Does Overconfidence Promote Cooperation? Experimental Evidence from a Threshold Public Goods Game*

Jianbiao Li, Xile Yin and Te Bao

Abstract: This paper studies the effects of two types of overconfidence—overestimation and overprecision—on investment in a public good in a two-person threshold public good game. Our experimental results show that the influence of overconfidence on investment in public goods crucially depends on the agents' type of social preference. The marginal per capita return (MPCR) leads to a higher willingness to cooperate in conditional cooperators, but has little effect on the willingness of free-riders. The influence of overestimation on cooperation depends on the type of social preference that the agents have; overestimates lead to higher investment by conditional cooperators, but lower investment by free-riders. Finally, overprecision in general leads to higher investment by conditional cooperators, and tunes down the effect of changing MPCR on cooperation.

Keywords: Overconfidence, Overprecision, Overestimation, Heterogeneous Preferences, Threshold Public Good Game.

JEL Classification: C92, D64, H41

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Jianbiao Li: Selten Laboratory, Business School, Nankai University, Tianjin 300071, China, Email: biaojl99@gmail.com.

Xile Yin: Selten Laboratory, Business School, Nankai University, 300071 Tianjin, Email: yinxile@126.com.

Te Bao: Corresponding author, Division of Economics, School of Humanities and Social Sciences, Nanyang Technological University, 637332 Singapore, Email: baote@ntu.edu.sg

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1. Introduction

Recent studies in behavioral and experimental economics show that people do not only care about individual material payoffs in a social dilemma such as a public goods game. There is heterogeneity in individual preferences: some people are free-riders, but many others can be categorized as absolute or conditional cooperators. Conditional cooperators are typically the largest group, making up around 50% of the whole population (Liebrand, 1984; Fischbacher et al., 2001; Burlando and Guala, 2005; Zhou et al., 2013).

Beliefs about other group members' contributions influence individuals' contributions in a public goods game (Fischbacher and Gächter, 2010). As contributions to a public good depend on belief, any systematic bias in belief (Klayman et al., 1999; Moore and Healy, 2008; Beer et al., 2009), such as overconfidence, should also influence contributions. For example, when a conditional cooperator is overconfident in his or her ability to forecast others' behavior and holds the belief that others will contribute a lot, he or she will also tend to contribute a large amount.

Offerman et al. (1996) show evidence of the existence of overconfidence in a public goods game. They find that individuals' beliefs about others' contributions are systematically higher than the real values. However, to our knowledge, no study has investigated the influence of overconfidence on contribution in public goods games.

Here they refer to overconfidence in beliefs about others behavior, but afterwards they talk about overestimation and overprecision....let's see how they relate!

The main contribution of this paper is to report the effect of overconfidence on investments in public goods games. Overconfidence is apparent in overestimation and overprecision (Cain et al., 2015). Overestimation occurs when belief in one's ability, performance, or success rate is above the true level, and overprecision occurs when the variance of a variable is underestimated (Moore and Healy, 2008). We find that the influence of overconfidence depends on an individual's type of social preference. Overestimating leads to higher increases in investment by conditional cooperators, but lower increases in investment by free-riders. Overprecision in general leads to greater investment by conditional cooperators.

We design a threshold public good game with cheap talk to investigate these questions. This framework is an effective tool to elicit overconfidence and isolate the mechanism through which overconfidence influences cooperation.

A threshold public good imposes an additional incentive/punishment on the traditional linear public good, as seen in some cases in reality (Bagnoli and McKee, 1991). In real life, supervising authorities sometimes use threshold public goods to discourage free-riding. For instance, there is a minimum requirement for the performance of a team in a firm and the whole team will face severe punishment (e.g., layoff) if the performance is below this minimum level. This is designed to ensure that the team members have less incentive to free-ride on other members.

According to theory on illusion of control, if individuals consider themselves capable of controlling an event (though they may not be actually able to), they will have a tendency to think they have the ability to steer the event to a desirable outcome, and thus be overconfident (Weinstein, 1980; Malmendier and Tate, 2005). In the context of a public goods game, when an individual thinks he can influence his partner's contribution via a channel such as verbal communication/cheap talk (Cason et al., 2012; Palfrey et al., 2015), he is more likely to consider himself able to influence others' contribution decision, and thus will overestimate his partner's contribution. Cheap talk between partners in the same group is the "channel" that generates overconfidence in our paper.

We set up a model with heterogeneous preferences to study how overconfidence influences investment in a public good. We differentiate between overestimation and overprecision, hypothesize how they influence the contribution decision and test our hypotheses. To the best of our knowledge, our paper is the first to set up a model to analyze the effect of overconfidence on contribution in a public good game in a comprehensive way.

The remainder of the paper is organized as follows: Section 2 reviews the literature; Section 3 provides the theoretical analysis and testable hypotheses; Section 4 details the experimental design; Section 5 reports the experimental results and tests of the hypotheses; and Section 6 concludes the paper and discusses potential future extensions.

2. Literature Review

This paper studies how the interaction between heterogeneous preference and overconfidence influence investment in a public good. The related literature falls into three areas: the first is the study of belief formation and heterogeneous preference in public goods games, the second is the measurement of overconfidence in experiments and the third is cheap talk and the threshold public goods game.

2.1 Studies on Heterogeneous Social Preference and Belief Formation in Public Goods Games

Ample experimental evidence shows that individuals exhibit social preference; they are not only concerned about their own material benefit, but also the welfare of others (Charness and Rabin, 2002, Fehr and Schmidt, 1999). Important types of social preference include altruism, reciprocity and inequality aversion (Rabin, 1993; Fehr and Schmidt, 1999; Andreoni and Miller, 2002, Yang et al., 2016). As pure altruism is less often seen in experiments, more attention is paid to reciprocity and inequality aversion (Ashley et al., 2009; Chen, 2009; Ambrus and Pathak, 2011).

Fischbacher et al. (2001) differentiate between four types of social preferences: conditional cooperators, free-riders, triangle contributors and uncategorized players in a two-stage, strategic form public goods game. More than 50% of players can be categorized by conditional cooperators, and they typically exhibit self-serving bias, namely, investing lower amounts than the average. Fischbacher et al. (2001) attribute conditional cooperation behavior to inequality aversion and reciprocity. Their method of categorizing heterogeneous players is now the industry standard in the literature. Burlando and Guala (2005) survey four methods to measure heterogeneity in social preference—a two-stages strategic form public goods game, the decomposed game technique, a repeated linear public goods game and a questionnaire survey—and find the results from the four methods to be highly correlated.

Conditional cooperation occurs when belief in others' contribution is crucial in determining an individual's own contribution: an individual will lower (increase) her level of cooperation if she believes others will free-ride (cooperate). Offerman et al. (1996) and Croson (2007) show that investment in public goods is indeed highly influenced by individuals' beliefs. Fischbacher and Gächter (2010) find that investment in public goods is influenced by both belief formation and the type of social preference. If investment in public goods is determined by belief, it should also be heavily influenced by a bias in belief due to overconfidence.

2.2 Experimental Literature on the Definition and Measurement of Overconfidence

Like social preference, overconfidence (Camerer and Lovallo, 1999) also stems from rejection of the homo-economicus framework. Social preference is related to social psychology, whereas overconfidence is closer to cognitive psychology (Ben-David et al., 2010). Using modern technology such as fMRI and MEG, recent biological and neuroeconomics studies find that overconfidence is highly correlated with activity in the right prefrontal cortex and orbitofrontal cortex (Camchong et al., 2007; Beer et al., 2009). In general, studies on overconfidence fall into three categories: definitions of overconfidence, measurement of overconfidence and explorations of how overconfidence influences decision making at both individual and organizational levels.

Moore and Healy (2008) define three types of overconfidence: overestimation, overprecision and overplacement. Overestimation occurs when individuals' beliefs in their own ability, performance, level of control and success rate are systematically higher than reality. For example, leaders of corporations may overestimate the success of expanding their firms (Malmendier and Tate, 2005; Brown and Sarma, 2007; Jiang et al., 2009). Overprecision occurs when an individual underestimates the variance or variation of the value of the random variable, such as when "newsvendors" in the seminal newsvendor problem underestimate the variation in demand for newspapers (Ren and Croson, 2013). Overplacement, also called the "better than average effect," refers to cases in which people believe they are better than others in terms of ability or luck (Moore and Healy, 2008). It is important to understand how different types of overconfidence correlate or interact with each other (Cain et al., 2015). Moore and Healy (2008) find that individuals may exhibit different types of overconfidence in different games. They may tend to overestimate their ability but consider themselves worse than others at difficult tasks, or underestimate their absolute performance but consider themselves better than others at easy tasks. We focus on overestimation and overprecision because they are the most prevalent according to the literature. Moore and Healy (2008) find 64% of subjects overestimate and 31% display overprecision.

Effectively measuring overconfidence is a major challenge to studies on overconfidence (Jiang et al. 2009). Current empirical research using field data tends to focus on the CEO's performance forecast (Lin et al., 2005; Hribar and Yang, 2010), executives' stockholdings (Malmendier and Tate, 2005) and the frequency/scale of mergers and acquisitions (Aktas, 2009) as indices for overconfidence. The potential concern with these measures is that managers' more aggressive decisions may be due to private information on the profitability of the firms rather than to overconfidence. Experimental literature has proposed more accurate definitions of overconfidence. Klayman et al. (1999), Moore and Healy (2008), and Beer et al. (2009) ask the subjects a few test questions before the experiment. They use the difference between a participant's estimate of their number of correct answers and the actual number as a measure of overestimation. The measurement of overprecision usually takes the form confidence intervals: the subjects give the maximum and minimum possible number for the answers to 10 questions, such that there is a 90% chance that the correct answer falls into this interval (Nosic and Weber, 2010; Ren and Croson, 2013). Assuming perfect rationality of the subject, the interval should include the correct answer for 9 out of 10 questions. If r is the number of correct answers provided by a subject, $9 - r$ is the measure for overprecision. For example, if a subject misses the correct answer for all 10 questions, i.e., he answers no question correctly, his intervals are over-precise, and the level of overprecision is 9. If he answers all 10 questions correctly, his level of overprecision is -1, meaning he is very unconfident in his judgment and is enlarging the interval too much. Mathematical modeling of overconfidence considers an individual to overestimate if his belief of the expected value of a random variable is upwardly biased, and to demonstrate overprecision if his belief in the variance is too small (Ren and Croson, 2013). We build our mathematical model following this definition.

Although overconfidence has been studied in different contexts in economics and business, including expansion of firms (Roll, 1986, Jiang et al., 2009), asset trading (Ko and Huang, 2007; Grégoire, 2016), the principal–agent problem (Zhou, 2015) and supply chain decisions (Ren and Croson, 2013), to our knowledge, no studies have been done on the public goods game.

2.3 Cheap Talk and Threshold Public Goods

We adopt a threshold public goods game with cheap talk in this paper. Compared to the standard linear public goods game, the features of threshold public goods and cheap talk can also influence willingness to cooperate (Ostrom, 1990).

Threshold public goods are a form of nonlinear public good for which individual returns from the public good follow a piecewise linear function, and depend on whether the total contribution of the group reaches a threshold. Usually, the public good is only provided (and generates a positive return) if the total contribution exceeds the threshold. Otherwise, no group members will receive any return (Cadsby and Maynes, 1999; Palfrey et al., 2015). A threshold public good imposes an additional incentive/punishment on the linear public good, to better capture the mechanism in some real-life situations (Bagnoli and McKee, 1991). Usually, a threshold public good game has multiple Nash Equilibria, with the threshold as a focal point (Cadsby and Maynes, 1999). The threshold public good thus typically discourages free-riding more than a linear public good does, although it may result in lower contributions when the current total contribution is well above the threshold.

We allow subjects in the same group to communicate with each other via cheap talk (Cason et al. 2012, Palfrey et al. 2015). Cheap talk may influence our result in two ways. First, allowing subjects to communicate may generate a larger illusion of control such that a subject may be overconfident about how their message can influence others' investment level. Second, all communication, including non-binding cheap talk, can lower the strategic uncertainty from others (Riechmann and Weimann, 2008), which may also influence willingness to cooperate (Cason et al. 2012). If our subjects are overconfident about (i.e., overestimate) their ability to influence their partner, they should also overestimate the contribution made by their partners.

To sum up, Croson (2007) and Gächter and Renner (2010) find that investment in public goods is influenced by beliefs. This paper investigates how cognitive biases[1] such as overestimation and overprecision may influence belief formation, and hence investment in public goods. Fischbacher and Gächter (2010) argue that individual investment in public goods is influenced by both heterogeneous social preferences and belief, but they do not study how the two factors interact. The second contribution of this paper is to pin down the interaction between belief formation and heterogeneous social preferences when individuals exhibit overconfidence.

3. Theoretical Framework and Testable Hypotheses

3.1 Theoretical Framework

According to the theory of social preferences, individuals do not only care about their own material benefit, but also others' benefits. The utility function of individuals can be then written as $U_i\left(I_i\right) = x_i\left(I_i\right) + S_i\left(I_i\right)$, where I_i is the choice variable (e.g., investment in public goods), $x_i\left(I_i\right)$ is the material return from I_i to the individual and $S_i\left(I_i\right)$ is the return in terms of social preference generated by I_i. Burlando and Guala (2005) differentiate three types of individual—free-riders, conditional cooperators and cooperators—according to their social preferences. Free-riders purely maximize their own material benefit. Conditional cooperators' investment increases with their belief in the level of the investment by other group members, and cooperators include unconditional cooperators in addition to those whose investments have an inverse U-shaped relation[2] to belief about others' contributions.

In a standard *n*-person linear public good game $x_i = E_i - I_i + \lambda \sum_1^n I_j, \frac{1}{n} < \lambda < 1$, where E_i is the initial cash endowment, λ is the marginal per capita return (MPCR) of the public good. In this paper, we adopt a threshold public good design, where x_i depends on whether the total investment in *i*'s group, $\sum_1^n I_i$ reaches or exceeds *T*: if $\sum_1^n I_i > T$, the difference between the total investment and *T*, $\sum_1^n I_i - T$, generates returns for all individuals, otherwise every group member is punished according to the difference between the total investment and *T* multiplied by a linear coefficient δ, in which case 1 unit

[1] For examples of the influence of other types of cognitive biases, such as depletion of will power on social preferences, see Achtziger et al. (2015).
[2] This means the contribution of the individual is low when his belief in others' contribution is very low or very high, but high when he thinks others' contribution is moderate.

increase in individual investment leads to δ unit decrease in the punishment. The return function for each individual *I* can be written as

$$x_i = \begin{cases} E_i - I_i - \delta\left(T - \sum_{1}^{n} I_j\right), if \quad \sum_{1}^{n} I_j < T, \\ E_i - I_i + \lambda\left(\sum_{1}^{n} I_j - T\right), if \quad \sum_{1}^{n} I_j \geq T \end{cases}, \text{ where } 0 < \lambda < 1/n,\ \delta > 1.$$

This can be simplified to $x_i = E_i - I_i - \delta \max\left(T - \sum_{j=1}^{n} I_j\,, 0\right) + \lambda(\sum_{j=1}^{n} I_j - T, 0)$. The introduction of the threshold adds to the incentive to invest in the public good compared to the standard linear public good game. In this case, the optimal investment is not zero even for purely self-interested individuals. Instead, they should try to at least ensure $\sum_{1}^{n} I_i = T$. When the threshold $T = 0$, the threshold public good game degenerates to a standard linear public good game.

In the following section, we discuss how the effect of overconfidence on investment in a public good depends on the social preference of the subjects.

3.1.1 Overconfidence and investment by pure free-riders

Pure free-riders maximize their own material benefit and therefore have the following utility function:

$$x_i = E_i - I_i - \delta \max\left(T - \sum_{j=1}^{n} I_j\,, 0\right) + \lambda(\sum_{j=1}^{n} I_j - T, 0).$$

To simplify the model and the experimental design, we consider a case with two people in a group, and remove the subscript i. Player *i* assumes the investment by his partner, j. I_j is a random variable *Y*,[3] which has a cumulative distribution function $F(\cdot)$and density function $f(\cdot)$. The total investment in this player's group is therefore $Y + I$. We can transform the expression of the material benefit function x to Equation (1),

$$x = E - I - \delta \int_0^{T-I} (T - y - I) f(y) dy + \lambda \int_{T-1}^{E} (y + I - T) f(y) dy, \tag{1}$$

which can be simplified into (2),

[3] In an *n*-person public good game, we can assume that player *i* assumes the average investment by all other players is a random variable *Y* and the total investment of the group is hence $I_i + (n-1)Y$. Our model can be extended to the *n*-person case in this way.

$$x = E - I + (\lambda - \delta)(T - I)F(T - I) - \lambda(T - I) + \delta \int_{0}^{T-I} yf(y)dy + \lambda \int_{T-I}^{E} yf(y)dy \cdot \tag{2}$$

According to (2) we have Equation (3), which provides the first and second order conditions to maximize x,

$$\begin{cases} \dfrac{dx}{dI} = \lambda - 1 + (\delta - \lambda) F(T - I) \\ \dfrac{d^2 x}{dI^2} = -(\delta - \lambda) f(T - I) \end{cases} \tag{3}$$

As $\delta > \lambda$, the density function $f(T - I) > 0$, and together with (3) we obtain $\dfrac{d^2 x}{dI^2} < 0$. The benefit function $x(I)$ is thus a concave function of I. There exists a unique optimal I^* that satisfies $\dfrac{dx}{dI^*} = 0$ and maximizes $x(I^*)$. The optimal investment is given by (4).[4]

$$I^* = T - F^{-1}\left(\frac{1-\lambda}{\delta - \lambda}\right) \tag{4}$$

Based on the above equation, I^* is the optimal investment for an individual i who maximizes his own material benefit. However, the result relies on the assumption that this individual makes unbiased estimates of the investment by others, which does not necessarily always hold in reality. Offerman et al. (1996) find that individuals tend to significantly overestimate investment by others, which suggests some degree of overconfidence. Following the definition of Ren and Croson (2013), the players' overconfidence in the others' investment Y may take the form of overestimation (upward bias in the value) or overprecision (underestimates of the variance). If Y has an expected value μ and variance σ^2, an overestimate means that the expectation of the player has a mean $\alpha\mu$, $\alpha > 1$, where the parameter α measures the degree of overestimation. Overprecision means that the expectation of the player for the standard error of Y is $(1-\beta)\sigma$, $0 < \beta < 1$. A larger β means a higher degree of overprecision.

[4]Given $0.5 < \lambda < 1$, $\delta > 1$, we have $0 < \dfrac{1-\lambda}{\delta - \lambda} < 1$, which satisfies the property of a cumulative distribution function $F(x) \in [0,1]$.

How do the parameters α and β influence investment in a public good via their influence on player i's belief about the mean and variance $\left(\mu,\sigma^2\right)$ of Y ? Equation (4) $I^* = T - F^{-1}\left(\frac{1-\lambda}{\delta-\lambda}\right)$ does not contain $\left(\mu,\sigma^2\right)$ directly. We introduce $\left(\mu,\sigma^2\right)$ to the optimal investment I^* using a standard transformation of the cumulative distribution function as proposed by Ren and Croson (2013).

First, we normalize Y to $X = \frac{Y-u}{\sigma}$, where X follows a stochastic distribution with 0 mean and variance of 1. Let $G(X)$ be the cumulative distribution function and $g(X)$ be the density function. Given Equation (4) $F\left(T - I^*\right) = \frac{1-\lambda}{\delta-\lambda}$, let b be an argument in $G(b) = \frac{1-\lambda}{\delta-\lambda}$, which leads to Equation (5),

$$\frac{1-\lambda}{\delta-\lambda} = G\left(b\right) = p(X < b) = p(\frac{Y-\mu}{\sigma} < b) = p(Y < \mu+\sigma b) = F(\mu+\sigma b). \quad (5)$$

From (5), $\frac{1-\lambda}{\delta-\lambda} = F(\mu+\sigma b)$, and $F\left(T - I^*\right) = \frac{1-\lambda}{\delta-\lambda}$, we have $F(\mu+\sigma b) = F\left(T - I^*\right)$. Further, as the F function is an increasing function of its argument, we have $T - I^* = \mu + \sigma b$, namely, $I^* = T - \left(\mu+\sigma b\right)$.

Overconfidence influences the player's belief about Y. More specifically, let Y_o be the belief of the player of Y. Then Y_o should have an expected value of $\alpha\mu$ and standard deviation $(1-\beta)\sigma$. Let I_o^* be the optimal investment level under overconfidence. Using $I^* = T - \left(\mu+\sigma b\right)$, we can arrive at Equation (6),

$$I_o^* = T - \left(\alpha\mu + \left(1-\beta\right)\sigma b\right) = T - \left(\alpha\mu + \left(1-\beta\right)\sigma G^{-1}(\frac{1-\lambda}{\delta-\lambda})\right). \qquad (6)$$

When an individual is subject to the cognitive bias of overconfidence, his optimal investment conditional on his belief is I_o^* as defined in Equation (6). Equation (6) reveals the following properties of the conditionally optimal investment.

Theorem 1: *The conditional optimal investment I_o^* is positively correlated with the marginal per capita return λ.*

Theorem 2: *A higher* β *results in less influence of* λ *on the conditionally optimal investment* I_o^*.

Theorem 3: *A higher value of overestimation* α *results in lower investment* I_o^*.

To prove Theorem 1, derive the first order condition of Equation (6) $\frac{\partial I_o^*}{\partial \lambda}$, leading to Equation (7),

$$\frac{\partial I_o^*}{\partial \lambda} = -(1-\beta)\sigma \frac{1}{G(b)} \frac{-(\delta-\lambda)+1-\lambda}{(\delta-\lambda)^2} = (1-\beta)\sigma \frac{1}{G(b)} \frac{\delta-1}{(\delta-\lambda)^2} > 0 \qquad (7)$$

which shows that the optimal investment to public good is positively correlated with the MPCR of the public good, in accord with previous findings (e.g., Carpenter (2007)). However, the influence of λ on I_o^* will decay with a larger overprecision parameter β. In particular, when $\beta = 1$, the influence of λ on I_o^* is 0,[5] which proves Theorem 2. Finally, $\frac{\partial I_o^*}{\partial \alpha} = -\mu < 0$, proving Theorem 3.[6]

3.1.2 Overconfidence and investment by conditional cooperators

Fischbacher et al. (2001), Burlando and Guala (2005), Fischbacher and Gächter (2010) and Zhou et al. (2013) find the largest fraction (about 50%) of subjects in public good experiments can be categorized as conditional cooperators. Conditional cooperation happens when "the investment to public good increases when the investment by others, or one's belief on the investment by others increases" (Fischbacher et al., 2001). Fischbacher et al. (2001) attribute conditional cooperation to inequality aversion and reciprocity, whereas Burlando and Guala (2005) and Zhou (2013) attribute it solely to reciprocity.

To model how overconfidence influences investment by conditional cooperators, we first need to understand which one of inequality aversion and reciprocity is most suitable to model conditional cooperation behavior. Although the definition of conditional cooperation is close to the definition of reciprocity (the degree of association between one's own and others' investment) by Ashley et al. (2009) and Chen (2009), inequality aversion can also lead to conditional cooperation due to the structure of a

[5] To confirm this theorem, we design a within subject treatment with two MPCR values (MPCR=0.8 VS MPCR=0.6) to examine whether the difference in investment is negatively correlated with overprecision.
[6] We elaborate on this point in the section on testable hypotheses.

public good game in which everyone has the same return from the public investment.[7] In this way, inequality aversion may also lead to conditional cooperation. Conditional cooperators usually exhibit self-serving tendencies to make their own investment level lower than the level of others. Fischbacher and Gächter (2010) call this imperfect conditional cooperation. The self-serving bias is in accord with the Fehr and Schmidt (1999) model in the sense that individuals dislike disadvantageous inequality more than advantageous inequality. Ashley et al. (2009) and Chen (2009) find experimental evidence in support of asymmetry in inequality aversion in the Fehr and Schmidt (1999) model. They find the result is mainly driven by inequality to disadvantageous inequality, and there is little evidence for reciprocity. Thus, we model conditional cooperation using the inequality aversion model.

In the inequality aversion model of Fehr and Schmidt (1999), the utility function of individual i is written as $U_i(x) = x_i - \varphi \sum_{j \neq i} \max\{x_i - x_j, 0\} - \theta \sum_{j \neq i} \max\{x_j - x_i, 0\}$, where x_i is her own monetary payoff, $\varphi \sum_{j \neq i} \max\{x_i - x_j, 0\} + \theta \sum_{j \neq i} \max\{x_j - x_i, 0\}$ is the loss of utility due to inequality in income distribution, φ ($0 \leq \varphi < 1$)is the parameter for advantageous inequality aversion, and θ ($\theta \geq \varphi$)is the parameter for disadvantageous inequality aversion. The utility function of an individual with inequality aversion can be expressed by Equation (8).[8]

$$S = -\varphi \max(x_i - x_j, 0) - \theta \max(x_j - x_i, 0), \theta > \varphi > 0 \tag{8}$$

The monetary payoff for individual i in a threshold public good game is $x_i = E - I - \delta \max(T - Y - I, 0) + \lambda(Y + I - T, 0)$, and his belief about the payoff to his partner j is $x_j = E - Y - \delta \max(T - Y - I, 0) + \lambda(Y + I - T, 0)$. Thus, we have $x_i - x_j = Y - I$. Substituting into Equation (8) we obtain Equation (9),

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[7] When the benefit function of individual i is $x_i = E - I - \delta \max(T - Y - I, 0) + \lambda(Y + I - T, 0)$, and his perceived benefit function of j is $x_j = E - Y - \delta \max(T - Y - I, 0) + \lambda(Y + I - T, 0)$, we have $x_i - x_j = Y - I$.

[8] The utility function of individuals with inequality aversion does not contain their own monetary payoff in our paper. This simplification allows us to have a concave objective function in later parts of the paper to solve the optimal investment. By the same argument, a pure free-rider's utility function only depends on his own payoff, but not on the income inequality between individuals. We further argue that in a world where another's investment in a public good is a stochastic variable, this simplification does not harm the generality of our results. For example, one potential concern about this utility function is that it is only maximized when the conditional cooperators always perfectly match their contribution with the expected other's contribution, i.e., $I = Y$. We argue that this is only the case if the individual is certain of I, and our model does allow individuals to invest a different amount, e.g., exhibit self-serving bias by investing $I < Y$. The reason is that in a stochastic world, individuals need to balance the trade-off between utility loss due to disadvantageous inequality (investing too much) and advantageous inequality (investing too little).It is optimal for them to invest less than others given they dislike disadvantageous inequality more than advantageous inequality ($\theta > \phi$).

$$S = -\varphi \max\left(Y - I, 0\right) - \theta \max\left(I - Y, 0\right). \qquad (9)$$

As Y is a random variable, Equation (9) can be rewritten as Equation (10)

$$S = -\varphi \int_{I}^{E} \left(Y - I\right) f\left(y\right) dy - \theta \int_{0}^{I} \left(I - Y\right) f\left(y\right) dy, \qquad (10)$$

which can be rearranged to (11),

$$= \varphi I \left(1 - F\left(I\right)\right) - \varphi \int_{I}^{E} y f\left(y\right) dy + \theta \int_{0}^{I} y f\left(y\right) dy - \theta I F\left(I\right). \qquad (11)$$

Taking the first and second order derivatives of (11) leads to (12)

$$\begin{cases} \dfrac{dS}{dI} = \varphi - \left(\varphi + \theta\right) F\left(I\right) \\ \dfrac{d^2S}{dI^2} = -\left(\varphi + \theta\right) f\left(I\right) \end{cases} \qquad (12)$$

as $\frac{d^2S}{dI^2} < 0$, $S\left(I\right)$ is a concave function. Therefore, there is a unique optimal level I^* that satisfies $\frac{dS}{dI^*} = 0$ and maximizes the value of $S\left(I^*\right)$. In this case, $F\left(I^*\right) = \frac{\varphi}{\varphi + \theta} \Leftrightarrow I^* = F^{-1}\left(\frac{\varphi}{\varphi + \theta}\right)$. To separate the effect of overestimation and overprecision on contributions to a public good, we transform the equations in a similar way as for (11) and (12). Let b_2 satisfy $G(b_2) = \frac{\varphi}{\varphi + \theta}$,

$\frac{\varphi}{\varphi + \theta} = G\left(b_2\right) = p(X < b_2) = p(\frac{Y - \mu}{\sigma} < b_2) = p(Y < \mu + \sigma b_2) = F(\mu + \sigma b_2)$. Thus,

$F\left(I^*\right) = \frac{\varphi}{\varphi + \theta} = F(\mu + \sigma b_2)$, together with the monotonicity of cumulative distribution functions, we know $I^* = \mu + \sigma b_2$. The contribution by an overly confident individual, I_o^* should be given by (13)

$$I_o^* = \alpha\mu + \left(1 - \beta\right)\sigma b_2, \qquad (13)$$

which leads to two the following two theorems.

Theorem 4: *A higher value for overestimation* α *leads to higher investment in public good* I_o^* *; and*

Theorem 5: *A higher value for overprecision* β *also leads to higher investment in public good* I_o^* *.*

First, $\frac{\partial I_o^*}{\partial \alpha} = \mu > 0$ leads to Theorem 4. Second, $\frac{\partial I_o^*}{\partial \beta} = -\sigma b_2$ means the influence of overprecision on public good investment depends on the sign of b_2. As $\theta > \varphi$, $G(b_2) = \frac{\varphi}{\varphi + \theta} < \frac{1}{2}$. Further, given the zero mean of the distribution function $G(x)$, if X is symmetrically distributed, we should have $b_2 < 0$. In this situation, $\frac{\partial I_o^*}{\partial \beta} = -\sigma b_2 > 0$, which confirms the positive relationship between overprecision and investment[9] in Theorem 5.

3.2 Testable Hypotheses

3.2.1 The influence of MPCR on investment in a public good

According to Theorem 1, a free-rider's investment in a public good is positively correlated with MPCR. A free-rider searches for an optimal investment level I^* to maximize his or her individual payoff. He receives a punishment of $\delta\left(I^* - I\right)$ if his investment is below the optimal level, and suffers from a "loss" of income $\left(1-\lambda\right)\left(I - I^*\right)$ due to failure to free-ride if he invests more. He thus faces a tradeoff between these two potential losses. When λ increases, he suffers less when he overinvests. He should then give more weight to the potential loss due to underinvestment, and hence invest more. This result also holds for conditional cooperators. The main reason is that the conditional cooperator may hold the belief that his partner is a free-rider. His belief in his partner's investment is higher when MPCR λ is higher. This leads to Hypothesis 1.

[9] The condition for X to follow a normal distribution is that Y follows a symmetric distribution such as a normal or uniform distribution. This is usually assumed to be the case in statistical analyses. In addition, we elicited the subjects' belief about their partner's investment in the experimental questionnaire. The result shows that 69.167% of the subjects think it follows a normal or uniform distribution, 20.833% think they can make an accurate point prediction, and only 10% think the investment follows a skewed distribution. We provided detailed information about those statistical distributions before they answered the questionnaire.

Hypothesis 1: *The investment in the public good increases with MPCR.*

Hypothesis 1a: *A free-rider's investment is higher when MPCR is higher.*

Hypothesis 1b: *A conditional cooperator's investment level is higher when MPCR is higher.*

3.2.2 The effect of overestimation on public good investment

According to Theorems 3 and 4, the contribution of a free-rider to the public good is negatively correlated with the level of his overestimate, whereas the contribution of a conditional cooperator is positively correlated with the level of his overestimate. Intuitively, free-riders maximize their own payoff, and try to invest less as long as the investment of the whole group passes the threshold. When they overestimate others' investment, they also overestimate the likelihood of the total investment of the group passing the threshold.[10] The logic behind Theorem 4 is easier to interpret: conditional cooperators try to "match" the investment level by their partners, and they tend to invest more if they overestimate their partners' investment.

Hypothesis 2: *Individuals' investments in a public good are influenced by their level of overestimation.*

Hypothesis 2a: *Free-rider's investments are lower when their level of overestimation is higher.*

Hypothesis 2b: *Conditional cooperators' investments are higher when their level of overestimation is higher.*

3.2.3 The effect of overprecision on the influence of MPCR on investment

Hypothesis 1 indicates that investment in a public good increases with MPCR, and Theorem 2 indicates that overprecision lowers the extent to which MPCR positively influences investment in a public good. Combining the theory behind Hypothesis 1 and Theorem 2, we expect overprecision to lead to a lower increase in investment in the public good when MPCR increases. Consider one extreme case as an example: suppose the threshold of public good investment is 10, and a free-rider knows his partner will certainly invest 6. In this situation, the free-rider will invest in 4 no matter how high or low the MPCR is. This holds for conditional cooperators too, because of their self-serving bias. To test Theorem 2, we vary the MPCR at two levels (MPCR = 0.8 VS MPCR = 0.6) and state Hypothesis 3 as follows.

Hypothesis 3: *The increase of investment when MPCR increases is negatively correlated with overprecision.*

[10] Though he thinks he maximizes his payoff in this situation, he may suffer some loss due to underinvestment ($I < I^*$).

Hypothesis 3a: *The increase of the investment by free-riders when MPCR increases is negatively correlated with overprecision.*

Hypothesis 3b: *The increase of the investment by conditional cooperators when MPCR increases is negatively correlated with overprecision.*

3.2.4 The effect of overprecision on investment in a public good

According to Theorem 5, conditional cooperators' overprecision leads to higher investment in a public good. For example, when an individual exhibits inequality aversion, he will incur utility loss due to advantageous inequality aversion $\varphi\left(Y-I\right)$ if his investment *I* is smaller than his partner's investment *Y*, and disadvantageous inequality aversion $\theta\left(I-Y\right)$ if the opposite is true. As the investment by his partner is a stochastic variable to the conditional cooperator, he needs to evaluate the tradeoff between $\varphi\left(Y-I\right)$ and $\theta\left(I-Y\right)$.As $\theta>\varphi$, the conditional cooperator will tend to underinvest because he dislikes disadvantageous inequality more than advantageous inequality. Overprecision means lower uncertainty in the investment by the partner, and hence lower underinvestment due to the tradeoff. Thus, overprecision should lead to higher investment by conditional cooperators.

Hypothesis 4: *Investment by conditional cooperators increases with overprecision.*

4. Experimental Design

4.1 Setup and Parameterization

This experiment consists of four parts. The first part measures the degree of overprecision of each individual, the second part measures the overestimation. Both the first and second parts are pen-and-paper based. The third part is the computerized experiment and the fourth part is the post-experiment questionnaire. Payments are made after all parts of the experiment.

In the first part, overprecision is measured using the standard confidence interval method, i.e., by finding the minimum and maximum value of the 90% confidence interval of the answer to 10 general knowledge questions. The 10 questions are based on Nosic and Weber (2010) and Ren and Croson (2013), with some variations to adapt for the cultural context in China. For example:[11]

How long is the River Nile? (in kilometers)   Minimum: _______ Maximum:______

[11]The subjects receive a fixed reward of 5 yuan after the completion of the first part.

The second part measures the level of overestimation. The subjects first answer 10 questions, and are then asked "How many questions do you think you have answered correctly among the last 10 questions?" The subjects are rewarded with 0.5 yuan for each of the 10 questions they answer correctly. We use the actual number of correct answers minus the number of questions they think they answered correctly as the measure of overestimation. The 10 questions are based on Moore and Healy (2008), with some adaption for the cultural context in China. The question topics include science, history, geography, sports and economics.

The third part comprises two computerized experiments (Experiment I and Experiment II). Both experiments are threshold public good games with cheap talk; the only difference is in the value of MPCR.

In Experiment I, the subjects have an initial endowment of G$20 each. The payoff functions for each subject are as follows.

(1) When the total number of G$ invested in the public good is below 10,

$$payoff_i = 20 - Investment_i - 1.3(10 - Total\ Investment).$$

(2) When the total number of G$ invested in the public good is greater than or equal to 10,

$$payoff_i = 20 - Investment_i - 0.8(Total\ Investment - 10).$$

The subjects can conduct 90-second non-binding verbal communication (cheap talk) after the beginning of each round. They are not allowed to mention identity information such as their name, major or school. They are asked to predict how much their partners are going to invest in the public good after the communication. As communication can influence individual decisions (Cason et al., 2012), we also ask them to evaluate the effectiveness of the communication (on a 5-point scale) to control the effect of communication.

Experiment I consists of five rounds. One randomly chosen round is paid after the experiment. The subjects are rematched after each round to avoid reputation and reciprocity effects between subjects in repeated games. The subjects do not know the investment and belief of their partner, or the payoff in the last round. This is implemented to avoid subjects updating their beliefs via dynamic learning.[12] Thus, we can treat the five rounds as five independent observations (Chen, 2009).[13] We use the multi-round design to increase the number of observations and thus give more power to the results. Based on Burlando and

[12] We only consider static analysis in our paper, and do not discuss how people update their beliefs in dynamic games.
[13] The communication in this experiment also helps to alleviate subjects' boredom and tiredness in repeated game experiments.

Guala (2005), the multi-period design is also useful for measuring the heterogeneity of individual preferences.

Experiment II is the same as Experiment I except that the MPCR decreases from 0.8 to 0.6. The comparison between Experiment I and II is helpful in testing Hypotheses 1 and 3.

The last part is the post-experiment questionnaire, which collects the subjects' demographic information such as sex, age, education and degree level.

4.2 Method to Categorize Heterogeneous Preferences

Burlando and Guala (2005) summarize four methods to categorize heterogeneous social preferences: a two-stage strategic game, the decomposed game technique, a repeated linear public good game and the questionnaire method.

The repeated linear public good game works as follows: let IA be the average investment by a subject, and AD be defined as individual *IA* minus the group *IA*. Use F to denote free-riders, R for reciprocators (conditional cooperators) and C for cooperators. When the initial endowment for each subject is 20, his type of preference is categorized using criteria 1:

i. When $IA > 12$, he is classified as type R or C.
ii. When $8 \leq IA \leq 12$, he is classified as type R.
iii. When $IA < 8$, he is classified as R or F.

Undetermined cases under (i) and (iii) are further classified by criteria 2:

a) When $AD \geq 1$, the subject is classified as type C.
b) When $-1 \leq AD \leq 1$, the subject is classified as type R.
c) When $AD \leq -1$, he is type F.

We follow a classification similar to the repeated linear public good game for the following reasons. First, Burlando and Guala (2005) show that there is remarkable convergence between their four methods of categorizing heterogeneous social preferences. Second, this method is easier for the subjects to understand than the two-stage game method. As we have a communication stage in our experiment, and communication tends to promote prosocial behavior even when it is non-binding (Stiff et al., 1988; Cason et al., 2012), the strategic method is not very suitable.[14]

The above method requires information about AD (the difference between own and average investment in the group), which is not available for the subjects in our experiment. We thus apply the criteria “the difference between a subject’s own investment and his belief in his partner’s investment is less than 10% of the initial endowment” in Burlando and Guala (2005) to replace criteria 2 in the above method. We use the first two rounds of the five-round game to classify types of preference, and the last three rounds to collect data on investment in the public good.

To check the robustness of the above method, we also elicit the type of social preference using a questionnaire, as suggested by Burlando and Guala (2005).

4.3 Definition of Variables and Explanations

The names and meaning of the variables in the experiment are reported in Table 1.

Table 1 Names and Meanings of Variables

Name of variable	**Meaning**	**Remark**
	Dependent variable	
Contribution	Investment in public good	$0 \leqslant \text{contribution} \leqslant 20$
△contribution	Investment when treatment = 1 minus investment when treatment = 0	The influence of change of MPCR on investment in public good
	Independent variable	
Overprecision	Degree of overprecision measured in Part I	Overprecision for positive values, underprecision for negative values, and 0 for no overprecision
Overestimation	Degree of overestimation measured in Part II	Overestimate for positive values, underestimate for negative values, and 0 for no overestimate
Belief	Belief about partner’s investment	$0 \leqslant \text{belief} \leqslant 20$
Conditional cooperator	Conditional cooperator	Dummy variable (1 for this type, 0 otherwise)
Free-rider	Free-rider	Dummy variable (1 for this type, 0 otherwise)
Inequ_aversion	Have inequality aversion according to answers in the questionnaire	Dummy variable (1 for having inequality aversion, 0 otherwise)
Reciprocity	Exhibit reciprocity according to answers in the questionnaire	Dummy variable (1for exhibiting reciprocity，0 otherwise)
	Control variables	
Commu_effect	Effectiveness of communication	5 point scale
Treatment	Treatment based on MPCR	Dummy variable (1 for MPCR = 0.8, 0 for MPCR = 0.6)

[14] It is not appropriate to add a communication phase in strategic method games because the subjects will form a relatively stable belief about the others’ actions, and neglect the possibility of some hypothetical action. Fischbacher and Gächter (2010) find that subjects exhibit higher levels of conditional cooperation in games in which they take actions directly than in the strategic form games. This result casts doubt on the reliability of the strategic form method.

Sequence	Sequence of treatments	Dummy variable(1 for MPCR = 0.8 before MPCR = 0.6, 0 otherwise)
Period	Round number	1≤period≤3
Sex	Sex	Dummy variable for female(1 for female,0 for male)
Education	Education	Dummy variable(1 for master student，0 for bachelor)
GPA	GPA of courses	5-point scale, the higher the score, the better the GPA

5. Experimental Results

The experiment was run in the Selten Experimental Economics Lab of Nankai University in June 2015. Six sessions were conducted, and 20 subjects participated in each session. All 120 subjects were Bachelor's or Master's students at Nankai University or Tianjin University; 66% of them were female, and 55% were Master's students. To take into account the order effect, we ran treatment = 1 (high MPCR) first in sessions 1-3, and treatment = 0 (low MPCR) first in sessions 4-6. The experimental software was Z-tree (Fischbacher, 2007). The average duration of each session was 90 minutes, and the average payment was 36.5 yuan (about 6-7 dollars). We report the results in three parts. Part 1 reports the descriptive statistics, Part 2 shows the influence of overestimation, and Part 3 shows the influence of overprecision.

5.1 Descriptive Statistics

Table 2 shows that the average investment in the public good is 13.139, equivalent to 65.695% of the initial endowment. Most of the participants (69.2%) can be categorized as conditional cooperators, 10% as free-riders and 20.8% as other cooperators. Compared to the results in Fischbacher and Gächter (2010) and Zhou et al. (2013), we have substantially fewer free-riders in our experiment (the fraction of free-riders is 22.9% in Zhou et al.). This result suggests that the communication device and the setting of the threshold discouraged participants from free-riding. In addition, the average degree of overestimation and overprecision is positive, which suggests an overall tendency to exhibit overconfidence. The degree of overprecision is 4.992, a remarkably high level, whereas the degree of overestimation is much smaller (0.817).

Table 2 Descriptive Statistics

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
Contribution	13.139	7.780	0	20
△contribution	0.84	8.496	-20	20

Belief	15.784	5.965	0	20
Overprecision	4.992	2.453	-1	9
Overestimation	0.817	1.799	-3	5
Free-rider	0.100	0.300	0	1
Conditional cooperator	0.692	0.462	0	1
GPA	2.858	1.605	1	5
Commu_effect	3.958	0.851	2	5

5.2 The Coefficients of Control Variables

The control variables used in the regressions include effectiveness of communication (Commu_effect), MPCR (Treatment), order of treatments (Sequence), round number, sex, education and GPA. Table 3 reports the effects of these variables on contribution to the public good when investment is regressed only on the control variables. We report both OLS and Tobit regression outputs. It is clear that the variables Sequence, Education and GPA have no significant effect on contribution to the public good. For other variables **the effectiveness of communication is associated with higher investment in the public good.** Almost all (97.5%) of the subjects think the effectiveness of communication is greater than 3 (on a 5-point scale). The average investment is 10.302, 12.985, 16.055 for effectiveness of communication levels “average (3),” “good (4)” and “very good (5),” respectively.(χ^2 for the Kruskal-Wallis test is 66.234, p = 0.00<0.01). Thus, it is clear that more effective communication leads to higher investment in a public good. This is also confirmed by the significant and positive coefficient for Commu_effect in the regression (p <0.01). This result is in line with the results of Cason et al. (2012) and Palfrey et al. (2015).

Female subjects behave more cooperatively than male subjects. The average investment in the public good is 13.97 (out of 20) for females and 11.54 for males. The difference is significant at the 5% level according to the Wilcoxon rank sum test ($z = 3.352$, $p = 0.001$). The dummy variable for female is also significant at 1% in the regression reported in Table 3. Croson et al. (2008) argue that females are better at coordinating than males are, and therefore behave more cooperatively than males in games with multiple equilibria. Our result supports this argument

Table 3: The Results of Regressing Contribution on Control Variables

Dependent variable	**Contribution**

Specification	OLS	Tobit
Sequence	0.392	1.691
	(0.603)	(1.607)
Treatment	0.84	2.563*
	(0.55)	(1.488)
Period	0.395	1.276
	(0.336)	(0.912)
Commu_effect	2.534***	7.178***
	(0.342)	(0.965)
Postgraduate	-0.068	-0.731
	(0.634)	(1.697)
GPA	-0.149	-0.216
	(0.178)	(0.488)
Sex	2.744***	6.372***
	(0.602)	(1.616)
Constant	0.34	-17.742***
	(1.684)	(4.589)
Number of observations	720	720
R^2	0.108	0.03
F-statistic	13.329***	11.2***

Note: (1) *, **, and *** represent significance at 10%, 5% and 1% respectively; robust standard errors are in brackets. (2) In the Tobit regression, there are 117 left-censored observations (= 0), and 343 right-censored observations (= 20).

Round number is not significant in this game without historical information. Unlike many current public good experiments, the coefficient for round number (period) is not significant in Table 3, irrespective of whether the OLS or Tobit specification is used (OLS p = 0.241; Tobit p = 0.162) Fischbacher and Gächter (2010) argue that when a repeated public good game goes to later rounds/periods, there is less incentive for free-riders to pretend to be cooperators. Knowing this, conditional cooperators lower their belief in their partners' investment, and hence their investment. As we do not provide historical information on actions and payoffs in our experiment, it is harder for the subjects to adjust their beliefs, which leads to an insignificant coefficient for round number.

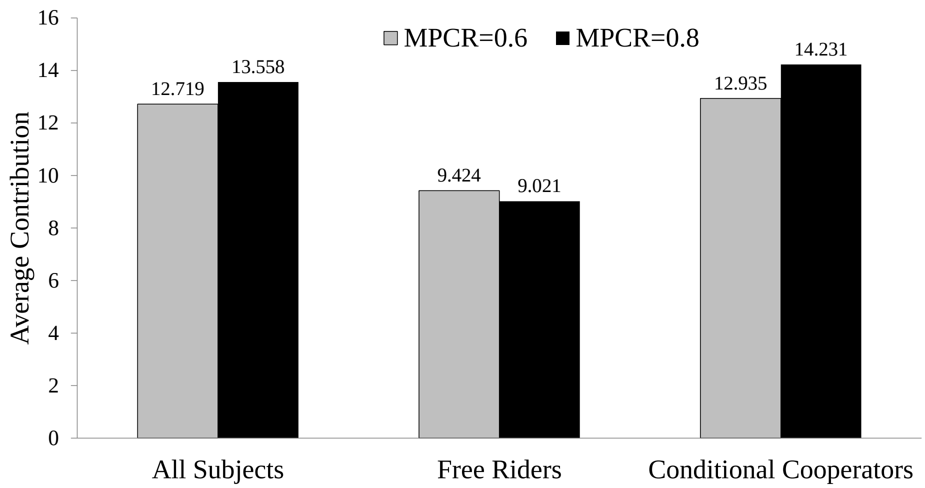

Figure 1 The influence of MPCR on average contribution

The average investment is significantly higher in the high MPCR treatment than in the low MPCR treatment. As shown in Figure 1, higher MPCR in general leads to higher investment in the public good (average contribution increases from 12.719 to 13.558). The difference is significant according to the Wilcoxon rank sum test reported in Table 4 (matched Wilcoxon rank sum test $z = 3.492, p = 0.001$). The regression result in Table 3 indicates that the treatment dummy based on MPCR is significant at the 10% level in the Tobit specification (p = 0.085), but insignificant in the OLS model (p = 0.128).

For free-riders, high MPCR leads to slightly lower investment in the public good (average contribution decreases from 9.424 to 9.021). The coefficient for the treatment dummy is not significant in the regressions (OLS, p = 0.967; Tobit, p = 0.879). There is no support for Hypothesis 1a as there is no significant correlation between MPCR and investment. A possible reason is that although higher MPCR lowers the potential loss when free-riders underinvest, which should lead to higher investment, higher MPCR also leads the free-riders to believe that their partners' investment level is higher (matched Wilcoxon rank sum test $z = 2.652, p = 0.008$), and hence there is a lower subjective probability that the total investment of the group will go below the threshold. Knowing this, the free-riders feel "safer" when they free-ride. The second effect leads to the opposite results to those predicted by Hypothesis 1.

For conditional cooperators, higher MPCR does lead to higher investment (average contribution increases from 12.935 to 14.231), and the coefficient for Treatment is significant at the 5% level (OLS p = 0.046; Tobit p = 0.021), which supports Hypothesis 1b.

We summarize these findings as follows:

Result 1: *There is insufficient evidence to support Hypothesis 1 as a general conclusion. We do not find robust results to support that "higher MPCR leads to higher average investment in a public good" at the whole sample level. Although we do find MPCR leads to higher investment by conditional cooperators, which supports Hypothesis 1b, there is no evidence that higher MPCR leads to higher investment by free-riders.*

Table 4 Difference in Contribution Level with Respect to the Control Variables

Variable	**Treatment**		**Sex**		**Education**	
	Low MPCR	High MPCR	Male	Female	Bachelor's	Master's
Average contribution	12.719	13.558	11.537	13.97	12.724	13.309
Wilcoxon rank sum test	3.492*(0.001)		3.352***(0.001)		0.957(0.338)	

5.3 The Influence of Overestimation on Investment in Public Good under Heterogeneous Social Preference

The influence of overestimates on investment in the public good is reported in Table 5. First, the interaction terms of overestimation, free-rider and conditional cooperators are significant at the 1% level. This supports Hypothesis 2 that the effect of overestimating depends on the type of social preference. Further, we run regressions for each type, and find that the overestimates by free-riders do lead to lower investment in the public good ($coefficient = -5.969 < 0,\ p < 0.01$), whereas the overestimates by conditional cooperators lead to higher investment in the public good ($coefficient = 0.329 > 0,\ p < 0.05$), which supports both Hypothesis 2a and 2b.[15]

In addition, we elicited the social preferences (mainly inequality aversion and reciprocity) of the subjects using questionnaires. The effect is estimated in Model 5. The result of this model also shows significance for the interaction term between inequality aversion/reciprocity and overestimation. These results are consistent with the results of Model 1.

We can summarize these findings as follows:

[15] Model 4 shows that the investment by cooperators is negatively correlated with overestimation. The reason is that we do not differentiate between unconditional cooperators and triangle contributors. The non-parametric test shows that the contribution of cooperators is lower than their belief about their partners' investment (average contribution is 13.467, whereas average belief is 16.47; paired Wilcoxon rank sum test $z = -4.6752, p = 0.000$). This suggests the majority of the cooperators in our experiment are triangle contributors. When their investment level is already high (contribution >12) overestimation leads to higher belief in the level of their partners' investment, but lower investment by the cooperators themselves.

Result 2: *Our experimental results lend support to Hypothesis 2. Overestimation does lead to higher investment by conditional cooperators, and lower investment by free-riders.*

Table 5: OLS Model of the Influence of Overestimation on Investment in a Public Good

Dependent variable	**Contribution**				
Model	1	2 Free-rider	3 Conditional cooperator	4 Cooperator	5
Overestimation	-1.083***	-5.969***	0.329**	-0.84***	-0.952***
	(0.286)	(1.748)	(0.161)	(0.32)	(0.289)
Free-rider	-1.353				
	(1.241)				
Overestimation × Free-rider	-3.327***				
	(1.014)				
Conditional cooperator	-1.065				
	(0.735)				
Overestimation × Conditional cooperator	1.401***				
	(0.328)				
Inequ_aversion					7.867***
					(0.693)
Overestimation × Inequ_aversion					0.75**
					(0.353)
Reciprocity					4.826***
					(0.784)
Overestimation ×					1.118**

Reciprocity					*
					(0.37)
Sequence	0.858	4.928	0.757	-0.366	-0.355
	(0.623)	(5.641)	(0.701)	(1.678)	(0.532)
Treatment	0.84	-0.083	1.296**	-0.233	0.793
	(0.537)	(1.869)	(0.645)	(1.091)	(0.495)
Period	0.395	1.401	0.248	0.4	0.517*
	(0.329)	(1.082)	(0.394)	(0.682)	(0.299)
Commu_effect	2.426***	5.788**	2.126***	2.978***	1.957***
	(0.339)	(2.496)	(0.42)	(0.691)	(0.329)
Postgraduate	-0.069	-5.289	-0.422	1.364	0.125
	(0.63)	(6.556)	(0.779)	(1.193)	(0.581)
GPA	-0.236	-1.22*	-0.405*	1.072***	-0.105
	(0.177)	(0.728)	(0.212)	(0.374)	(0.165)
Sex	3.149***	4.437*	3.274***	3.128***	1.329**
	(0.614)	(2.597)	(0.709)	(1.447)	(0.548)
Constant	1.722	-8.96	2.652	-3.562	-1.195
	(1.748)	(7.85)	(2.074)	(3.414)	(1.568)
Number of observations	720	72	498	150	720
R^2	0.157	0.286	0.129	0.191	0.283
F-statistic	13.591***	8.273***	10.831***	6.28***	24.382***

Note: (1) *, **, *** represents significance at 10%, 5% and 1% respectively; robust standard errors are in brackets. (2) We also perform Tobit regressions for the same model specifications, and find that except for the treatment dummy being significant at 10% in the Tobit model, the significance and size of coefficients are the same under OLS and Tobit.

5.4 Overprecision and Investment in a Public Good

Table 6 reports the estimation results for how overprecision influences investment in a public good. The dependent variable in Models 1 and 2 is △contribution (the difference between the investments in the high and low MPCR treatments). In Model 1 the coefficient for overprecision is negative and significant at the 1% level ($coefficient = -0.371，p < 0.01$), which supports Hypothesis 3. Model 2 takes into account the effect of heterogeneous social preferences. The result shows that the interaction term between overprecision and free-rider is negative and significant at the 5% level, whereas the interaction term between conditional cooperator and overprecision is not significant. This finding suggests that the effect of overprecision on △contribution is larger for free-riders than it is for cooperators. If we run the regression for Model 1, the coefficient for overprecision is -1.53 and significant at the 1% level for free-riders, -0.439 and significant at the 1% level for conditional cooperators, and -0.244 but insignificant(p = 0.292) for cooperators. These results support Hypothesis 3a and 3b. The findings can be summarized as follows.

Result 3: *Our findings support Hypothesis 3, namely, overprecision is negatively correlated with increase in investment in a public good when MPCR increases.*

Models 3-5 in Table 6 use the investment in public good game (contribution) as the dependent variable. The result of estimating Model 3 shows that the coefficient for overprecision is positive and significant at the 1% level.($coefficient = 0.364，p < 0.01$). Model 4 shows that the interaction between overprecision and free-rider is positive and significant at the 10% level, whereas the interaction between overprecision and cooperators is not significant. This result suggests that compared to cooperators, the positive effect of overprecision on contribution is larger for free-riders. When we run Model 3 for each type of social preference, the coefficient for overprecision is 0.87 but insignificant for free-riders (p = 0.114), 0.354 and significant at the 5%level (p = 0.016) for conditional cooperators and -0.043 but insignificant for cooperators (p = 0.843). Based on these above results we have the following result.

Result 4: *Our results support Hypothesis 4: overprecision is significantly positively correlated with investment by conditional cooperators.*

Model 5 examines the interaction between overprecision and overestimation on investment. When both overestimation and overprecision are included in the regression model, the coefficients for overprecision are positive and significant at the 5% level in both the OLS and Tobit models; the coefficient for overestimation is not significant in the OLS regression, but is negative and significant at the 10% level in the Tobit model. The interaction term between overestimation and overprecision is positive and significant at the 10% level in the Tobit model. The results suggest that the interaction between overestimation and overprecision may have an effect on investment, but not in a robust way.

Table 6 How Overprecision Influences Investment in a Public Good

Dependent variable	**△ contribution**		**Contribution**			
Model	1 OLS	2 OLS	3 OLS	4 OLS	5 OLS	 Tobit
Overprecision	-0.371*** (0.12)	0.103 (0.202)	0.364*** (0.115)	0.138 (0.204)	0.305** (0.131)	0.776** (0.355)
Free-rider		5.849* (3.174)		-6.406** (2.507)	-2.401** (1.195)	-5.296* (3.046)
Overprecision × Free-rider		-1.029** (0.507)		0.739* (0.429)		
Conditional cooperator		2.496* (1.364)		-0.866 (1.376)	0.452 (0.672)	2.270 (1.797)
Overprecision × Conditional cooperator		-2.567 (0.251)		0.280 (0.248)		
Overestimation					-0.575 (0.393)	-1.891* (1.035)
Overestimation × Overprecision					0.087 (0.064)	0.327* (0.173)
Sequence	-1.122 (0.69)	-0.893 (0.724)	0.658 (0.616)	0.850 (0.642)	0.636 (0.633)	2.294 (1.703)
Treatment	——	——	0.84 (0.547)	0.84 (0.543)	0.84 (0.544)	2.546* (1.465)
Period	0.427	0.427	0.395	0.395	0.395	1.270

	(0.373)	(0.372)	(0.335)	(0.333)	(0.333)	(0.897)
Commu_effect	0.382	0.378	2.651***	2.432***	2.526***	7.334***
	(0.377)	(0.39)	(0.332)	(0.338)	(0.338)	(0.966)
Postgraduate	1.434*	1.218	-0.352	-0.514	-0.431	-1.886
	(0.759)	(0.768)	(0.644)	(0.661)	(0.662)	(1.813)
GPA	-0.111	-0.136	-0.079	-0.054	-0.091	-0.082
	(0.202)	(0.202)	(0.177)	(0.175)	(0.178)	(0.495)
Sex	0.001	0.129	2.359***	2.119***	2.372***	5.554***
	(0.686)	(0.691)	(0.61)	(0.62)	(0.622)	(1.666)
Constant	0.282	-1.908	-1.843	0.117	-0.97	-22.668***
	(1.872)	(2.174)	(1.684)	(1.912)	(1.764)	(4.937)
Number of observations	720	720	720	720	720	720
R^2	0.02	0.029	0.12	0.136	0.135	0.037
F-statistic	1.992*	1.857**	14.831***	11.568***	11.325***	8.24***

Note: (1) *, **, and *** represent significance at 10%, 5% and 1% respectively; robust standard errors are within the brackets. (2) In the Tobit model, there are 117 left-censored observations (= 0), 343 right-censored observations (= 20). The estimated coefficients and significance are not very different in Models 1-4. We do not show the Tobit output to save space.

6. Conclusion

Based on Fischbacher and Gächter (2010), we first introduce the effect of overconfidence into the two-person threshold public good game with cheap talk. We consider two forms of overconfidence—overestimation and overprecision—and study the interaction between overconfidence and heterogeneous social preferences. We find that high MPCR leads to higher investment by conditional cooperators, but (insignificantly) lower investment by free-riders. In addition, overprecision lowers the magnitude of the effect of changing MPCR on investment level. Moreover, we find that the effect of overestimates on investment depends on the type of agent: it leads to higher investment for conditional cooperators, but lower investment by free-riders. The above findings have two main implications.

First, although overconfidence usually leads to lower individual utility, it may improve social welfare under some conditions. Overconfidence leads one's investment in a public good to deviate from the optimal level, but it may lead to higher total investment in the public good in some cases, such as when conditional cooperators overestimate the investment by their partners. This is an example of how overconfidence may help to solve a social dilemma, internalize positive externality and enhance social welfare.

Second, although higher MPCR in general leads to higher willingness to cooperate, overprecision weakens this effect. This implies that for social dilemmas like the threshold public good game, the designers of institutions should take the cognitive biases of individuals into account. In some cases, if overprecision generates undesirable outcomes, the policy makers may want to provide additional incentives to discourage people from gathering too much information about their decision or giving too narrow a confidence interval to their predictions.

Our study considers the interaction between overconfidence and heterogeneous social preferences in a static setting. We leave the case in which individuals can update their beliefs and experience learning in dynamic games to future studies.

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