The Role of Information Structure on Cooperation and Coordination: An Experiment

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Abstract

We economists normally think that an environment with complete and thus symmetric (CS) information would deliver the best economic outcome since each agent can fully optimize without paying any informational rent to anyone else. However, in a simple threshold public goods game with three different information structures about the threshold value (CS, Complete and Symmetric; IS, Incomplete and Symmetric; IA, Incomplete and Asymmetric), the theory prediction suggests that the CS information structure actually performs the worst, while the IS information structure performs the best, which is counterintuitive. We then experimentally investigate how people would actually behave under those different information structures, and the result shows, a bit surprised, that the IA information structure (with cheap talk) leads to the highest contribution and highest provision of public goods. The reason is twofold: the subjects are less manipulative when they are privately informed, and they are more willing to coordinate at the suggested level when they are not privately informed. This suggests that, in order to achieve economic optimality, we can cultivate a certain set of attributes to jointly deliver the best outcome under information asymmetry, rather than trying to eliminate information asymmetry. We also investigate how the change in MPCR would interact with these three information structures, and our main results are robust against MPCR changes.

Keywords: Information Structure, Asymmetric Information, Threshold Public Goods Game, Cooperation, Coordination.

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1 Introduction

Stiglitz (2000) emphasis the role of information in economics. He said that "The key question is ... how the economy adapts to new information, creates knowledge, and how that knowledge is disseminated, absorbed, and used throughout the economy." Many economic activities are conducted under incomplete information and probably asymmetric information. Depending on how information is disseminated, different information structures will be constructed. Consider a simple case where a group of salesmen works together to achieve a sales target above which a proportional bonus will be rewarded. The manager chooses among a set of pre-determined values as the sales target for a certain period. Is it better to reveal this threshold value to the whole group or only to a single person (e.g., the group leader) or even conceal the information entirely from them (while making the support and the distribution of this information common knowledge)?

Consider another example where several researchers jointly work on a project trying to achieve a certain goal. In order to achieve the goal, at least a certain amount of resources (time, money, etc.) should be devoted to this project, and they all share a common prior about the distribution of the threshold. If they do not manage to achieve the goal, all the resources put into this project would be wasted. However, if the goal is achieved, a shared benefit is provided for the entire group. If they even go beyond the goal, a higher benefit is generated. Which information structure would be the best in this case? Revealing the threshold value ex-ante before they start working on the project? Or concealing the information from all the group members? Or informing only one of the group members to create information asymmetry?

In a groundbreaking paper, Akerlof (1970) showed that it was asymmetric information instead of uncertainty (in a symmetric way) that caused market failure[1]. Generally, the party who has private information over others would demand an information rent which creates inefficiencies and maybe even market failure.

In this paper, we investigate how three different information structures of threshold level affect cooperation and coordination in a provision point mechanism. The information structure could be complete and symmetric (CS) where all players know the threshold value, incomplete and symmetric (IS) where all players do not know it, as well as incomplete and asymmetric (IA) where only one player is privately informed of the threshold value and later he sends a message to others about the threshold value. A simple theoretical framework is developed and shows that IS should perform better than IA because asymmetric information implies an information rent charged by the privately informed player. While the comparison between CS and IS is not that clear. In addition, MPCR (marginal per capita return) also plays a role in such a setting by changing the number of equilibria at which players should coordinate

[1] Another related example is that monopoly and oligopoly are often considered harmful to the economy because they raise the price and produce less, and they (can) do this because of two things: 1, they have market power; 2, they do not know consumers' reservation price. In a market with complete information, they would not cause any dead-weight loss, and any Pareto optimal outcome can be obtained by transfers.

at[2].

We then experimentally investigate how these three information structures work with different MPCR values and discuss possible explanations. The experiment features both a between-subject and within-subject design. Information structures are implemented between-subject, and the MPCR change is implemented within-subject. The main experimental results show that, surprisingly, the IA treatment significantly induces a higher average contribution than both IS and CS treatment, and IS treatment does the worst job. We propose two possible explanations. First, in games that require coordination, the presence of an obvious focal point (or a rule of thumb) is crucial to successful coordination. In CS, every player observes the actual threshold and the symmetric play defined by equal cost share serves as an obvious focal point to coordinate at. In IA, the message sent by the privately informed sender serves as an obvious focal point to coordinate at, even though other players are aware that the sender can lie about the true threshold value. However, there is not an obvious focal point in IS, so successful coordination falls dramatically. Second, a large proportion of players in CS tend to contribute exactly one third of the threshold level (which is consistent with the theory). The privately informed sender in IA helps to overcome this issue by inflating the threshold level in general, and thus results in a higher welfare status on average.

We further investigate whether the IA treatment generates higher contributions(and provision ratio, etc.) at the cost of higher inequality. The data shows that this is not the case. The distribution of the Gini index of profit is not (significantly) different between IA and CS treatment, while the IS treatment has the lowest Gini index because of a significantly lower contribution. Last we show that our results are robust against the potential order effect caused by the order of MPCR change.

The experimental parameters are chosen specifically so that the privately informed sender in IA treatment can take advantage of others to the highest degree by free-riding to the highest extent. Therefore, our results as an estimation of the effect of IA treatment are the most conservative.

The remainder of the paper is organized as follows. The next section reviews related literature, section 3 provides a simple framework for analysis. The experimental design and procedure are described in section 4. section 5 presents our results and section 6 concludes.

2 Related Literature

The key group of literature that we are closely related is the literature on incomplete information in linear public goods game (LPGG hereafter) or threshold public goods game (TPGG). Various forms of

[2]We consider only the *partial* symmetric equilibrium where players play identical strategies if they have identical information sets. Details are presented in **??**.

incomplete information are examined, and the impact on contribution as well as public goods provision is dependent on the setting.

In LPGG, the form of incomplete information is mainly about asymmetric endowments among players or asymmetric valuation of the public goods. For example, van Dijk and Grodzka (1992) examined how incomplete information about asymmetric endowments with symmetric valuations would affect contributions and found no significant difference against the case with complete information. M. B. Marks and Croson (1999) experimentally studied a TPGG where subjects had different valuations for the public goods and reported that incomplete information about valuations did not change the contribution or provision ratio significantly.

In TPGG, the form of incomplete information is mainly about the threshold value. Suleiman, Budescu, and Rapoport (2001) examined the joint impact of the degree of threshold uncertainty and the threshold mean on people's contribution behavior in a TPGG. The results showed that subjects' contribution increases with an increase of the degree of threshold uncertainty when the threshold mean is low, and decreases when the threshold mean is high. Compared against a subjective expected utility model, their data supported the cooperative model proposed by Laffont (1975)[3]

McBride (2006) theoretically showed that threshold uncertainty would affect equilibrium contributions differently with different threshold distributions and public goods value. McBride (2010) further tested this theoretical prediction in an experimental study and only find limited support. He did find that subject's subjective pivotalness had a positive impact on contribution[4].

Kotani, Tanaka, and Managi (2014) investigated how a uniformly distributed threshold affects contribution in both a threshold public goods and bads game. They reported that in both paradigms contribution fell significantly when the degree of uncertainty became the highest.

Dannenberg, Löschel, Paolacci, Reif, and Tavoni (2015) studied a TPGG where subjects had to contribute over periods to achieve a threshold. Otherwise, their remaining wealth would shrink to a certain percentage. They showed that incomplete information about the uncertain threshold was detrimental to achieving the threshold, and even worse when subjects did not know the distribution of the thresholds.

Many studies also examined the impact of threshold uncertainty in common pool resource game (CPR)[5] under threshold uncertainty (see Maas, Goemans, Manning, Kroll, & Brown, 2017, for example). They all found that uncertain threshold is detrimental to successful coordination, while taxation and punishment did help ease the Tragedy of the Commons (Maas et al., 2017). Guilfoos, Miao, Trandafir, and Uchida (2019) also showed that communication was effective in enhancing successful coordination merely through

[3]The model is based on Kant's principle, and Laffont (1975) proposed that "a typical agent assumes (according to Kant's moral) that the other agents will act as he does, and he maximizes his utility function under this new constraint.

[4]The contribution decision is binary.

[5]Some refers it as threshold public bad game.

cheap talk, while a written message from the last generation had a less significant effect. The form of cheap talk in their study is free chat without any restriction between group members, while the form of cheap talk in our study is the typical one where the sender sends a restricted message to receivers.

Another important branch of literature is on cheap talk. Since the influential work by Crawford and Sobel (1982) on a typical model of cheap talk, extensive studies have investigated many issues in such a cheap talk game and extended the model in various ways. Relevant work by Farrell and Gibbons (1989) study the cheap talk game in which the sender can talk to two receivers. There are two states of the world, and each receiver's utility only depends on his own action and the state of world. Under those settings, they study both public and private communication in this cheap talk game, and one of their results suggests that the sender should take the two receivers as a single receiver whose preference lies somewhere between the two receivers'. Goltsman and Pavlov (2011) extend their work to allow a continuous range of state of world as well as a continuous action space, and they also study the combination of public and private communications. Goltsman and Pavlov (2011) show that, under public communication between the sender and symmetric receivers, any equilibrium of the cheap talk game is in a form of partition equilibrium similar to the one specified by Crawford and Sobel (1982). They also showed that if the receiver's preferences were perfectly aligned, then "private and public communication are equivalent".

T. R. Palfrey and Rosenthal (1991) and T. Palfrey, Rosenthal, and Roy (2017) examined the effect of cheap talk on contribution and provision in a TPGG where players had homogeneous valuations but heterogeneous costs of contribution [6] . T. R. Palfrey and Rosenthal (1991) utilize the solution concept of sequential equilibrium on the issue, while T. Palfrey et al. (2017) take the approach of mechanism design to address the issue, and they found that only the richest and unrestricted text chat approach yielded a significantly higher provision. The key difference between our study and theirs is where the asymmetric information comes in. In our game setting, we construct three different information structures by designing how the information of threshold value is revealed among the players.

3 The Game

There are N players in this threshold public goods game. Each player $i \in \{1, \cdots, N\}$ has an endowment E, and contributes $a_i \in [0, E]$ to a public account to achieve public goods provision. The provision of public goods is dependent on the state of the world $\theta \in \Theta \equiv \{\theta_i | 0 < \theta_1 < \cdots < \theta_K \leqslant E \times N\}$, and all players share a common prior over the states that is characterized by $\mathbb{P} \equiv \{p_i \,|\, p_i > 0, \sum_{i=1}^{K} p_i = 1\}$ correspondingly.

The public goods will be provided only if the total contribution $\sum_i a_i \geqslant \theta$, and it will benefit all players

[6] Contribution is binary.

equally with $\rho \in (\frac{1}{N}, 1)$ as the marginal per capita return (MPCR) once provided[7].

Another important aspect in the threshold public goods game is about rebate and refund policies. A rebate policy takes care of excess contributions over the threshold so that they are not wasted, while a refund policy takes care of inadequate contributions below the threshold. Normally, excess contributions increase either the quantity or quality of the goods provided. However, all investments would become sunk costs if they are below the threshold and thus fail to provide any goods.

Isaac, Schmidtz, and Walker (1989) first examine the utilization rebate policy which was further studied by M. Marks and Croson (1998). M. Marks and Croson (1998) examined three rebate policies, proportional rebate, utilization rebate, and no rebate in TPGG, and their results showed that, although the provision ratio of public goods did not differ among different rebate policies, contributions are significantly higher under utilization rebate than the other two while the variance of contributions was also the highest under utilization rebate policy.

We consider the game with a rebate policy but no refund policy to be more relevant to real life scenarios. In addition, having both rebate and refund policies in the experiment makes the contribution so cheap and coordination so easy. With the utilization rebate policy, excess contributions continue to provide more public goods in the same. Therefore, player i's utility function is:

$$U_i = E - a_i + I\left(\sum_i a_i \geqslant \theta\right)\rho \sum_i a_i \tag{1}$$

where $I(\cdot)$ is an indicator function that takes the value of 1 if $\sum_i a_i \geqslant \theta$ and 0 otherwise[8].

It is straightforward to see that collectively free-riding, $a_i = 0$ for all $i \in \{1, \cdots, N\}$, is a Nash equilibrium (NE) irrespective of the state of world θ and how the information about θ is disseminated. No one has any incentive to deviate from free-riding as it would only make him/her worse off. In the following part of the paper, we mainly focus on other non-free-riding equilibria under certain assumptions.

3.1 Complete & Symmetric Information Structure

Let us first consider the case where θ is common knowledge. Each player knows the true state of world θ and knows that it is in equilibrium to coordinate at θ with $\sum_i a_i = \theta$. As a result, there is an infinite number of equilibria for each θ which makes it extremely difficult (almost impossible) to perform equilibrium analyses of the game.

[7] Since there are N players, $\rho > \frac{1}{N}$ implies that individual contributions produce a larger benefit for the entire public as long as public goods are provided, and $\rho < 1$ implies that individual contributions are not optimal for each individual. This creates a tension between individual and collective interests such that the question is worth investigating.

[8] In general, an indicator function $I(\cdot)$ equals 1 when the condition in its parenthesis is satisfied and 0 otherwise.

One simplification we make in the game is by introducing the notion of equity. As Fehr and Schmidt (1999) and Bolton and Ockenfels (2000) both suggest that equity is an important concern when people make cooperative decisions, we propose that each player would contribute $\frac{\theta}{N}$ and expect others to contribute $\frac{\theta}{N}$ as well if all of them consider that coordinating at θ is in equilibrium. Such a particular NE featuring the *equal sharing principle* probably would be the most prominent equilibrium that they coordinate at for each θ.

This speculation is also in the spirit of focal point theory. Schelling (1960) proposes the idea of focal point and states that "people can often concert their intentions or expectations with others if each knows that the other is trying to do the same". Since equity is usually a common concern for most people, the *equal sharing principle* becomes a natural focal point for them to coordinate at. As a result, all players form the multilateral expectation of each contributing an equal share of the targeting coordination level θ, and thus produces the most acceptable equity among them. Therefore, we have the following assumption:

Assumption 1 (Equal Sharing Principle): *Players use identical contribution strategies if they share the same information on $\theta \in \Theta$.*

Assumption 1 helps us ease the analyses of the game in two important ways while enabling us to obtain the key insights on the issue at the same time. First, it allows us to focus on the issue at which specific θ players can successfully coordinate and thus constitute an equilibrium, rather than the issue of equilibrium selection at a particular θ among many different combinations of contributions that can lead to successful coordination. Second, it simplifies our analyses and comparisons between different information structures by a lot. Though it does not encompass all the potential equilibria out there, it still provides important insights about the impacts of information structure on coordination and cooperation.

Proposition 1: *Under complete and symmetric information, we have a unique NE where each player contributes $\frac{\theta}{N}$, $\forall\, \theta \in \Theta$.*

3.2 Incomplete & Symmetric Information Structure

In this part, we consider the case where no player knows anything about θ. Suppose that all players decide to coordinate at $\theta_k \in \Theta$ and each contributes $\frac{\theta_k}{N}$ according to Assumption 1. For any state $\theta \leqslant \theta_k$, public goods will be provided. However, if the state $\theta > \theta_k$, public goods will not be provided and all the contributions are wasted since there is no refund rule in the game. Thus, each player's utility is given by the following equation:

$$U_i = E - \frac{\theta_k}{N} + \rho\theta_k \sum_{i=1}^{k} p_i \tag{2}$$

Would this be a NE? It is easy to see that each player has no incentive to deviate his/her contribution upwardly, namely, to increase his/her contribution which would only make him/her worse off. Therefore, we only have to examine whether each player has an incentive to deviate his/her contribution downwardly.

If player i decreases his contribution by an extremely tiny bit, public goods will not be provided at state $\theta = \theta_k$ anymore, however, it will still be successfully provided at state $\theta = theta_{k-1}$. Therefore, it is optimal for him to further decrease his contribution as long as the total contribution equals or exceeds $theta_{k-1}$. There are two cases to consider here: (i) $\theta_{k-1} \leqslant \dfrac{(N-1)\theta_k}{N}$, so he does not have to contribute anything in order to achieve public goods provision at θ_{k-1}; (ii) $\theta_{k-1} > \dfrac{(N-1)\theta_k}{N}$, so he needs to contribute the margin $\left(\theta_{k-1} - \dfrac{(N-1)\theta_k}{N}\right)$ in order to achieve public goods provision at θ_{k-1}. Combine them together, the player would decrease his contribution to $\max\left(0,\, \theta_{k-1} - \dfrac{(N-1)\theta_k}{N}\right) \equiv a_{i,k-1}$. Thus, coordinating at θ_k might be a NE if the following inequality holds:

$$U_i = E - \frac{\theta_k}{N} + \rho\theta_k \sum_{i=1}^{k} p_k \geqslant E - a_{i,k-1} + \rho\left(\frac{(N-1)\theta_k}{N} + a_{i,k-1}\right)\sum_{i=1}^{k-1} p_i \tag{3}$$

The player can further decrease his contribution such that public goods will be provided at $\theta = \theta_{k-2}$ but not at $\theta = \theta_{k-1}$ anymore. It comes with a new inequality to check that is very similar to Equation (3), so that we know whether coordinating at θ_k might be a NE. Similarly, we need to check every state $\theta_j, 1 \leqslant j < k$ to see whether the player has an incentive to deviate his contribution downwardly. A special case to be checked is that the player cannot benefit from free-riding on others. Let us define $\theta_0 = p_0 = 0$, and thus $a_{i,0} = 0$, consequently, the conditions that coordinating at θ_k is a NE for each player can be unified and summarized in the following proposition.

Proposition 2: *Under incomplete and symmetric information, coordinating at θ_k is a NE if the following condition is satisfied:*

$$E - \frac{\theta_k}{N} + \rho\theta_k \sum_{i=0}^{k} p_k \geqslant E - a_{i,j} + \rho\left(\frac{(N-1)\theta_k}{N} + a_{i,j}\right)\sum_{i=0}^{j} p_i, \quad \forall 0 \leqslant j < k. \tag{4}$$

3.3 Incomplete & Asymmetric Information Structure

Among all the players, one is the sender (she) who privately observes the state θ, and the others are receivers (they, he) who do not observe θ. The sender then needs to send a public message $m \in \Theta$ to all the receivers according to a specific messaging strategy $q(m|\theta)$, and the receivers will update their prior about θ according to Bayes rule and the sender's messaging strategy $q(m|\theta)$. Then all players decide their contribution decisions *simultaneously* when the receivers have received m. The only difference between the sender and the receiver is the information they have on θ.

On top of the multilateral dependence among all the players' contribution strategies, the sender's contribution strategy also depends on the true state of world θ while the receivers' depends on the received message m, which is the key difference between the sender and the receivers. Thus, it is hardly convincing to say that they would consider the same $\theta_k \in \Theta$ at which to coordinate in equilibrium. However, the receivers all make their contribution strategy according to m as well as the sender's contribution strategy and thus would consider the same θ_k to coordinate at in equilibrium. According to Assumption 1, the receivers would choose the same contribution strategy.

Furthermore, considering strategic interactions between the sender and the receivers, the sender does not discriminate one receiver against any other, so only the sum of the receivers' contributions would actually affect the sender's strategy. It is very likely that all receivers would "concert their intentions or expectations" (on the concern of equity) with one another and make the same contribution decisions, which is consistent with the above statement.

Suppose the receivers all consider that it is in equilibrium to coordinate at θ_k together with the sender[9], based on the focal point implied by equal sharing principle, they would each contribute $\dfrac{\theta}{N}$ and expecting the sender to contribute $\dfrac{\theta}{N}$ as well.

However, the sender does not necessarily contribute $\dfrac{\theta}{N}$ as the receivers expect, and her contribution strategy depends on both θ_k and the true state of world θ. If $\theta_k = \theta$, it is also in equilibrium for the sender to coordinate at θ_k which is consistent with the receivers. According to the Assumption 1 we know that the sender would also contribute $\dfrac{\theta}{N}$ that is the same as the receivers' contribution. However, if $\theta_k \neq \theta$, the Assumption 1 does not hold anymore, thus the sender would contribute at her will to maximize her expected utility.

The sender's contribution strategy when $\theta_k \neq \theta$ is further specified as follows: if $\theta < \theta_k$, the sender would basically contribute $\max\left(0,\, \theta - \dfrac{(N-1)\theta_k}{N}\right)$ to achieve public goods provision; if $\theta > \theta_k$, the sender would only contribute if two conditions are met: (i) $\theta - \dfrac{(N-1)\theta_k}{N} \leqslant E$ so the sender is able to make the contribution required to reach θ; (ii) $\theta - \dfrac{(N-1)\theta_k}{N} \leqslant \rho\theta$ so the sender benefits from successful provision of public goods. Combine them together, the sender would only contribute $\theta - \dfrac{(N-1)\theta_k}{N}$ if and only if $\theta - \dfrac{(N-1)\theta_k}{N} \leqslant \min(E,\, \rho\theta)$, and nothing otherwise. The above discussed cases about θ_k and θ can be unified together, and we have the following lemma:

Lemma 1: *Suppose the receivers all consider that it is in equilibrium to coordinate at θ_k, each of them would contribute $\dfrac{\theta_k}{N}$, while the sender would contribute $a_{s,i} = \max\left(0,\, \theta_i - \dfrac{(N-1)\theta_k}{N}\right)$ if and only if $\left(\theta_i - \dfrac{(N-1)\theta_k}{N} \leqslant \min(E,\, \rho\theta_i)\right)$ and nothing otherwise.*

With the Assumption 1 and the Lemma 1, we now consider the equilibria when there is a sender who

[9] This does not necessarily imply that the receivers believe θ_k is the most likely state of world. Consider the case with θ being common knowledge, the players choose to coordinate at θ according to equal sharing principle because it is in equilibrium to do so, but not simply because θ is the true state of world.

privately observes θ. The sender is essentially cheap talking since the message sent does not affect anyone's utility directly. Since the influential work by Crawford and Sobel (1982) on a typical model of cheap talk, extensive studies have investigated many issues in such a cheap talk game and extended the model in various ways. Relevant work by Farrell and Gibbons (1989) study the cheap talk game in which the sender can talk to two receivers. There are two states of the world, and each receiver's utility only depends on his own action and the state of world. Under those settings, they study both public and private communication in this cheap talk game. Goltsman and Pavlov (2011) extends their work to allow a continuous range of state of world, and they also study the combination of public and private communications.

However, our game is different from the above models of cheap talk in several significant ways: (i) The sender in our game does not only send a utility-irrelevant message to receivers, she also has to choose an action that is similar to the receiver's action decisions. In contrast, the sender in the traditional cheap talk model only decides on the messaging strategies. (ii) The utility function is the same for the sender and the receiver(s) in our game, and it depends on each player's action. The traditional cheap talk model features different utility functions for sender and receivers such that the preferences are misaligned to some extent. (iii) The sender's utility function in our game is neither supermodular nor submodular, while it is normally assumed to be supermodular in the traditional model of cheap talk (see Crawford and Sobel (1982) and Goltsman and Pavlov (2011) for example.) Therefore, our analyses have to take care of both the messaging strategy and the actions of the sender and investigate potential equilibria out there.

The Babbling Messaging Strategy

We start with the case that the sender's messaging strategy is simply babbling, so no information is actually transmitted. Suppose that, based on the common prior, the receivers decide to coordinate at $\theta_k \in \Theta$ and thus each of them would contribute $\dfrac{\theta_k}{N}$. According to our Lemma 1, the sender would contribute $a_{s,i} = \max\left(0,\, \theta_i - \dfrac{(N-1)\theta_k}{N}\right)$ if and only if $\left(\theta_i - \dfrac{(N-1)\theta_k}{N} \leqslant \min(E,\, \rho\theta_i)\right)$ and nothing otherwise. This is actually the sender's best response given that the receivers decide to coordinate at θ_k. As a result, we only need to investigate whether each receiver has an incentive to deviate in order to determine whether coordinating at θ_k is in equilibrium. Each receiver's expected utility function is as follows:

$$
\begin{aligned}
U_r(\theta_k) = E - \frac{\theta_k}{N} + \rho \times \\
\sum_{i=1}^{K} I\left(\theta_i - \frac{(N-1)\theta_k}{N} \leqslant \min(E,\, \rho\theta_i)\right) p_i \left(a_{s,i} + \frac{(N-1)\theta_k}{N}\right)
\end{aligned}
\tag{5}
$$

where $I(\cdot)$ is an indicator function which takes the value of 1 if condition $\left(\theta_i - \dfrac{(N-1)\theta_k}{N} \leqslant \min(E,\, \rho\theta_i)\right)$ is satisfied and 0 otherwise. This indicator function selects all the state of world θ at which public goods will be provided.

Similar to the case of Incomplete & Symmetric information, each receiver has no incentive to deviate his contribution upwardly. However, the case is different when one receiver wants to deviate his contribution downwardly. Now there is a sender who privately observes the state of world θ, so she would vary his contribution based on θ. Conditional on the receiver's contribution strategies, she would only contribute the margin that is necessary to achieve public goods provision as long as it is possible and beneficial for her to do so, specifically, she contributes $a_{s,i} = \max\left(0,\, \theta_i - \dfrac{(N-1)\theta_k}{N}\right)$ if and only if $\left(\theta_i - \dfrac{(N-1)\theta_k}{N} \leqslant \min(E,\, \rho\theta_i)\right)$. As long as $\left(\theta_i - \dfrac{(N-1)\theta_k}{N}\right) \geqslant 0$, the sender has to make a non-negative contribution to achieve public goods provision[10], and there is no excess contributions at state θ. As a result, any deviation would result in a failure in public goods provision.

Define $\Theta_D = \{\theta_i \,|\, \theta_i \in \Theta,\, \theta_i - \dfrac{(N-1)\theta_k}{N} < 0\}$. For any state of world $\theta \in \Theta \setminus \Theta_D$, any deviation would result in a public goods failure, therefore, as long as one receiver deviates his contribution downwardly (even by a tiny bit), public goods will not be provided anymore. Consequently, once deviated, the receiver should decrease his contribution further until the public goods is provided without excess contribution at any state $\theta_d \in \Theta_D$. In these cases, the sender contributes nothing to the public goods, and the deviated receiver has to contribute the margin $a_{r,d} \equiv \max\left(0,\, \theta_d - \dfrac{(N-2)\theta_k}{N}\right)$ to achieve public goods provision conditional on $\left(\theta_d - \dfrac{(N-2)\theta_k}{N} \leqslant \min(E,\, \rho\theta_d)\right)$.

As long as one receiver does not benefit from doing so, coordinating at state θ_k establishes a NE. Therefore, we have the following proposition:

Proposition 3: *Suppose the sender adopts a babbling messaging strategy under incomplete and asymmetric information, coordinating at θ_k establishes a NE if the receivers' expected utility function satisfies the equation specified as follows:*

$$U_r(\theta_k) \geqslant E - a_{r,d} + \rho\left(a_{r,d} + \frac{(N-2)\theta_k}{N}\right)\sum_{i=0}^{d} p_i\,, \qquad \forall\, \theta_d \in \Theta_D \cup \{\theta_0\}. \tag{6}$$

Let Θ^*_{babble} denote the set of θ at which coordination is a NE (satisfy Equation (6) for each $\theta \in \Theta^*_{babble}$).

The Truth-Telling Messaging Strategy

Suppose the sender is always truth-telling, so the sender always sends a message $m = \theta$. Therefore, the sender and the receivers all consider that it is in equilibrium (also optimal) to coordinate at θ. According to Assumption 1, each of them would contribute $\dfrac{m}{N} = \dfrac{\theta}{N}$. Since the receivers only get to know the message m, the sender does have an incentive to send a message $m > \theta$ so that the receivers would

[10] When $\left(\theta_i - \dfrac{(N-1)\theta_k}{N}\right) = 0$, the sender does not have to contribute anything, and the public goods are just provided with each receiver's contribution at $a_i = \dfrac{\theta}{N}$.

contribute $\frac{m}{N}$ and the sender only needs to make up the margin $\theta - \frac{(N-1)m}{N} < \frac{\theta}{N}$, and the latter is the contribution the sender needs to make if he sends $m = \theta$. Therefore, truth-telling is never going to be the messaging strategy in equilibrium.

A General Messaging Strategy

$\forall\, m_i \in \Theta$, $\forall\, \theta \in \Theta$, a general messaging strategy is characterized by $q(m_i|\theta_j)$ with $\sum_i q(m_i|\theta) = 1$, $\forall\, \theta \in \Theta$. All receivers then form their posteriors $f(\theta|m_i)$ according to Bayes' rule.

Let us use Θ^* to denote the set of θ at which coordination is in equilibrium (for receivers). Suppose first that, for a specific massaging strategy $q(m_i|\theta)$, $\exists\, m_1, m_2 \in \Theta$, and the associated equilibrium set Θ_1^* and Θ_2^* is NOT the same. The sender then will discriminate one against another and deviate her messaging strategy from m_1 to m_2 (or the opposite), therefore, this cannot be the case in equilibrium.

Then we are left with the case where $\forall\, m_i \in \Theta$, the associated Θ^* is the same. This implies that, $\forall\, m_i$, the associated posterior $f(\theta|m_i)$ characterizes a distribution of θ over Θ, and the receivers make their decisions according to this posterior $f(\theta|m_i)$ when they receiver the message m_i. Therefore, $f(\theta|m_i)$ must be very similar across all m_i. More specifically, $\forall\, \theta_k \in \Theta$, $\forall\, i \neq j$, $f(\theta_k|m_i)$ is very close to $f(\theta_k|m_j)$.

Since $\sum_i f(\theta_k|m_i)p(m_i) = p_k$ and $\sum_i p(m_i) = 1$, we know that $f(\theta_k|m_i)$ should be close to p_k if they are not the same (given $f(\theta_k|m_i)$ is very close to $f(\theta_k|m_j)$). Suppose $f(\theta_k|m_i) > p_k$, then $\exists\, j, f(\theta_k|m_j) < p_k$, such that $f(\theta_k|m_i)p(m_i) + f(\theta_k|m_j)p(m_j) = p_k$.[11] A posterior with $f(\theta_k|m_i) > p_k$ and a posterior with $f(\theta_k|m_j) < p_k$ have the same Θ^*, then they must share the same Θ^* with a posterior with p_k, which is actually the common prior.

To sum up, a general messaging strategy in equilibrium produces a posterior that is the same as the common prior, thus, the equilibrium strategy of receivers is the same as if the sender is babbling. Therefore, we have the following proposition.

Proposition 4: *In equilibrium, the sender's messaging strategy is always babbling, and no information would be transmitted.*

In equilibrium, the exact set of θ (Θ^*) at which the receivers would coordinate is dependent on the parametrization of the game. Next, we show a simple parametric example as well as the corresponding equilibrium set Θ^*.

[11] It can be more troublesome which involves more states of world, for example, θ_a, θ_b, etc. Eventually, they should altogether ensure that $\sum_i f(\theta_k|m_i)p(m_i) = p_k$.

3.4 A Parametric Example

Let us consider $N = 3$, $E = 20$, $\Theta = \{24, 36, 60\}$, and $\mathbb{P} \equiv \{1/3, 1/3, 1/3\}$. The value of possible threshold values are chosen such that, in the IA scenario, the privately informed sender can take advantage of the receivers to the maximum degree.

<u>*Complete and Symmetric information structure*</u>

Under CS, according to Proposition 1, players' equilibrium strategy is to contribute $\theta/3, \forall\, \theta \in \Theta$.

<u>*Incomplete and Symmetric information structure*</u>

Under IS, according to Proposition 2, coordinating at $\theta = 24$ (so each player contributes 8) is an equilibrium if any receiver cannot benefit by deviating to free-riding:

$$20 - 8 + \frac{1}{3} \times 24\rho \geqslant 20 \quad \Longrightarrow \rho \geq 1.$$

Therefore, $\theta = 24$ can never be an equilibrium since $\rho < 1$ by definition.

Similarly, we can get the result that coordinating at $\theta = 36$ is an equilibrium iff $\rho \geqslant 0.75$, and $\theta = 60$ iff $\rho \geqslant 0.6$.

<u>*Incomplete and Asymmetric information structure*</u>

Under IA, according to Proposition 4, there's only going to be babbling equilibria in such a game. Let us first look at whether coordinating at $\theta = 60$ can be an equilibrium.

The two receivers would each contribute 20 and expects the sender contribute 20 as well when $\theta = 60$. The sender would indeed contribute 20 when $\theta = 60$ but free ride on them when $\theta = 24$ or 36 since the receivers' contributions are enough to provide the public goods. In order to make this an equilibrium such that deviation of any receiver is not beneficial, ρ has to meet certain conditions specified as follows:

$$\begin{cases} \frac{1}{3} \times 60\rho + \frac{2}{3} \times 40\rho \geqslant 20 - 16 + \frac{1}{3} \times 36\rho + \frac{1}{3} \times 24\rho & \Longrightarrow \quad \rho \geqslant 0.15 \\ \frac{1}{3} \times 60\rho + \frac{2}{3} \times 40\rho \geqslant 20 - 4 + \frac{1}{3} \times 24\rho & \Longrightarrow \quad \rho \geqslant \frac{48}{116} \approx 0.41 \\ \frac{1}{3} \times 60\rho + \frac{2}{3} \times 40\rho \geqslant 20 & \Longrightarrow \quad \rho \geqslant \frac{60}{140} \approx 0.43 \end{cases}$$

So, as long as $\rho \geqslant 0.43$, this is an equilibrium.

Similarly, coordinating at $\theta = 36$ being an equilibrium requires:

$$20 - 12 + \frac{1}{3} \times 36\rho + \frac{1}{3} \times 24\rho \geqslant 20 \quad \Longrightarrow \quad \rho \geqslant 0.6$$

Therefore, under IA, coordinating at $\theta = 36$ is an equilibrium iff $\rho \geqslant 0.6$.

However, things become a bit different when determining whether receivers' coordinating at $\theta = 24$ is going to be an equilibrium. Each receiver would contribute 8. The sender would of course contribute 8 when $\theta = 24$ and thus the public goods would be provided. However, when $\theta = 36$, the sender has to contribute 20 (which is not larger than $E = 20$) such that the public goods can be provided, and the benefits she can receive is 36ρ. Therefore, the sender is better off to contribute 20 as long as $36\rho \geqslant 20$, i.e., $\rho \geq 5/9$. Thus, the expected payoff of each receiver is:

$$20 - 8 + \frac{1}{3} \times 24 \times \frac{5}{9} + \frac{1}{3} \times 36 \times \frac{5}{9} > 12 + 8 \times 0.5 + 12 \times 0.5 > 20$$

Therefore, it is in equilibrium for the receivers' to coordinate at $\theta = 24$ as long as $\rho \geqslant 5/9$. When $\rho < 5/9$, the sender is worse off by contributing 20 into the public goods when $\theta = 36$, therefore, he would not do so and it cannot be in equilibrium to coordinate at $\theta = 24$.

To sum up, the MPCR value ρ affects the equilibria of the game under different information structures, and it is summed up in Table 1 (free-riding is a universal equilibrium in this game, so we do not include it in this table):

Table 1: Equilibria With Respect to Information Structure and MPCR

<table>
<tr><th></th><th>Complete Symmetric</th><th>Incomplete Asymmetric</th><th>Incomplete Symmetric</th></tr>
<tr><td>$\rho \in (1/3, 0.43)$</td><td rowspan="5">Coordinating at θ</td><td>None</td><td>None</td></tr>
<tr><td>$\rho \in [0.43, 0.57)$</td><td>Coordinating at $\theta = 60$</td><td>None</td></tr>
<tr><td>$\rho \in [0.57, 0.6)$</td><td>Coordinating at $\theta = 60$
or $\theta = 24$</td><td>None</td></tr>
<tr><td>$\rho \in [0.6, 0.75)$</td><td rowspan="2">Coordinating at $\theta = 60$
or $\theta = 36$
or $\theta = 24$</td><td>Coordinating at $\theta = 60$</td></tr>
<tr><td>$\rho \in [0.75, 1)$</td><td>Coordinating at $\theta = 60$
or $\theta = 36$</td></tr>
</table>

4 Experimental Design & Procedure

The stage game that is played in our experiment closely resembles the framework presented in Section 3, and the parameters we use are the same as the example presented in Section 3.4, specifically, we continue to take $N = 3$, $E = 20$, $\Theta = \{24, 36, 60\}$, and $\mathbb{P} \equiv \{1/3, 1/3, 1/3\}$.

4.1 Design and Treatments

We have three experimental treatments investigating three different information structures, (i) Complete and Symmetric (CS) where the realized threshold value is common knowledge; (ii) Incomplete and Symmetric (IS) where it is unknown to all players; and (iii) Incomplete and Asymmetric (IA) where it is privately observed by one player. With this parametrization, the privately informed subject under IA is able to take the most advantage of other group members because of the information advantage.

As shown in Table 1, the MPCR value ρ affects the equilibria under certain information structures. Specifically, a change in ρ would not affect the equilibria strategies under CS, so it only influences the attractiveness of cooperation and coordination but does not affect the difficulty of coordination. The same argument goes for IA as long as $\rho \in [0.6, 1)$. However, under IS, there are more alternative equilibria when $\rho \in [0.75, 1)$ than that when $\rho \in [0.6, 0.75)$, as a result, when MPCR goes beyond 0.75, although cooperation and coordination become more attractive, it also becomes more difficult. It is interesting and important as well to find out which effect dominates the other one and thus affects cooperation and coordination more.

Therefore, our experiment features both between-subject and within-subject design where the information structure is between-subject and the MPCR change is within-subject. The two parameter values chosen for ρ are 0.6 and 0.8, and subjects will play the game with $\rho = 0.6$ in the first stage of the experiment and $\rho = 0.8$ in the second stage.

In order to control for any potential order effect, we also reverse the order of experiencing these two ρ values in other sessions. In this way, we can test whether there will be any order effect or not, and more importantly, how robust are our results against the order effect if there is any. The experimental design is summarized in Table 2.

Each stage will last for 20 periods, and there's no feedback provided for each player after each period, so that any potential learning effect is minimized and, to the largest extent, the game becomes a repetition of the one-shot stage game. At the very end of the experiment, they get a summary of the outcomes of all previous plays in each period including their payment, the profit in each period, and provision status of public goods.

Table 2: Experimental Design

Treatment	Complete Symmetric		Incomplete Symmetric		Incomplete Asymmetric	
Session	CS6	CS8	IS6	IS8	IA6	IA8
Stage 1	$\rho = 0.6$	$\rho = 0.8$	$\rho = 0.6$	$\rho = 0.8$	$\rho = 0.6$	$\rho = 0.8$
Stage 2	$\rho = 0.8$	$\rho = 0.6$	$\rho = 0.8$	$\rho = 0.6$	$\rho = 0.8$	$\rho = 0.6$
Stage 3	Lottery Task To Control Risk Attitude					

After the two stages of threshold public goods game with different ρ values, subjects also go through a multiple price list lottery tasks as a control of their risk attitudes. After the lottery task, a short follow-up questionnaire is presented.

4.2 Hypotheses

As Table 1 shows that, except for the free-riding equilibrium which is universal across treatments, information structure and the ρ value jointly affects the equilibrium at which players are going to coordinate.

At equilibrium, players under CS would contribute exactly one third of the realized threshold level, $\theta/3$, no matter what value ρ takes. Players under IS and IA will behave differently according to ρ. Based on the theoretical predictions summarized in Table 1, we have our first hypothesis.

Hypothesis 1 *Except for free-riding, players under CS contribute one third of the realized threshold θ, players under IA will contribute either 0 or 8 or 12 or 20, and players under IS will contribute 20 when $\rho = 0.6$ and 12 or 20 when $\rho = 0.8$.*

From a theoretical point of view, IS is actually better than IA for two reasons. First, the IS treatment's number of equilibria is less than that of the IA treatment, which is an advantage for coordination problems. Second, one player in the IA treatment will claim an information rent by free-riding when the threshold level is low, however, in the IS treatment, no one has any information advantage so no one can be taken advantage of. Therefore, we would expect a higher contribution level as well as a higher level of public goods provided under IS than IA. Similarly, IS should perform better than CS.

Hypothesis 2 *IS performs better than IA and CS in general, e.g., IS results in a higher contribution, a higher provision ratio, and thus provides more public goods.*

Hypothesis 2 is also consistent with the literature. Previous studies also adopt a random threshold mechanism (even drawn from unknown distributions) hypothesizing that it might help increase contributions by withholding threshold information so that players need to contribute more in order to achieve public goods provision (Rondeau, D. Schulze, & Poe, 1999; Spencer, Swallow, Shogren, & List, 2009).

4.3 Experimental Procedure

The experiment was conducted at the CATI lab, School of Social Science, Nanyang Technological University using ztree (Fischbacher, 2007). Participants were recruited from a pool of undergraduate volunteer subjects via emails. Upon arrival, the experimenter read the instructions aloud while participants were reading their own copies at the same time. Each stage of our experimental instructions is read separately from the next one, so participants can focus on the current task. Sessions lasted around 60 minutes and each participant earned on average S$15 including a show-up fee of S$2. In total, we have 141 undergraduate students who participated in our experiment with 85 male students and 56 female students. The detailed demographics across all the treatments are shown in Table 3.

Table 3: Demographics Across All The Treatments

Treatment	No. of Subjects	Male Ratio	Age	Nationality	% Experiment-Exp	% Theory-Exp
CS6	24	54.2%	22.9	70.8%	91.7%	37.5%
CS8	21	76.2%	23.0	52.4%	100%	42.9%
IA6	24	50.0%	23.0	87.5%	95.8%	37.5%
IA8	24	66.7%	22.4	70.8%	87.5%	50.0%
IS6	24	62.5%	22.6	54.2%	100%	25.0%
IS8	24	54.2%	22.5	62.5%	83.3%	29.2%
Total	141	60.3%	22.7	66.7%	92.9%	36.9%

5 Results

Since the randomness of threshold level is implemented period by period through a computer random device, it could be the case that the realized distribution of threshold is significantly different in one or several treatments from others, and the observed results might be due to this difference rather than the difference in information structures. Therefore, we first perform a K-W test of the distribution of realized threshold values across treatments to make sure this is not the case.

The K-W test p-values presented in Table 4 show that we cannot reject the null hypothesis that the threshold distributions in different treatments are originated from the same distribution. Therefore, the observed treatment differences in the following sections are mainly driven by the difference in information

Table 4: K-W Test of Threshold Distribution Across Treatments

	MPCR = 0.6	MPCR = 0.8	Pooled
p value	0.945	0.342	0.387

structures.

5.1 Equilibria Play Across Treatments

We first look at the contribution behavior across different treatments and see to what extent it conforms to our theoretical predictions. Figure 1 shows the distribution of contributions under different threshold values across different treatments, where each column represents a specific treatment, and each row corresponds to a specific threshold level. Each session has a within-subject variation of MPCR value, so this is the contribution distribution pooled over MPCR = 0.6 and MPCR = 0.8 for each treatment[12].

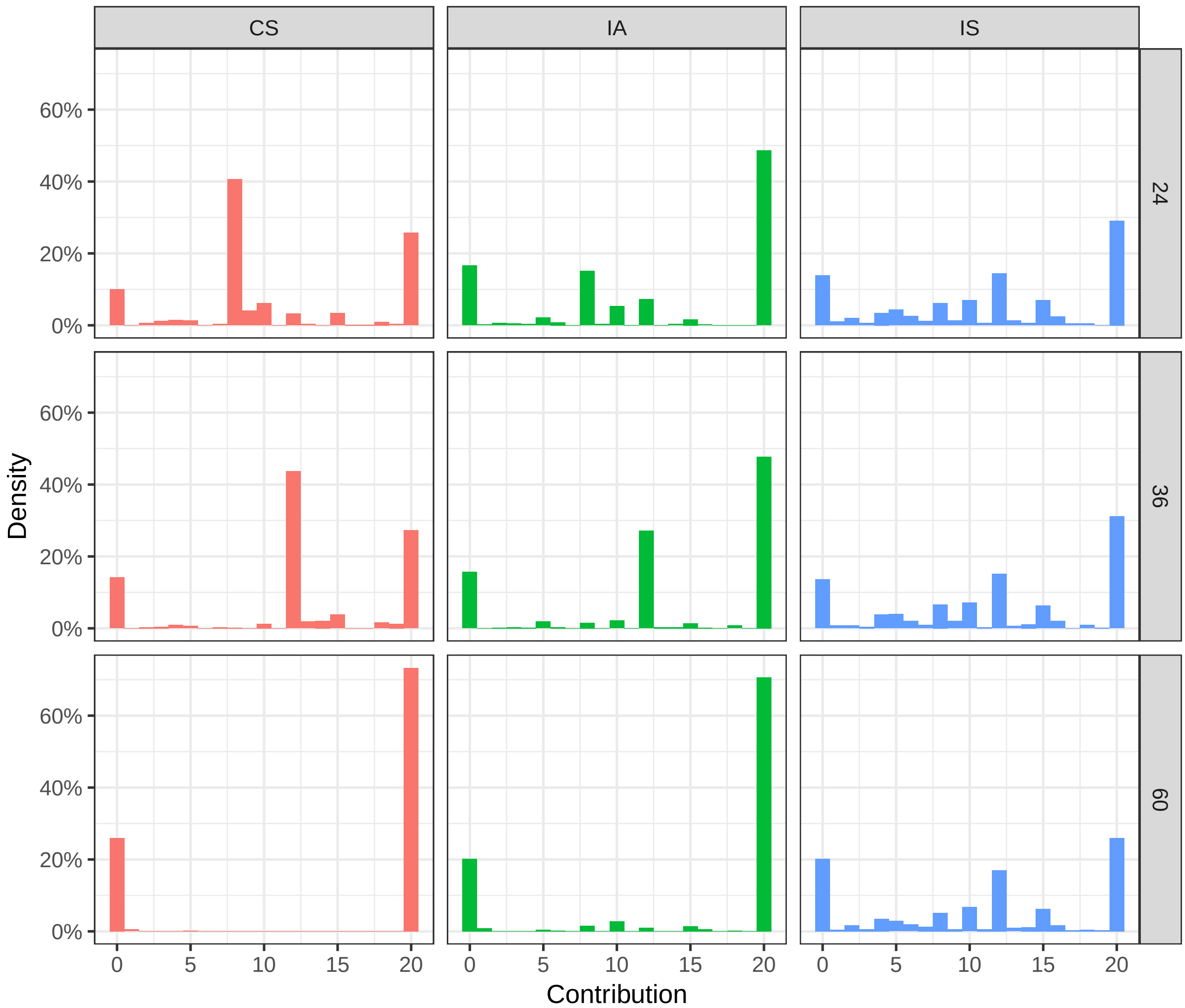


Figure 1: Contribution Distribution Across Treatments & Threshold Levels

[12]Separating the data into MPCR = 0.6 and MPCR = 0.8 does not change the result so much. The distribution for each MPCR value is presented in Appendix.

From Figure 1 we can see that, under CS, the contribution level has a high spike where it equals one third of the threshold level. For example, when the threshold level is 24, there is a spike at contribution level 8 consists of more than 40% of the strategies. Aside from this, there are also two spikes at contribution levels 0 and 20, which we refer to as free-riding and unconditional full contribution. These two types of play seem to constitute a rather stable portion of the population. Next look at the case when the threshold level is 36, despite the two spikes at contribution levels 0 and 20, there is an even higher spike at 12 which is also one third of the threshold. Finally, when the threshold level is 60, the equilibrium play, one third of the threshold level, coincides with the unconditional full contribution strategy, so we observe an extremely high spike at contribution level 20 that constitutes over 70% of the strategy. And there's almost no other contribution except free-riding and full contribution. Thus, Hypothesis 1 is well supported under CS information structure.

Moving to IA, our theoretical analysis predicts that the receivers will coordinate at either $\theta = 60$ or $\theta = 36$ and thus contribute 20 or 12 respectively. The sender only contributes 0 or 12 or 20 depending on the true threshold θ that she privately observed, so we should expect, under any threshold level, three spikes of contribution at 0, 12, and 20. This is only partially supported. The contribution distribution roughly mimics the pattern observed under CS with a shift from equal split contribution strategy to full contributions[13]. Therefore, Hypothesis 1 is only partially supported under IA information structure.

By contrast, under IS, the contribution behavior deviates the most from the equilibrium prediction. Hypothesis 1 suggests that we should only observe two spikes of contribution at 0 and 20 for $\rho = 0.6$ and three at 0, 12, and 20 when $\rho = 0.8$. However, we observe the same contribution distribution with both MPCR values [14]. Therefore, Hypothesis 1 is not supported under IS information structure.

Figure 1 is mainly about to what extent subjects coordinate at the focal point of the equal sharing principle. Players in both CS and IA treatments are able to play the predicted equilibrium strategy except for some free-riders and full contributors, while players in IS treatment do not conform to the theoretical predictions and their contributions are a bit noisy. One explanation is that players under CS and IA have an obvious focal point (for example, the equal cost sharing contribution rule) to coordinate at no matter whether it is the true realization of the state or a mere signal about the state sent by another player. Although the sender might lie and the receivers know that the sender might lie, the signal still serves as a focal point for them to coordinate at, and many studies show that people are usually more credulous than the rational agent (see Irlenbusch & Ter Meer, 2013; Kartik, Ottaviani, & Squintani, 2007, for example). By contrast, players under IS do not have such an obvious focal point to coordinate at and then many of them fail to see through the game and play the equilibrium strategy.

Result 1: *Despite a rather constant portion of free-riders and full contributors, a great majority of*

[13] This is mainly the result of the sender's messaging strategy which generally over-reports the threshold instead of babbling, and this will be discussed in later parts of this paper.

[14] Figure B.1 and Figure B.2 show the contribution distribution separated by MPCR values under each session and threshold level, which are presented in **??**.

players adopt the equal sharing principle as a focal point to guide and facilitate their coordination whenever they can.

5.2 Impact of Information Structure

Figure 2 presents the results comparing different variables across treatments including mean contributions, mean provision ratio of public goods, the amount of public goods provided, the mean wasted contributions due to mis-coordination, mean welfare (provided public goods minus mean wasted contribution), and mean individual profit.

Figure 2(a) shows the mean contributions across these three information structures[15]. The mean contribution under IA (13.9) is higher than that under CS (12.6) and the difference is statistically significant ($p < 0.001$, two-sided Wilcoxon rank-sum test), and the mean contribution under CS is also significantly higher than that under IS (11.3, $p < 0.001$). The IA treatment induces the highest mean contribution among these three information structures (Please refer to Table A.3 for more detailed rank-sum test results with respect to the value of ρ and the sequence of experiencing it.).

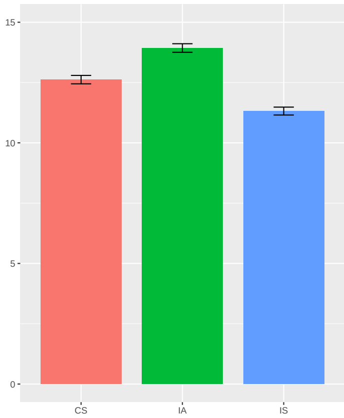
However, Figure 2(b) shows that the provision ratio between IA and CS is roughly the same (62.7% vs 61.5%)[16], although they both deliver a significantly higher provision ratio than the IS treatment does (45.0%, and $p < 0.001$, please refer to Table A.4 for a more detailed and comprehensive results of rank-sum tests on provision ratio across treatments). This casts doubts on the effectiveness of the IA treatment in raising contributions. It is possible that the higher level of contribution delivers a higher level of public goods provided, it is also possible that the higher level of contribution results in a higher wasted contribution due to mis-coordination (Please see Table A.4 for a more detailed rank-sum test results with respect to the value of ρ and the sequence of experiencing it.).

Figure 2(c) and Figure 2(d) together clear this doubt . Figure 2(c) shows that, conditional on successful provision, the mean public goods provided under IA (29.9) is higher than that under CS (26.0) and the difference is significant ($p < 0.001$). In addition, Figure 2(d) shows that the mean wasted contribution is almost the same under both treatment (both are rounded to 11.9). This implies that IA treatment is generally better than CS treatment in providing more public goods without wasting more resources. These results are combined in Figure 2(e) which shows the mean welfare status by taking the benefit of public goods and the cost of wasted contribution together, and readily shows that IA performs significantly better than CS (18 against 14, and $p < 0.001$).

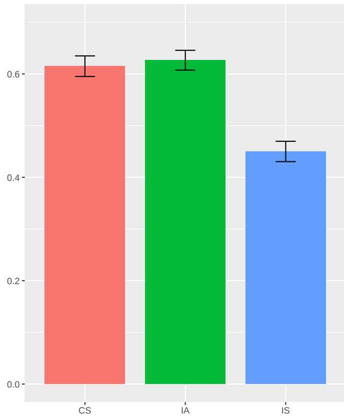
However, the IS treatment provides significantly lower public goods (19.6) compared against the other

[15]For a more detailed descriptives on contributions with respect to each value of ρ and θ as well as the sequence of implementing different values of ρ, please see Table A.1 in **??**.

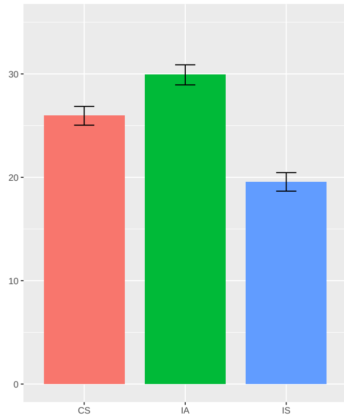
[16]For a more detailed descriptives on provision ratios with respect to each value of ρ and θ as well as the sequence of implementing different values of ρ, please see Table A.2 in **??**.



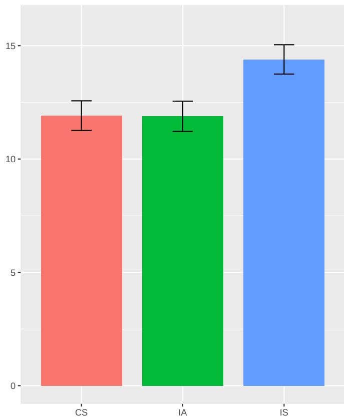
(a) Mean Contribution



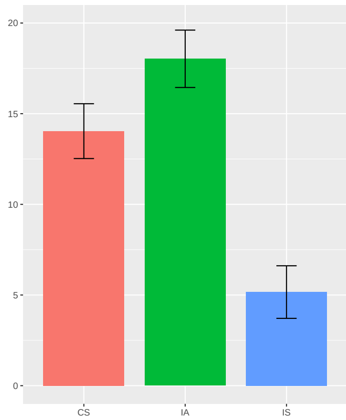
(b) Provision Ratio



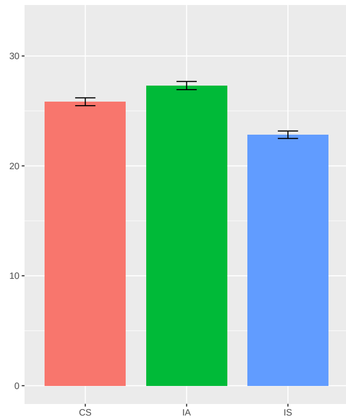
(c) Mean Public Goods Provided



(d) Mean Wasted Contribution



(e) Mean Welfare



(f) Mean Profit

Figure 2: Contribution, Provision, Efficiency, and Welfare Across Treatments

two treatments, and generates significantly higher wasted contributions (14.4), and thus has the lowest welfare status (5.16). This is not consistent with Hypothesis 2 which states that IS is better than IA at least since there's no information asymmetry and thus no information rent is demanded. The reasons are twofold. On one hand, the senders in IA do not babbling as the theory predicts, but they inflate the message about threshold value in general which will be discussed further in the next part. On the other hand, the receives are less strategic and are more credulous. These two factors together make the disadvantage of IA less severe and coordination much easier. Furthermore, the inflated signal helps the receivers to *"overcome"* the equal cost share principal and be able to contribute more and provide more public goods when the threshold level is low.

By contrast, players under IS cannot find a rule of thumb to facilitate their coordination. A large proportion of players seems do not have the capacity to reason about the equilibrium play so that they rely heavily on obvious focal points to coordinate at, and they fail to coordinate when such focal points are absent.

Let us also look at the mean profit in each treatment. Figure 2(f) shows that IA also yields the highest mean profit at the individual level, and it is significantly higher than that under CS (27.3 vs 25.8, $p < 0.001$). The IS treatment, however, yields the lowest mean profit.

Result 2: *The IA treatment elicits the highest contribution, provides the highest public goods and delivers the highest social welfare in general. The IS treatment performs the worst due to the lack of an obvious focal point to coordinate at.*

Table 5, Table 6, Table 7 and Table 8 are results of pooled OLS regressions with dependent variables of contribution, provision ratio, public goods provided, and welfare respectively, and CS is the benchmark treatment.

The regressions show that Result 2 is robust against different specifications. It is significant that IA performs better than CS which in turn performs significantly better than IS in both inducing contributions and enhancing welfare status.

5.3 Sender Behavior and Inequality Across Treatments

Now one natural concern is that, although the IA treatment is generally the best among the three in inducing higher contributions and providing more public goods, there might be a higher inequality among the players in IA treatment than the other two because of information asymmetry which grants the sender an advantageous position. Therefore, we first look at the sender's messaging strategy and then examine the inequalities among players in different treatments.

Table 5: Regression of Contribution Comparison Across Treatments

	Dependent variable: Contribution					
	(1)	(2)	(3)	(4)	(5)	(6)
	IS vs IA	IS vs CS	CS vs IA	IS vs IA	IS vs CS	CS vs IA
IA	3.118***		1.841	3.479***		1.693
	(1.058)		(1.180)	(0.937)		(1.154)
CS		1.424			2.201**	
		(1.148)			(1.045)	
MPCR	9.544***	9.662***	5.375***	9.544***	9.662***	5.375***
	(2.321)	(2.436)	(1.803)	(2.323)	(2.438)	(1.805)
Constant	−2.489	11.171	−3.966	−8.019	12.717	−9.516
	(10.317)	(8.772)	(9.626)	(10.783)	(10.316)	(11.174)
Covariate	Yes	Yes	Yes	Yes	Yes	Yes
Agreeableness	No	No	No	Yes	Yes	Yes
Observations	3,840	3,720	3,720	3,840	3,720	3,720
R^2	0.111	0.075	0.045	0.187	0.116	0.068
Adjusted R^2	0.109	0.073	0.043	0.184	0.112	0.064
Residual Std. Error	7.179	7.043	7.467	6.870	6.894	7.384
	(df = 3830)	(df = 3710)	(df = 3710)	(df = 3824)	(df = 3704)	(df = 3704)

Note: *p<0.1; **p<0.05; ***p<0.01. Robust standard errors clustered at individual level are presented in parenthesis. *Covariate* includes gender, age, nationality, risk preference, past experience of participating in lab experiments, past experience with game theory, period. *Agreeableness* includes measurements of six facets of agreeableness which are trust, morality, altruism, cooperation, modesty, sympathy.

Table 6: Logit Regression of Provision Ratio Across Treatments

	Dependent variable: Provision Ratio					
	(1)	(2)	(3)	(4)	(5)	(6)
	IS vs IA	IS vs CS	CS vs IA	IS vs IA	IS vs CS	CS vs IA
IA	0.685^{**}		0.072	0.767^{**}		0.129
	(0.331)		(0.378)	(0.331)		(0.464)
CS		0.889^{**}			1.121^{***}	
		(0.365)			(0.414)	
MPCR	2.595^{**}	2.819^{***}	2.079^{**}	2.814^{**}	2.925^{***}	2.163^{**}
	(1.095)	(0.977)	(0.943)	(1.189)	(0.999)	(0.978)
Constant	3.909	9.175	−0.503	2.701	9.659	−10.567
	(4.911)	(5.619)	(6.005)	(6.455)	(6.331)	(7.859)
Covariate_GM	Yes	Yes	Yes	Yes	Yes	Yes
Agreeableness_GM	No	No	No	Yes	Yes	Yes
Observations	1,280	1,240	1,240	1,280	1,240	1,240
Log Likelihood	−833.767	−791.374	−812.438	−783.102	−768.759	−787.902
Akaike Inf. Crit.	1,681.535	1,596.748	1,638.876	1,592.205	1,563.518	1,601.803

Note: *p<0.1; **p<0.05; ***p<0.01. Robust standard errors clustered at individual level are presented in parenthesis. *Covariate_GM* includes group mean of age and risk preference, gender composition of the group, and period. *Agreeableness_GM* includes group mean of the six measurements of agreeableness which are trust, morality, altruism, cooperation, modesty, sympathy.

Table 7: Regression of Public Goods Provided Across Treatments

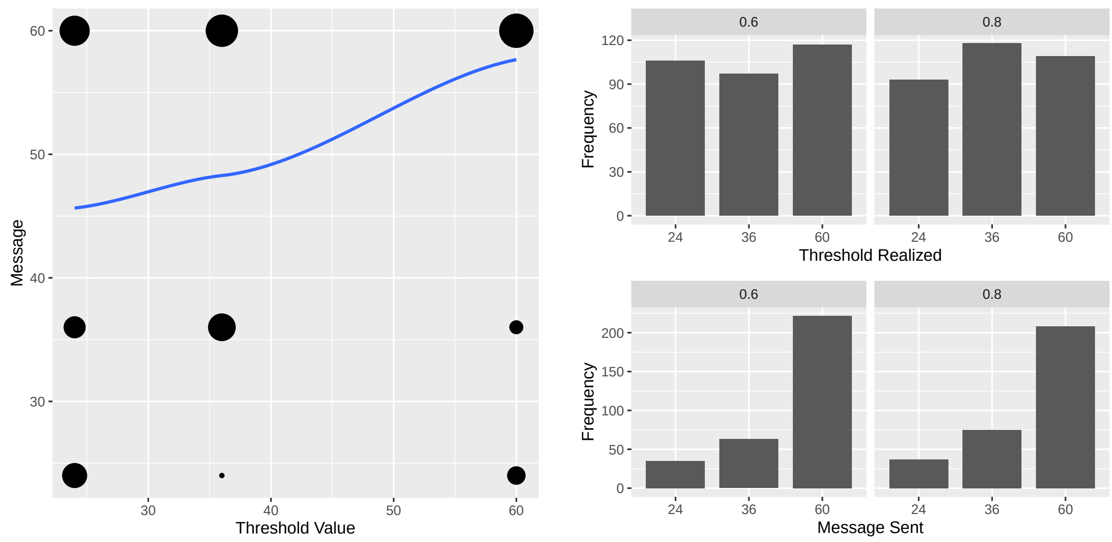
	Dependent variable: Public Goods Provided					
	(1)	(2)	(3)	(4)	(5)	(6)
	IS vs IA	IS vs CS	CS vs IA	IS vs IA	IS vs CS	CS vs IA
IA	9.372**		3.940	9.789***		3.625
	(4.167)		(4.874)	(3.787)		(5.861)
CS		8.138**			9.024**	
		(4.041)			(4.219)	
MPCR	38.344***	37.947***	29.769***	38.344***	37.947***	29.769***
	(12.611)	(11.811)	(10.393)	(12.641)	(11.840)	(10.419)
Constant	97.451	141.194**	30.120	79.863	122.415**	−113.159
	(60.380)	(62.843)	(69.054)	(75.108)	(60.414)	(94.815)
Covariate_GM	Yes	Yes	Yes	Yes	Yes	Yes
Agreeableness_GM	No	No	No	Yes	Yes	Yes
Observations	1,280	1,240	1,240	1,280	1,240	1,240
R^2	0.121	0.144	0.036	0.216	0.174	0.085
Adjusted R^2	0.117	0.140	0.032	0.209	0.166	0.076
Residual Std. Error	22.735	21.034	23.18	21.518	20.707	22.647
	(df = 1273)	(df = 1233)	(df = 1233)	(df = 1267)	(df = 1227)	(df = 1227)

Note: *p<0.1; **p<0.05; ***p<0.01. Robust standard errors clustered at individual level are presented in parenthesis. *Covariate_GM* includes group mean of age and risk preference, gender composition of the group, and period. *Agreeableness_GM* includes group mean of the six measurements of agreeableness which are trust, morality, altruism, cooperation, modesty, sympathy.

Table 8: Regression of Welfare Across Treatments

	Dependent variable: Welfare					
	(1)	(2)	(3)	(4)	(5)	(6)
	IS vs IA	IS vs CS	CS vs IA	IS vs IA	IS vs CS	CS vs IA
IA	10.970*		3.810	10.785**		3.507
	(5.701)		(7.560)	(5.421)		(9.244)
CS		10.998*			11.477*	
		(5.669)			(5.980)	
MPCR	48.055***	46.906***	43.415***	48.055***	46.906***	43.415***
	(18.535)	(17.447)	(15.976)	(18.579)	(17.489)	(16.015)
Constant	93.186	154.137*	15.665	43.234	102.540	−178.277
	(84.476)	(86.991)	(110.324)	(99.534)	(81.331)	(151.434)
Covariate_GM	Yes	Yes	Yes	Yes	Yes	Yes
Agreeableness_GM	No	No	No	Yes	Yes	Yes
Observations	1,280	1,240	1,240	1,280	1,240	1,240
R^2	0.077	0.084	0.026	0.132	0.097	0.057
Adjusted R^2	0.072	0.080	0.021	0.124	0.088	0.048
Residual Std. Error	37.474	35.583	38.227	36.426	35.427	37.701
	(df = 1273)	(df = 1233)	(df = 1233)	(df = 1267)	(df = 1227)	(df = 1227)

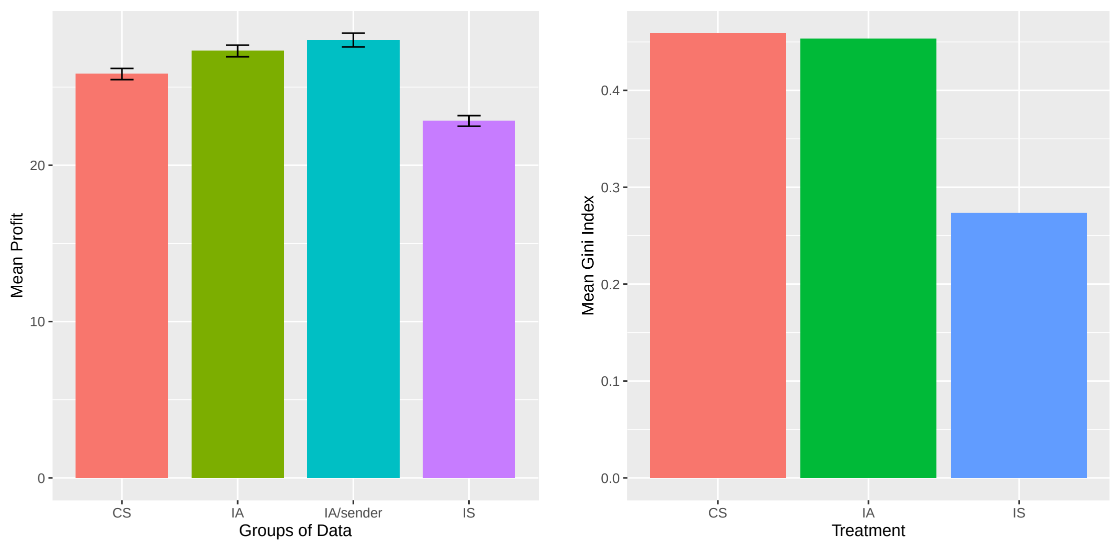
Note: *p<0.1; **p<0.05; ***p<0.01. Robust standard errors clustered at individual level are presented in parenthesis. *Covariate_GM* includes group mean of age and risk preference, gender composition of the group, and period. *Agreeableness_GM* includes group mean of the six measurements of agreeableness which are trust, morality, altruism, cooperation, modesty, sympathy.



(a) Messaging Strategy (b) Distribution of Threshold and Message

Figure 3: Sender's Messaging Strategy under IA

Figure 3(a) shows that the senders over-report the threshold level, however, there is also a non-negligible portion of senders who truthfully reports the threshold level. Figure 3(b) shows the distribution of both threshold levels and reported messages with respect to different MPCR values. The over-reporting strategy appears to be robust against the MPCR change in our experiment. This further raises the concern that receivers under IA might be taken advantage of and thus result in an overall poor status.



(a) Mean Profit Including Receivers under IA (b) Mean Gini Index Across Treatments

Figure 4: Mean Profits, Gini Index, and Inequality Across Treatments

We address this concern by excluding the senders from the IA treatment and comparing the receivers' mean profit against that in CS and IS. If the receivers' mean profit is less than that in CS and IS, then IA increases inequality among players though it makes them better as a whole.

However, Figure 4(a) shows that the receivers mean profit in IA (represented by "IA/sender") is not lower than that in CS and IS, but even significantly higher than that in CS (28 vs 25.8, $p < 0.001$) as well than that in IS (28 vs 22.8, $p < 0.001$). This implies that IA delivers a Pareto improvement. Figure 4(b) compares the mean Gini index across these three treatments, and it shows that the mean Gini index in the IA treatment (0.205) is not roughly the same as that in the CS treatment (0.212, $p = 0.426$). The IS treatment has the lowest Gini index in general (0.177) because they contribute less in general and thus result in a lower level of inequality[17].

Result 3: *While The IA information structure induces the highest contribution and welfare status, it does not come at the cost of a higher inequality level. The generated results by IA Pareto dominate that by CS and IS.*

5.4 Effect of MPCR Change

As documented by much research in linear public goods game that an MPCR increase significantly increases contribution, we test whether this is a robust result in our experiment. Table 9 shows the mean contribution under different treatments for different MPCR values. We also compare the stage one results and stage two results separately since stage two results might be subject to potential order effects which will be discussed in detail later.

Table 9 shows that, in general, an increase in MPCR significantly boosts the contribution at least in stage one of the experiment. Take CS treatment as an example, the mean contribution under MPCR = 0.6 is 11.60 in stage one of the experiment, and the mean contribution under MPCR = 0.8 is 13.97 which is significantly higher ($p < 0.001$). However, the stage two data shows a very close mean contribution and they are not significantly different from each other, which is largely due to an order effect. The IA treatment exhibits similar results.

Attractiveness vs Difficulty: Table 1 shows that such an increase in MPCR makes coordination harder under IS because of more potential equilibria. However, subjects still contribute significantly more when MPCR is higher. This implies that, at least in such an environment, attractiveness has a dominant effect on contribution and coordination than that of coordination difficulty.

Table 9: Between Subject MPCR Effect on Contribution For Each Treatment

	Complete Symmetric			Incomplete Asymmetric			Incomplete Symmetric		
	r =0.6	r = 0.8	p value	r =0.6	r = 0.8	p value	r =0.6	r = 0.8	p value
Stage 1	11.60	13.97	0.0000	12.85	14.75	0.0001	11.09	12.09	0.0471
Stage 2	12.64	12.45	0.3911	13.93	14.19	0.5996	8.80	13.29	0.0000
pool	12.1	13.2	0.0090	13.4	14.5	0.0168	9.95	12.7	0.0000

[17] Imagine an extreme case where no body contributes, the Gini index would be zero.

Public goods provision ratio exhibits the same pattern as contribution which is presented in Table A.5 in Appendix A. In addition, the more detailed results with respect to each value of *theta* are presented in Table A.6 and Table A.7 showing the MPCR change impact on contribution and provision ratio respectively.

Result 4: *An increase in the MPCR value significantly boosts contribution and the ratio of successful provision of public goods, and this effect dominates the effect of an increase in coordination difficulty in IS treatment.*

Table 10: Within Subject MPCR Effect on Contribution Across Treatments

	Complete Symmetric		Incomplete Asymmetric		Incomplete Symmetric	
	CS6	CS8	IA6	IA8	IS6	IS8
$r = 0.6$	11.60	12.64	12.85	13.93	11.09	8.80
$r = 0.8$	12.45	13.97	14.19	14.75	13.29	12.09
Mean Changes	0.85	-1.33	1.34	-0.82	2.20	-3.29
p value	0.0143	0.0006	0.0007	0.0178	0.0000	0.0000

Table 10 shows the MPCR effect on contribution through a within subject comparison, and consistently and significantly a higher MPCR leads to a higher contribution across all three treatments[18].

Another observation from Table 10 is that contributions in the IS treatment are more responsive to MPCR changes than those in the other two treatments. For example, when there is an MPCR increase from 0.6 to 0.8, session IS6 yields an increase of 2.20 in the mean contribution, while this increase is only 0.85 in session CS6 and 1.34 in session IA6. When there's a decrease of MPCR from 0.8 to 0.6, the resulting decrease of contribution is 3.29 in session IS8, 1.33 in session CS6, and 0.82 in session IA. One possible explanation is that, when people lack the information to make decisions accordingly, they will pay too much attention to an exogenous change and over-response to it, especially when the exogenous change is negative.

Result 5: *Due to the lack of relevant information to make decisions accordingly, players under IS will over-response to exogenous shocks, especially for negative shocks. On the other hand, players under IA respond to a positive shock more than they do to a negative shock.*

5.5 Robustness Against Order Effect

Recall the experimental design shown in Table 2, we have a within-subject variation of MPCR value ($r = 0.6$ or 0.8), so that subjects play the game with each MPCR value for 20 periods. We vary the order

[18] The statistical test we use in this case is the signed-rank test. However, the data is not essentially paired data because the randomly realized threshold level is likely to be different in corresponding periods of stage 1 and stage 2.

of play of each MPCR value in order to control for any potential order effect. This section is going to explore more on this issue to see whether there is any order effect and how it affects our main results.

Table 11: Order Effects on Contribution w.r.t. Treatment & MPCR

	Complete Symmetric			Incomplete Asymmetric			Incomplete Symmetric		
	Stage 1	Stage 2	p value	Stage 1	Stage 2	p value	Stage 1	Stage 2	p value
$r = 0.6$	11.60	12.64	0.0398	12.85	13.93	0.0140	11.09	8.80	0.0000
$r = 0.8$	13.97	12.45	0.0004	14.75	14.19	0.0794	12.09	13.29	0.0008

We first test whether the subjects play differently when a certain MPCR value is implemented in the first stage than it is in the second stage in each treatment separately.

Table 11 displays the mean contribution in each treatment and each MPCR value distinguishing stage one from stage two. Under CS with MPCR = 0.6, it the contribution is significantly higher when it is played in stage two after subjects have played MPCR = 0.8 (12.64 vs 11.60, $p = 0.0398$). This is related to the previous result that an increase in MPCR induces significantly higher contributions. A reasonable argument is that, when the subject first plays with MPCR = 0.8, their contribution is significantly higher than those who first play with MPCR = 0.6, and they carry this “high contribution norm” over to the second stage where MPCR = 0.6. On the contrary, when MPCR = 0.8, the contribution is significantly lower when it is played in stage two after subjects have played MPCR = 0.6 (13.97 vs 12.45, $p = 0.0004$).

Similarly, the results of order effect on provision ratio have roughly the same pattern as that on contribution, which are presented in Table A.8 in Appendix.

Our experimental data does exhibit the order effect. However, our results are obtained mainly using the pooled data, so our results are robust against the order effect.

6 Conclusion and Discussion

We economists normally (intuitively) think that an environment with complete and thus symmetric (CS) information would deliver the best economic outcome since each agent can fully optimize without paying any informational rent to anyone else. The incomplete and symmetric information structure would be worse since each agent optimizes with incomplete (maybe wrong) constraints. The incomplete and asymmetric information structure would be the worst since additional informational rent would be charged by those who have more information.

However, in a simple threshold public goods game with three different information structures about the threshold value (CS, Complete and Symmetric; IS, Incomplete and Symmetric; IA, Incomplete and

Asymmetric), the theory predicts something counterintuitive: the CS information structure actually performs the worst, while the IS information structure performs the best, with the IA information structure (with cheap talk) lying in between.

We then experimentally investigate how people would actually behave under those different information structures, and the result shows, a bit surprisingly, that the IA information structure leads to the highest contribution and highest provision of public goods. One importantly implication is that, in certain scenarios similar to our experimental setting, having a privately informed agent (normally the *sender* might be better than revealing the information completely to the entire group, although the sender might behave strategically and manipulate others.

The reason is twofold: on one hand, the agents are less manipulative when they are privately informed. Even if they lie about their private information, they do not lie only for their own sake, but also for the benefits of the entire group. On the other hand, the agents are more willing to coordinate at the suggested level when they are not privately informed. These agents exhibits a certain kind of credulity towards the cheap-talk messages. Those two aspects of our subjects jointly produced this seemingly surprising result that the information asymmetric is desirable and delivers the best economic outcome.

This further sheds light on how we can achieve economically desirable outcomes - economic optimality. Traditionally, economic optimality is achieved with the assumptions of complete information and economic agents with full calculating capacity and stable decision rules that are not affected by any emotion. Therefore, we try to promote information transparency, and liberal education on economics and finance so that our economic agents would make rational decisions more often. Unfortunately, neither the information can be complete nor the agent can be fully rational. Alternatively, the results obtained in this paper suggest another way: By cultivating a certain set of attributes of our economic agents, information asymmetry becomes desirable and can possibly produce an economic outcome better than that is produced under complete information and full rationality. Following this insight, we can design institutions to institutionalize some concepts, for example, we can promote some social norms or cultural values. Lastly, these two ways of achieving economically desirable outcomes can be complementary to each other.

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Appendix A Extra Tables

Table A.1: Descriptive Statistics of Contribution

Mean & SD		CS0.6	CS0.8	IA0.6	IA0.8	IS0.6	IS0.8
MPCR = 0.6	K = 24	9.76	10.68	11.45	13.22	11.48	9.24
		(6.28)	(6.51)	(7.93)	(8.14)	(7.43)	(6.78)
	K = 36	11.33	12.68	12.45	13.48	11.36	9.43
		(7.06)	(6.44)	(7.45)	(7.94)	(7.03)	(7.14)
	K = 60	13.91	14.47	14.51	14.92	10.52	7.81
		(9.19)	(8.98)	(8.32)	(8.50)	(7.44)	(7.52)
	Pool	11.60	12.64	12.85	13.93	11.09	8.80
		(7.74)	(7.42)	(8.02)	(8.24)	(7.31)	(7.17)
MPCR = 0.8	K = 24	10.54	12.47	12.63	14.22	13.17	12.08
		(6.37)	(6.15)	(7.62)	(7.01)	(7.32)	(6.32)
	K = 36	12.69	13.83	13.34	15.53	13.50	12.36
		(6.30)	(5.42)	(6.78)	(6.65)	(7.22)	(6.40)
	K = 60	14.78	15.60	16.29	14.45	13.17	11.73
		(8.81)	(8.31)	(7.12)	(8.68)	(7.21)	(5.86)
	Pool	12.45	13.97	14.19	14.75	13.29	12.09
		(7.33)	(6.86)	(7.28)	(7.50)	(7.24)	(6.22)
Pool Over All		12.03	13.30	13.52	14.34	12.19	10.45
		(7.55)	(7.17)	(7.68)	(7.88)	(7.35)	(6.90)

Table A.2: Descriptive Statistics on Provision Ratio

Provision Ratio (%)		CS0.6	CS0.8	IA0.6	IA0.8	IS0.6	IS0.8
MPCR = 0.6	K = 24	76.8	92.5	69.8	90.6	73.6	69.5
	K = 36	37.7	69.5	68.0	68.1	50.0	32.6
	K = 60	35.3	24.4	21.1	38.3	1.7	0
	Pool	50.6	62.9	51.9	64.4	40.0	35.0
MPCR = 0.8	K = 24	88.9	91.5	71.4	100	77.8	85.5
	K = 36	51.0	80.4	62.9	89.3	66.1	54.1
	K = 60	39.1	42.6	51.8	30.2	14.0	4.5
	Pool	62.5	71.4	61.2	73.1	53.8	51.3
Pool Over All		56.6	67.1	56.6	68.8	46.9	43.1

Table A.3: Rank-sum Test of Difference in Contribution Across Treatments

Mean Contribution	IA - CS	IA - IS	CS - IS
MPCR = 0.6	1.31***	3.44***	2.14***
MPCR = 0.8	1.31***	1.78***	0.47
Pool	1.31***	2.61***	1.30***
	IA6 - CS6	IA6 - IS6	CS6 - IS6
MPCR = 0.6	1.25**	1.76***	0.51
MPCR = 0.8	1.74***	0.90*	−0.84*
Pool	1.50***	1.33***	−0.16
	IA8 - CS8	IA8 - IS8	CS8 - IS8
MPCR = 0.6	1.30***	5.13***	3.83***
MPCR = 0.8	0.79**	2.67***	1.88***
Pool	1.04***	3.90***	2.86***

Table A.4: Rank-sum Test of Difference in Provision Ratio Across Treatments

Provision Ratio (%)	IA - CS	IA - IS	CS - IS
MPCR = 0.6	1.79	20.63***	18.83***
MPCR = 0.8	0.52	14.69***	14.17***
Pool	1.16	17.67***	16.5***
	IA6 - CS6	IA6 - IS6	CS6 - IS6
MPCR = 0.6	1.25	11.88*	10.63
MPCR = 0.8	−1.25	7.50	8.75
Pool	−0.00	9.69*	9.69*
	IA8 - CS8	IA8 - IS8	CS8 - IS8
MPCR = 0.6	1.52	29.38***	27.85***
MPCR = 0.8	1.70	21.88***	20.18***
Pool	1.61	25.63***	24.02***

Table A.5: Between Subject MPCR Effect on Provision Ratio For Each Treatment (%)

	Complete Symmetric			Incomplete Asymmetric			Incomplete Symmetric		
	r =0.6	r = 0.8	p value	r =0.6	r = 0.8	p value	r =0.6	r = 0.8	p value
Stage 1	50.6	71.4	0.0002	51.9	73.1	0.0001	40.0	51.3	0.0438
Stage 2	62.9	62.5	0.9498	64.4	61.2	0.5641	35.0	53.8	0.0008
pool	56.3	66.7	0.0090	58.1	67.2	0.0168	37.5	52.5	0.000

Table A.6: Between Subject MPCR Effect on Contribution With Respect To θ

Mean Contribution		CS8 - CS6	IA8 - IA6	IS8 - IS6
Stage 1	K = 24	2.71***	2.77**	0.60
	K = 36	2.5**	3.08***	1.00
	K = 60	1.69	−0.06	1.21
	Pool	2.37***	1.9***	1.00*
Stage 2	K = 24	0.14	0.59	−3.93***
	K = 36	−0.01	0.14	−4.07***
	K = 60	−0.31	−1.37	−5.36***
	Pool	0.19	−0.26	−4.49***

Table A.7: Between Subject MPCR Effect on Provision Ratio With Respect To θ

Provision Ratio(%)		CS8 - CS6	IA8 - IA6	IS8 - IS6
Stage 1	K = 24	14.7*	30.2***	11.9
	K = 36	42.7***	21.3**	4.1
	K = 60	7.1	9.1	2.8
	Pool	20.8***	21.2***	11.3*
Stage 2	K = 24	3.6	19.2*	−8.3
	K = 36	18.5*	5.2	−33.5***
	K = 60	−14.7	−13.5	−14.0**
	Pool	0.4	3.2	−18.8***

Table A.8: Order Effects on Provision Ratio w.r.t. Treatment & MPCR

	Complete Symmetric			Incomplete Asymmetric			Incomplete Symmetric		
	Stage 1	Stage 2	p value	Stage 1	Stage 2	p value	Stage 1	Stage 2	p value
$r = 0.6$	50.63%	62.86%	0.0334	51.88%	64.38%	0.0237	40.00%	35.00%	0.3567
$r = 0.8$	71.43%	62.50%	0.1025	68.75%	61.25%	0.0240	53.75%	51.25%	0.6553

Table A.9: Regression of Contribution Regarding The Impact of Personality

	Dependent variable: Contribution			
	CS	IA	IS	Pool
	(1)	(2)	(3)	(4)
MPCR	5.358*	5.391**	13.698***	8.208***
	(2.737)	(2.413)	(3.915)	(1.807)
Trust	0.053	0.572***	0.389***	0.215**
	(0.167)	(0.156)	(0.106)	(0.098)
Morality	−0.048	−0.141	−0.338*	−0.102
	(0.211)	(0.213)	(0.179)	(0.124)
Altruism	−0.645**	−0.115	0.216	0.002
	(0.272)	(0.259)	(0.244)	(0.170)
Cooperation	−0.132	0.114	−0.349**	−0.198
	(0.215)	(0.250)	(0.156)	(0.130)
Modesty	0.282	−0.125	0.091	0.038
	(0.176)	(0.149)	(0.151)	(0.087)
Sympathy	0.498*	−0.038	0.066	0.156
	(0.277)	(0.267)	(0.171)	(0.130)
Constant	27.845	−53.494***	9.919	2.478
	(17.672)	(15.320)	(14.302)	(8.432)
Control_A	Yes	Yes	Yes	Yes
Observations	1,800	1,920	1,920	5,640
R^2	0.111	0.218	0.273	0.078
Adjusted R^2	0.104	0.212	0.268	0.075
Residual Std. Error	7.003	6.917	6.145	7.250
	(df = 1785)	(df = 1905)	(df = 1905)	(df = 5625)

Note: *Robust standard errors clustered at group level are presented in parenthesis.*
*p<0.1; **p<0.05; ***p<0.01

Table A.10: Regression of Individual Profit Regarding The Impact of Personality

	Dependent variable: Individual Payoff			
	CS	IA	IS	Pool
	(1)	(2)	(3)	(4)
MPCR	40.944***	45.816***	38.246***	41.684***
	(5.536)	(5.937)	(7.323)	(3.638)
Trust	−0.200	−0.100	0.200	0.008
	(0.251)	(0.282)	(0.156)	(0.132)
Morality	0.240	0.210	0.291	0.291*
	(0.354)	(0.415)	(0.259)	(0.170)
Altruism	0.537	0.550	0.267	0.434*
	(0.588)	(0.517)	(0.227)	(0.236)
Cooperation	0.239	−1.024**	−0.180	−0.215
	(0.314)	(0.466)	(0.186)	(0.187)
Modesty	−0.428	0.267	−0.395**	−0.186
	(0.341)	(0.286)	(0.176)	(0.133)
Sympathy	−0.084	0.398	0.047	−0.053
	(0.463)	(0.476)	(0.184)	(0.172)
Constant	−42.162	5.873	−14.562	−1.991
	(35.387)	(29.223)	(16.741)	(12.699)
Observations	1,800	1,920	1,920	5,640
R^2	0.135	0.153	0.120	0.097
Adjusted R^2	0.129	0.147	0.113	0.095
Residual Std. Error	14.181	15.046	14.017	14.827
	(df = 1785)	(df = 1905)	(df = 1905)	(df = 5625)

Note: *Robust standard errors clustered at group level are presented in parenthesis.*
*p<0.1; **p<0.05; ***p<0.01

Appendix B Extra Figures

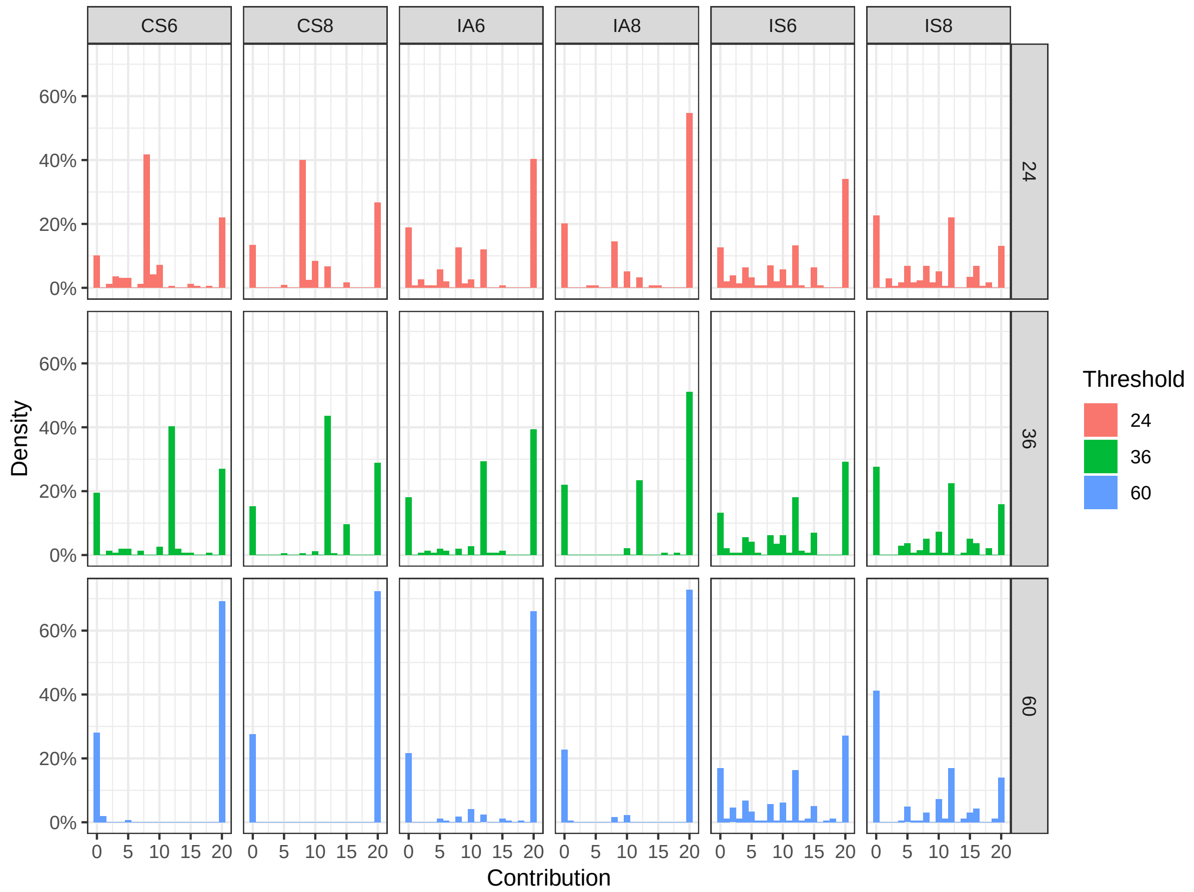


Figure B.1: Distribution of Contribution When MPCR = 0.6

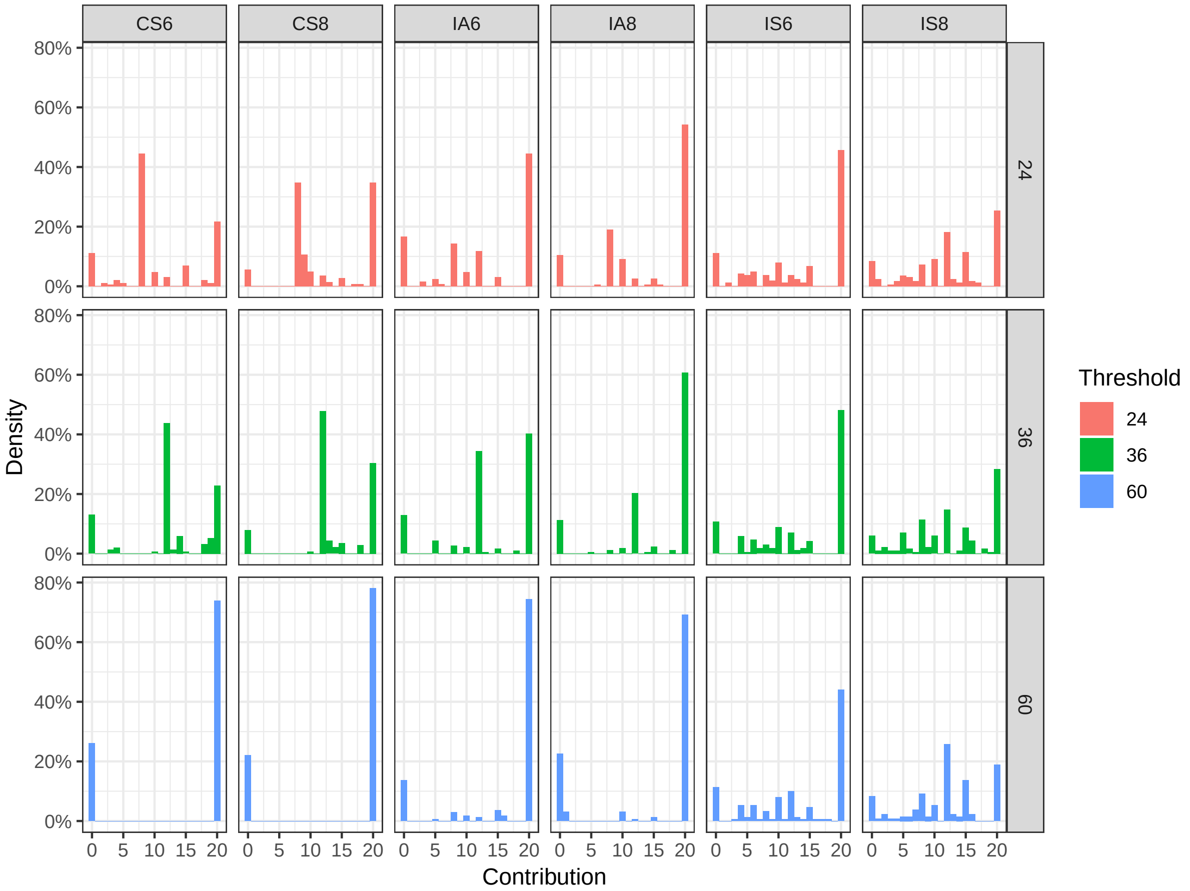
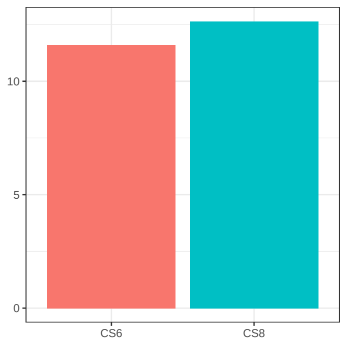
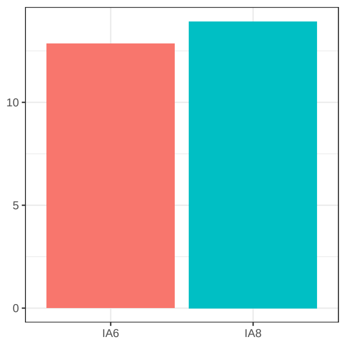


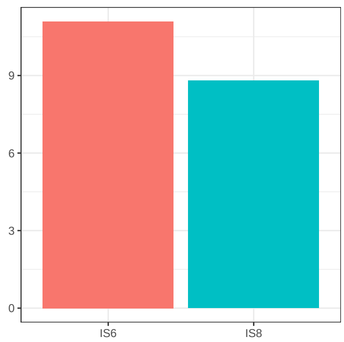
Figure B.2: Distribution of Contribution WhenMPCR = 0.8



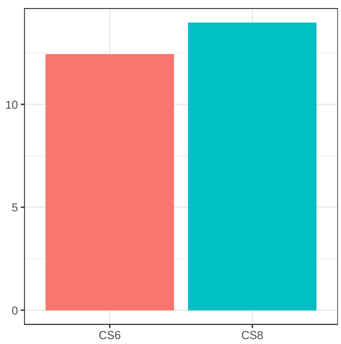
(a) MPCR = 0.6 & CS



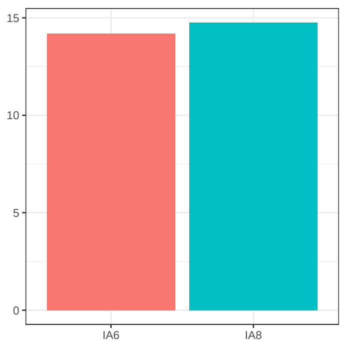
(b) MPCR = 0.6 & IA



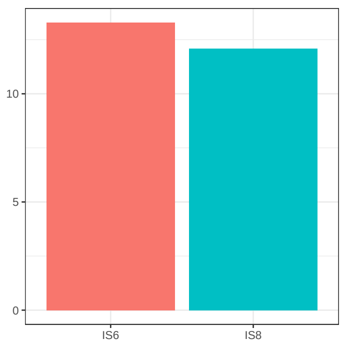
(c) MPCR = 0.6 & IS



(d) MPCR = 0.8 & CS



(e) MPCR = 0.8 & IA



(f) MPCR = 0.8 & IS

Figure B.3: Order Effects on Contribution w.r.t. Treatment & MPCR

Appendix C A Sample Experimental Instruction: Treatment IA

General Information

You are now taking part in an interactive study on decision making. **Please pay attention to the information provided here and make your decisions carefully. If at any time you have questions to ask, please raise your hand and we will attend to you in private.**

Please note that unauthorized communication is prohibited. Failure to adhere to this rule would force us to stop the experiment and you may be held liable for the cost incurred in this experiment. You have the right to withdraw from the experiment at any point, and if you decide to do so your payoff earned during this study will be forfeited.

By participating in this study, you will be able to earn a considerable amount of money. The amount depends on the decisions you and others make.

At the end of this session, this money will be paid to you privately and in cash. It would be contained in an envelope which is indicated with your unique subject ID. You will need to sign a receipt form to acknowledge that you have been given the correct amount.

General Instructions

Each of you will be given a unique subject ID at the beginning of the experiment. Your **anonymity will be preserved** for the study. You will **never be aware of** the personal identities of other players **during or after** the study. Similarly, other players will also **never be aware of** your personal identities **during or after** the study. You will only be identified by your subject ID in our data collection. All information collected will **strictly be kept confidential** for the sole purpose of this study.

Your earnings in the experiment are denominated by "**Experimental Currency Unit(s)**" or "**ECU(s)**". At the end of the experiment, they will be converted into Singapore Dollars at the rate of

1 ECU = 0.1 SGD.

The real-dollar equivalent of your final earnings will be added to your **show-up fee** as your final payoff and paid to you privately in cash at the end of the experiment.

Specific Instructions

You will participate in **three** stages, the specific instructions will be given to you at the beginning of each stage. The following is the specific instruction for stage one.

Stage One

Welcome to Stage One of our experiment. In this part of the experiment, you will **form a group of three** randomly with two other participants, and **the group composition will remain the same** throughout this experiment.

As a group, you are going to play an investment game for 20 periods. At the beginning of each period, each group member will be given an endowment of **20 ECUs**. Your decision is to **choose an amount X** out of your endowment (any number between 0 and 20, including 0 and 20) to invest in a group project and **keep the rest** $(20 - X)$ **privately**. The total investments made by you and your group members are denoted as X_{Total}.

The group project will be **successfully implemented** if the total investments (X_{Total}) are **NOT LESS** than **K** (ECUs), where K is a threshold value that is randomly drawn from **{24, 36, 60}** in each period. Therefore, K **has equal chance**, which is 1/3, to be 24, or 36, or 60 in each period. Note that the value of K can be different or the same from period to period.

The profitability coefficient $\mathbf{P = 1.8}$ defines how profitable your group project is. Once the group project is successfully implemented, the **total investments** X_{Total} **will be multiplied by this profitability coefficient 1.8**, and then distributed **equally** among you and your group members. Therefore, each member will get $X_{Total} \times 1.8 \div 3$ from the group project.

Taken together, you are left with $(20 - X)$ after you invested X into the group project. In addition to the amount you keep privately, you can get benefits from the group project depending on its implementation status. In case that $X_{Total} \geqslant K$, so the group project is successfully implemented, each member gets $(X_{Total} \times 1.8 \div 3)$ from the group project. In case that $X_{Total} < K$, the project is not successfully implemented, and **all the investments are gone**.

Therefore, your earning in each period is as follows:

- If $X_{Total} \geqslant K$, your earning is $(20 - X) + (X_{Total} \times 1.8 \div 3)$.
- If $X_{Total} < K$, your earning is $(20 - X)$.

For example, suppose that you invest 10 ECUs in the project (so $X = 10$), and the total investments in the project by all your group members including you are 30 ECUs (so $X_{Total} = 30$). If $K = 24$, then the project will be successfully implemented because $X_{Total} > K$ (as $30 > 24$), and your earning is $(20–10) + (30 \times 1.8 \div 3) = 28$ (ECUs). If $K = 36$, then the project will not be successfully implemented because now $X_{Total} < K$, and your earning in this period is $(20–10) = 10$ (ECUs).

As to the threshold value, **only one member in your group** will be informed of the value of K at the beginning of each period, and he/she is **randomly selected** among the three of you. Therefore, **each participant has 1/3 chance** to be selected as the person who will know the value of K in private throughout Stage One. Therefore, the value of K is a **private information** that **only the selected member knows**.

The selected member then needs to **send a message about the value of** K **to the rest of the group in each period.** After the message is received, all group members will make the investment decision X (how much you would like to invest in the group project).

For example, suppose the selected member observes that the threshold value $K = 36$, he/she then needs to send a message of 24 or 36 or 60 telling the other two group members that the threshold value is 24 or 36 or 60.

There are a few test questions before Stage One actually starts. You have to answer all of them correctly in order to proceed. There is a calculator at the bottom left corner of your screen in case you need it. Please raise your hand if you have any questions.

At the end of the experiment (after Stage Three), **two out of 20 periods** in this stage will be randomly selected and **the sum of your earnings in these periods will be your total earnings in Stage One**, which will be added to your final earnings from this experiment when the experiment is completed. Then you will be shown on your screen **your earnings and the implementation status** of your group project in each period in Stage One as well as the two periods that are selected. Since you do not know which periods are going to be selected, **the best strategy is to take each period equally important.**

Stage Two

In Stage Two, you are going to play the same game as you've played in Stage One for another 20 periods with only one change: Now the **profitability coefficient P = 2.4**. The group composition remains unchanged. Therefore, your earning in each period in Stage Two becomes:

- If $X_{Total} \geqslant K$, your earning is $(20 - X) + (X_{Total} \times 2.4 \div 3)$.
- If $X_{Total} < K$, your earning is $(20 - X)$.

For example, suppose that you invest 10 ECUs in the project (so $X = 10$), and the total investments in the project by all your group members including you are 30 ECUs (so $X_{Total} = 30$). If $K = 24$, then the project will be successfully implemented because $X_{Total} > K$ (as $30 > 24$), and your earning is $(20–10) + (30 \times 2.4 \div 3) = 34$ (ECUs). If $K = 36$, then the project will not be successfully implemented because now $X_{Total} < K$, and your earning in this period is $(20–10) = 10$ (ECUs).

The same as in Stage One, **only the same selected member in Stage One** will be informed of the value of K at the beginning of each period in Stage Two. He/she also needs to **send a message about the value of K to the rest of the group.** After the message is received, all members in your group needs to make an investment decision X (how much you would like to invest in the group project).

There are a few test questions before Stage Two actually starts. You have to answer all of them correctly in order to proceed. Please bear in mind that **the only difference of Stage Two from Stage One is the profitability coefficient P which equals 2.4 now.**

At the end of the experiment (after Stage Three), **two out of 20 periods** in this stage will be randomly selected and **the sum of your earnings in these periods will be your total earnings in Stage Two**, which will be added to your final earnings from this experiment when the experiment is completed. Then you will be shown on your screen **your earnings and the implementation status** of your group project in each period in Stage Two as well as the two periods that are selected. Since you do not know which periods are going to be selected, **the best strategy is to take each period equally important.**

Stage Three

In Stage Three, you will be asked to make a series of choices. How much you receive will depend partly on chance and partly on your own choices. The decision problems are not designed to test you. What we want to know is **what choices you would make** in them. The only right answer is what you really would choose.

For each of the ten lines in the table on the computer screen, please state whether you prefer **Option L** or **Option R**. Table 1 below is an example of what you will see on your computer screen later on. **Option L** gives you a sure amount of 20 ECUs, while **Option R** gives you either 40 ECUs or nothing with different chances in different lines. Take Line 1 as an example, **Option R** gives you 40 ECUs with 10% chance, and nothing with 90% chance, while **Option L** gives you 20 ECUs for sure.

In Line 1, if you think 10% chance of getting 40 ECUs is better than getting 20 ECUs for sure, then you would choose **Option R**. If not, you would choose **Option L**. Notably, as you go down the table from Line 1 to Line 10, the value of **Option L** keeps constant, while the average value of **Option R** increases as the chance of getting 40 ECUs increases. In particular, **Option R** in Line 10 gives you 40 ECUs with 100% chance.

Table C.1: Option Task

Line	Option L (ECUs)	Option R (ECUs)	Your Choice
1	20	(40 with 10% chance, 0 with 90% chance)	
2	20	(40 with 20% chance, 0 with 80% chance)	
3	20	(40 with 30% chance, 0 with 70% chance)	
4	20	(40 with 40% chance, 0 with 60% chance)	
5	20	(40 with 50% chance, 0 with 50% chance)	
6	20	(40 with 60% chance, 0 with 40% chance)	
7	20	(40 with 70% chance, 0 with 30% chance)	
8	20	(40 with 80% chance, 0 with 20% chance)	
9	20	(40 with 90% chance, 0 with 10% chance)	
10	20	(40 with 100% chance, 0 with 0% chance)	

Notice that there are a total of ten lines in the table but **just one line** will be randomly selected for your earning. Since you do not know which line will be paid when you make your choices, **you should pay attention to the choice you make in every line.** After you have completed all your choices, the computer will randomly choose a line to be paid with equal chance of 1/10 for each line.

Your earning for the selected line depends on which option you chose: If you chose **Option L** in that line, you will receive **20 ECUs**. If you chose **Option R** in that line, you will receive **either 40 ECUs or 0** with the **chances stated in Option R**, which will be executed by a computer program.

Your earning in Stage Three will be added to your final earnings from this experiment when the experiment is completed.

This is the end of the specific instructions for each stage.

Final Payoff

For your reference, your **total earnings** in this experiment would be the sum of the following parts:

1. Total earnings of **Two randomly chosen binding periods** in Stage One.
2. Total earnings of **Two randomly chosen binding periods** in Stage Two.
3. Earning in Stage Three.

Your total earnings will then be converted to S$ and added to your **show-up fee as your final payoff** in this experiment. You will be paid privately according to your unique subject ID.

Thank you again for your participation! If you have any questions, please raise your hand and an experimenter will come to you.