlation was used Wetzels and Wagenmakers, 2012). JAGS code for the model is included in Appendix 2. The other model focused on decision model parameters. This was identical to the model used to correlate Gini coefficient and decision parameters (Equations 1 to 4 and Equations 11 to (21), except that the linear equations (Equation 15 and Equation 21) included all five variables GDP, individualism, trust, adherence to civic norms, and Gini. The multivariate JZS prior for partial correlation was again used. JAGS code for the model is included in Appendix 2.

Our RQ4 is whether our findings from the analysis of the experimental public goods game generalize to naturalistic public goods behavior, specifically national social volunteering rates. Because they are rates, the national volunteering variable Y_{nation} is bounded by 0 and 1. This variable was therefore assumed to follow a Beta distribution, and the same beta regression model was used to represent this RQ as was used for the other rate variables/parameters Equations 11 to (15). JAGS code for the model is included in Appendix 2.

4. Results

Fig. 1 presents results relevant to our RQ1. Panel A presents the empirical relationship between national Gini coefficient and group contributions in the public goods game. The points represent the mean for the data collected within each nation, and the error bars represent standard deviations between groups recruited at the different national sites of the experiment. The plot suggests that in countries with higher income inequality, groups contributed less on average in the experimental game. Panel B presents the full posterior for the model of this relationship – the coefficient for the default Bayesian correlation model (Wetzels and Wagenmakers, 2012) – which supports this inference. The panel shows that the mean of the posterior distribution is negative, indicating a negative effect of Gini, or a negative relationship between Gini and group contributions, and the 95% Bayesian Credible Intervals do not include zero (indicated with the red line).

Fig. 2 presents the results relevant to our RQ2. These are the relationships between national level inequality and national level estimates for our (hierarchical) cognitive model parameters. Panel A presents the posterior distribution for the effect of national inequality (i.e. Gini coefficient) on the initial optimism parameter in the model. The panel shows that the mean of the posterior is negative, and the 95% Bayesian Credible Intervals do not include zero (indicated with the red line). This indicates that national level inequality is associated with a decrease in initial optimism. Panel B presents the posterior distribution for the effect of national inequality and the sensitivity to others' contributions parameter in the model. The panel shows that the mean of the posterior is positive, and the 95% Bayesian Credible Intervals do not include zero. This indicates that national level inequality is associated with an increase in sensitivity to others' contributions. Panel C presents the posterior distribution for the effect of national inequality on the conditional preferences to cooperate parameter in the model. The panel shows that the mean of the posterior is negative, but the 95% Bayesian Credible Intervals do include zero. This indicates that it is unlikely that inequality is associated with preferences for conditional cooperation or that more data would be required to demonstrate an association between national level inequality and preferences to match others' expected contributions.

Fig. 3 presents the results relevant to our RQ3. These results include our other national level social variables of interest. Panel A presents the

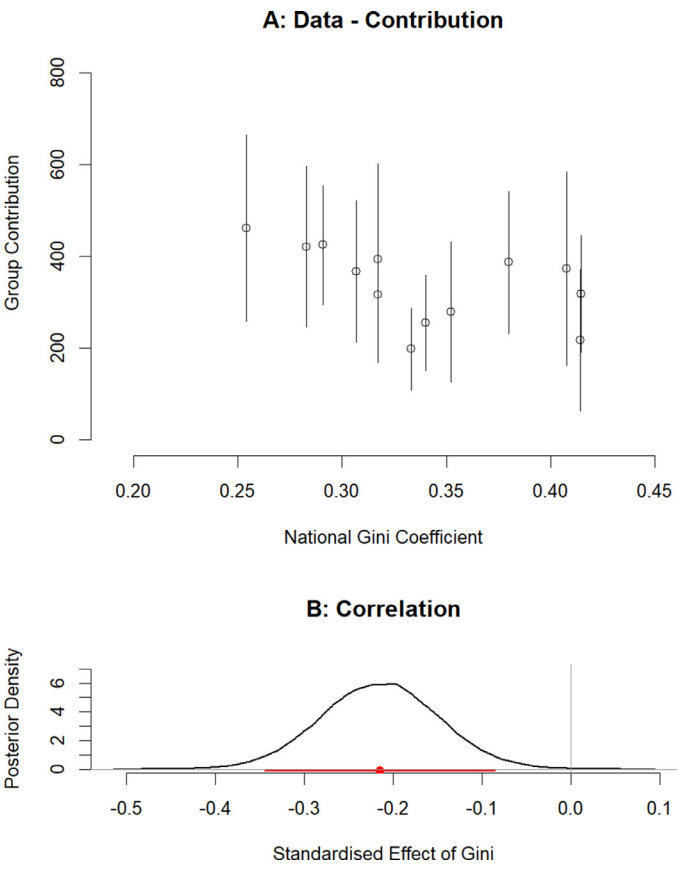

Fig. 1. Panel A: Scatterplot for the relationship between national level Gini coefficient and total contribution amount within a nation in the experimental public goods game. Error bars represent standard deviation calculated for experimental groups within a country. Panel B: Posterior distribution for the standardized effect of national Gini coefficient on contribution amount, as inferred using the default hierarchical correlation model. The point represents the mean of the posterior distribution of the effect of Gini coefficient on contribution amount, and the error bar represents the Bayesian Credible Interval.

posteriors for the partial correlation model relating national inequality and group contributions. The panel shows that when the other national level predictors are included in the model, inequality (i.e. Gini coefficient) is no longer associated with group contributions. The zero value for the effect of Gini coefficient is included in the 95% Bayesian Credible Interval. However, trust is associated positively with group contributions, and adherence to civic norms is associated negatively with contributions. Zero values for neither effect is included in the 95% Bayesian Credible Interval (red lines). This indicates that as national level trust increases, and national level adherence to civic norms decreases, group contributions in the experimental public goods game increase. There is no clear association with national level individualism or national GDP.

Panel B presents the posteriors for the partial correlation model relating national inequality and initial optimism, as inferred using the decision model. The panel shows that when the other national level predictors are included in the model, inequality (i.e. Gini coefficient) is no longer associated with initial optimism. However, trust is associated positively with initial optimism, and zero is not included in the 95% Bayesian Credible Interval for this effect. This indicates that national level trust is associated with people's initial optimism in the experimental public goods game. There is no clear association with adherence to civic norms, inequality, individualism, or national GDP for this parameter.

Panel C presents the posteriors for the partial correlation model relating national inequality and sensitivity to others' contributions, as in-

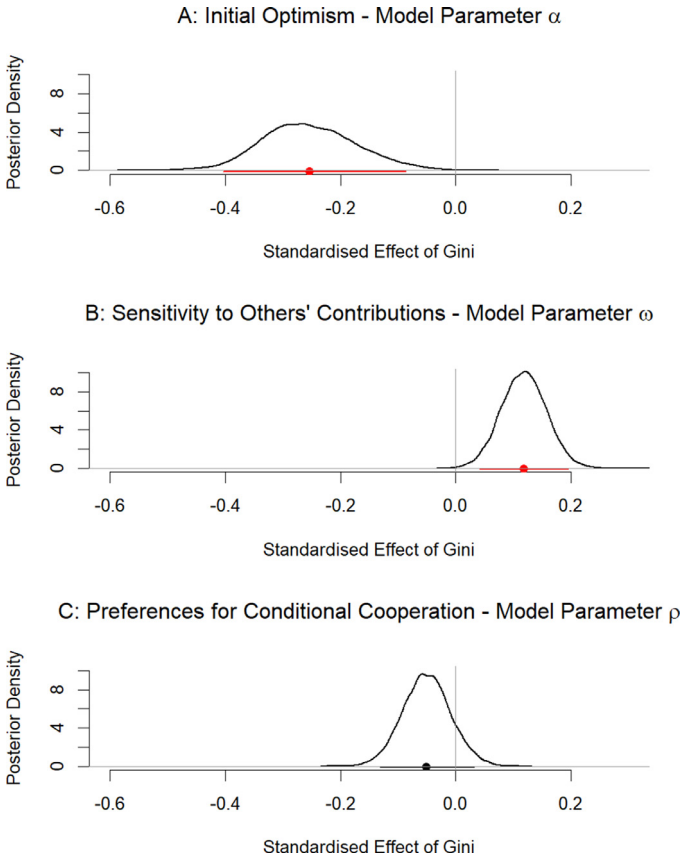

Fig. 2. Posterior distributions for the standardized effects of national level Gini coefficient on decision model parameters, as inferred using the hierarchical cognitive model. The points represent the means of the posterior distributions, and the error bar represents the Bayesian Credible Intervals. The figure shows that Gini coefficient is negatively associated with initial optimism (Panel A), and positively associated with sensitivity to others' contributions in the game (Panel B). Gini coefficient is not clearly associated with preferences for conditional cooperation (Panel C).

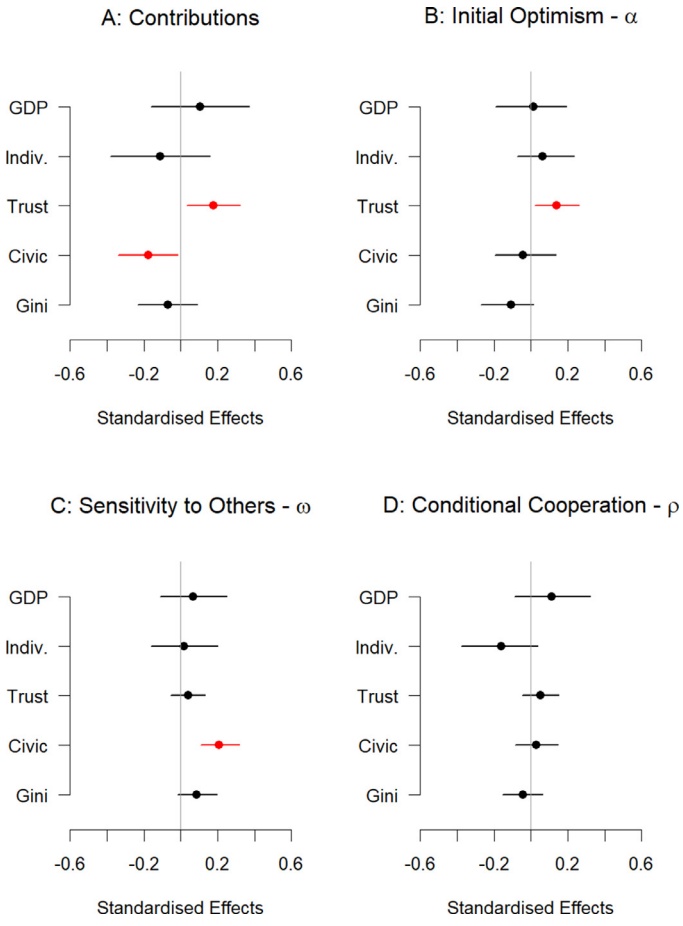

Fig. 3. Posterior distribution for the standardized effect of all national level social contextual variables on contribution amount (Panel A) and decision model parameters (Panel B-D). The point represents the mean of the posterior distribution, and the error bar represents the Bayesian Credible Intervals. Panel A shows that trust is positively associated with contribution amounts, and that adherence to civic norms is negatively associated with contributions. Panel B shows that trust is associated with initial optimism in the game. Panel C shows that adherence to civic norms is positively associated with sensitivity to others' contributions. Panel D shows that contextual variables are unrelated to preferences for conditional cooperation.

ferred using the decision model. The panel shows that when the other national level predictors are included in the model, inequality (i.e. Gini coefficient) is no longer associated with sensitivity to others' contributions. However, adherence to civic norms is associated negatively with sensitivity to others, and zero is not included in the 95% Bayesian Credible Interval. This indicates that national level adherence to civic norms is associated with increased sensitivity to others' contributions in the experimental public goods game. There is no clear association with trust, inequality, individualism, or national GDP for this parameter.

Panel D presents the posteriors for the partial correlation model relating national inequality and conditional preferences for cooperation, as inferred using the decision model. There is no clear association with national level trust, civic norms, individualism, national GDP, or national Gini coefficient for this parameter.

Fig. 4 presents the results relevant to our RQ4. Panel A presents the empirical relationship between national Gini coefficient and national level volunteering. The plot suggests that in countries with higher income inequality, volunteering rates are lower. Panel B presents the full posterior for the model of this relationship, and the model supports this inference. The panel shows that the mean of the posterior for the correlation is negative, and the 95% Bayesian Credible Intervals do not include zero (indicated with the red line). This indicates that national level inequality is associated with a lower national level volunteering rate.

Panel C presents the posteriors for the coefficients in the partial correlation model. The panel shows that when the other national level predictors are included in the model, inequality (i.e. Gini coefficient) is no longer associated with volunteering. The zero value for Gini is included in the 95% Bayesian Credible Interval. However, both GDP and trust are associated positively with volunteering rate. There is no clear association with civic norms.

5. Discussion

These results provide the following answers to our research questions. Concerning RQ1, national level income inequality is associated with reduced cooperation in the public goods game, measured as overall reduced contributions. Previous experimental research has induced or simulated inequality, by for example using different show-up fees (e.g. Anderson et al., 2008) or by providing different amounts of tokens on each trial to simulate income inequality (e.g. Schlösser et al, 2020). By comparing peoples' contributions to the public good across a range of societies with different Gini coefficients, the present research builds on these findings by investigating the effects of pre-existing inequality within different national communities. Our result suggests that research

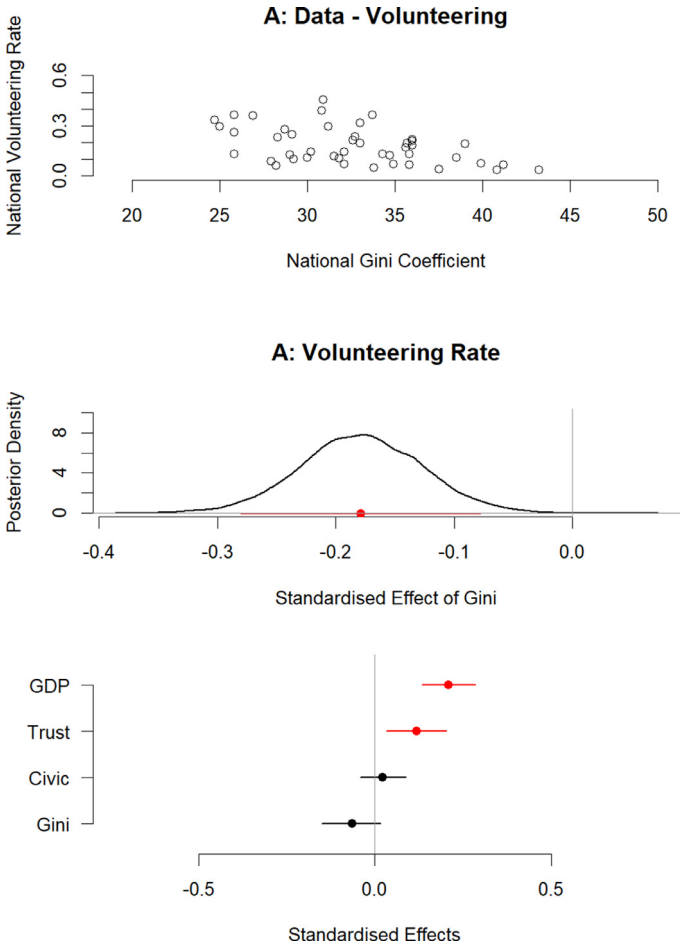

Fig. 4. Panel A: Scatterplot for the relationship between national level Gini coefficient and national level rate of social volunteering. Panel B: Posterior distribution for the standardized effect of national Gini coefficient on volunteering rate as inferred using the default correlation model, and the standardized effects of all social contextual variables on volunteering rate as inferred using the default partial correlation model. The points represent the mean of the posterior distributions, and the error bars represents the Bayesian Credible Intervals.

using simulated inequality in the lab is generalizable to more persistent forms of contextual inequality.

A recent meta-analysis on cooperation over time found a contrasting result; a positive association between income inequality and cooperation in experimental games (Yuan et al., 2022). It should be noted that this finding was obtained after controlling for a range of socio-economic variables which might impact the effect of inequality on cooperation, in a way similar to our own findings (see below). Also, data included in the meta-analysis was time-series cross-sectional, and from US participants only. Thus, the meta-analysis does not exclude the possibility that inequality has effects on cooperation which are not fully consistent across societies.

Concerning RQ2, our modelling indicates which individual level decision making processes might be responsible for reducing group contributions in less equal societies. Our model shows that national inequality is not related to preferences for conditional cooperation. In less equal societies, there is no systematic tendency for people to undermatch what they believe others will contribute. People are roughly equal in their level of conditional cooperation across different national level income distributions. However, national inequality is associated with decreased initial optimism about what others will contribute. This means that even though inequality does not affect how conditionally cooperative people prefer to be in the game, it may lead them to enter the game with the assumption that others will withhold more of their tokens. Given their more pessimistic beliefs, they will then contribute less at the outset. With the bar for cooperation thus set low, contributions will remain lower, even if groups are willing to match one another's contributions during the rest of the game.

Our model also shows that national inequality is associated with increased sensitivity to others' contributions. It is a well-known finding that in the experimental public goods game, group contributions decrease throughout the course of the game (Ledyard, 1995; Kopelman, Weber, and Messick, 2002; Zelmer, 2003). In this sort of context, people who are more sensitive to the group contribution will learn more quickly that others' contributions are declining. This will cause them to reduce their own contributions more steeply, as they match their contributions more accurately to the dropping contribution rate. This learning may create a vicious cycle that hastens decay in provision of the public good. Thus, the effect of national inequality on group contributions may be explained as a joint effect of decreased optimism about others' contribution intentions at the outset of the game, and increased sensitivity to others' contributions during the game.

Concerning RQ3, these relationships appear to be related to other national level social contextual variables. When other national economic and social variables (GDP, individualism, trust, and adherence to civic norms) were included in the models, there was no relation between Gini coefficient and contributions, and no relation between Gini coefficient and cognitive model parameters. Other social processes therefore seem important. Theoretical accounts exist to explain this importance.

Sánchez-Rodriguez and colleagues have shown that inequality causes people to perceive the social environment as more individualistic and competitive (Sánchez-Rodriguez et al, 2019). They have shown that in unequal environments, people are more likely to endorse values related to self-enhancement (Sánchez-Rodriguez et al, 2020). This is relevant, because self-enhancement emphasizes the importance of individual agency in one's placement within the resource distribution. Given that individualism was not related to contributions or model parameters, it is unlikely that these sorts of processes can account for the effects of inequality in the experimental public goods game. Further cross-national research will be required to reach a more definite conclusion.

The present analysis does suggest a relationship between contributions in the game and the social capital variables trust and adherence to civic norms. In more trusting nations, contributions were higher. Surprisingly, in nations where people expressed greater adherence to civic norms, the opposite was the case, and contributions were lower. Given that trust and civic norms are so closely related, this may appear contradictory. The decision model provides a way to resolve this contradiction.

In more trusting nations, people were more optimistic, and believed others would contribute more to the public good on the game's first round. Such a result is not so surprising (Chaudhuri et al., 2002; Evans and Krueger, 2016; Fiske et al., 2012). The concept of trust has been associated with the expectation of future reciprocity, and this expectation is understood to motivate cooperative behavior (Alós-Ferrer and Farolfi, 2019; Ostrom and Walker, 2003; see however Chaudhuri et al., 2002). Thus, it may be the case that as trust is reduced in less equal nations, people become less optimistic about others' contributions at the outset of the public goods game, leading to reduced overall group contributions as people match this lower expectation throughout the game.

In nations with higher adherence to civic norms, people were more sensitive to others' contributions, such that they more quickly updated their expectations about what others would contribute. Such a result is also not surprising. Adherence to civic norms is characterized by a belief about whether one's own and others' behavior will reliably follow social expectations for good interactions (Knack and Keefer, 1997; Granovetter, 2017). Thus we should expect that in nations with a higher adherence to civic norms, people monitor one another's actions more closely, to determine whether norms are being satisfied. This may explain the surprising result that groups in these nations contributed less.

As already indicated, if preferences for cooperation are held equal, then greater sensitivity to others' public goods contributions will lead to faster learning about reductions in contributions over trials, and faster decreases in one's own matching contributions. In this way, it appears that adherence to civic norms may be associated with an acceleration of the race-to-the-bottom dynamics typically observed in the experimental public goods game.

Thus, the following picture emerges. National level inequality is associated with lower provision of public goods in experimental games. This may in turn be explainable as an effect of inequality on social capital variables like trust and civic norms. Reduced trust may operate on contributions by decreasing initial optimism, and civic norms may operate by increasing sensitivity to the rest of the group, accelerating decay in cooperation.

There are important caveats to these interpretations. Research indicates that people do not perceive national wealth and income inequality accurately, and overall they tend to underestimate the level of inequality in their country (Kiatpongsan and Norton, 2014). It has further been proposed that it might be peoples' (mis)perceptions – and not real national inequality – that determine people's evaluations, including support for redistribution (Hauser and Norton, 2017). It should, however, be noted that the perception of inequality seems to also depend on which method is used to assess it (Eriksson and Simpson, 2012). Still, it might be an interesting avenue for future research to explore how perceived inequality impacts decision-making in the cooperative provision of public goods.

Further, any cross-national comparison ignores variation at more local levels. Inequality is not always uniform within a nation. Particularly in larger and more heterogeneous nations, some regions are more equal than others. The same is true of the other variables investigated. We nevertheless chose to use the national Gini coefficient as a measure of inequality, for two reasons. The first is that more local data was not available for many of the study sites. The second is that the research participants were university students, and it is therefore likely that at least some had been raised outside of the university regions in which the data were collected. Thus it is possible that more local Gini estimates are overly precise for this sample. Although these findings are indicative of persistent relationships between real-world inequality and decision making in the public goods game, efforts should be made to reproduce these results in more cleanly localized cultural and economic settings.

It should further be considered that the student samples recruited, and/or the location within a country that they were recruited from, can differ in how well they represent the national population. Research seeking to replicate these findings should aim to recruit participants who are more representative of national populations than university students, and to selectively recruit participants from cities that more consistently reflect their national economic and social context.

Despite these limitations, our results concerning RQ4 suggest that some of the insights gained from this research can be generalized. National level social volunteering was related to national level inequality, with less equal nations also contributing less to the community public good by engaging in social volunteering. This result could be partially explained by national differences in GDP. This is not surprising, given that people in wealthier nations should be expected to have more leisure time to dedicate to social volunteering. More interestingly, trust was also related to increased volunteering. This should be expected from our decision model. In more trusting nations, people are more likely to be optimistic about others' contributions, and so they are more likely to contribute more themselves, particularly at the outset. In the context of social volunteering, people may be more likely to sign-up to volunteer in more trusting and equal nations, because they appraise that there is more value in doing so when others will also be more likely to volunteer. The hands of many volunteers make light, and presumably more socially rewarding, work. More research is required to investigate how income distributions influence such social dynamics and the ways that they relate to the decision to volunteer. The present study indicates which conceptual and methodological tools might be useful in this research.

A further limitation of this study is that it cannot be used to make inferences about linear causal relationships. Although the models presented do suggest promising ways to interpret relationships between inequality, cognitive processes in decision-making, social capital, and the provision of public goods, linear causal inference concerning these relationships is only possible with time series data and/or experiments. The analyses presented here are not intended to answer causal questions, but to provide the building blocks for temporal models and experimental investigations in the future.

In any case we do not want to claim that inequality simply causes differences in the social capital of nations, which in turn causes differences in peoples' decision-making in public goods contexts. More likely, the right causal story is highly complex, with multiple interacting causal chains. Moreover, these causal processes are likely to be identifiable at multiple levels of analysis in society; at the micro-level scale of individual decision-makers, at the macro-level scale of cultures and nations, and no less importantly, at the meso-level scale of social networks (Granovetter, 2017). The present project is offered as a stimulus to understanding some of the relationships that might be involved in this larger perspective of explaining the effects of inequality on cooperative provision of public goods.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

All data are publicly available and data sources are referred to in text.

Ethics

No data were collected specifically for this study. All data analyzed in this study have been made publicly available. All efforts have been made to make the data analysis as transparent as possible, including the inclusion of all statistical modeling code as an appendix. All efforts have been made to generalize responsibly from the data and the analysis.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.cresp.2023.100112.

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