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Jun-ichi Itaya, Atsue Mizushima, Kengo Kurosaka

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Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email office@cesifo.de
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Abstract

This paper investigates how the heterogenous incomes and preferences of potential donors affect the timing of contribution decisions when it is endogenously determined by contributors themselves. More specifically, we use a simple setting with two donors, Cobb-Douglas preferences, and complete information to investigate how income inequality affects the endogenous choices of contribution timing and the level of the voluntary supplied public goods. This paper obtains the following results. First, when income is extremely unequal, potential contributors are indifferent between the timing choices of simultaneous and sequential moves, even if they have different preferences towards a public good. Second, as income inequality decreases, the simultaneous move-game is increasingly likely to emerge, because all potential contributors prefer to act as a leader. Third, in the presence of multiple public goods, contributors with higher valuations for one public good tend to be first contributors to that one. Fourth, these theoretical predictions regarding the timing decisions of individuals are not supported by the laboratory experiment, although those regarding individuals' contribution decisions are consistent with the experimental results.

JEL-Codes: D310, H410, H420.

Keywords: Nash equilibrium, Stackelberg equilibrium, public good, endogenous timing, voluntary provision, income distribution.

*Jun-ichi Itaya**
Graduate School of Economics
Hokkaido University, N9W7 Kita-ku, Sapporo
Japan – Hokkaido 060-0809
itaya@econ.hokudai.ac.jp

Atsue Mizushima
Faculty of Economics
Otaru University of Commerce
3-5-21 Midori, Otaru
Japan – Hokkaido, 047-8501
mizushima@res.otaru-uc.ac.jp

Kengo Kurosaka
Hokkaido Musashi Women's Junior College
N22 W13 Kita-ku, Sapporo
Japan – Hokkaido, 001-0022
kurosaka@hmjc.ac.jp

*corresponding author

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1 Introduction

This paper investigates how the heterogenous incomes and preferences of potential donors affect the timing and level of contribution decisions to public goods when the timing of contributions is endogenously determined by contributors themselves. This question is very important from a policy perspective because sequential moves in contribution games have a detrimental effect on the total supply of public goods, as found by Varian (1994). He shows that in a sequential contribution game where each individual contributes after observing the previous contributions, *in an exogenously fixed order of moves*, in a two-agent, quasi-linear preferences model, the individuals with higher valuations move first and contribute zero, while the lower-valuation individuals subsequently contribute their individually optimal levels so that the total contribution to a public good is less than if the individuals were to make their contributions *simultaneously*. Andreoni et al. (2002) experimentally confirm the comparative statics prediction of Varian (1994) that the total contribution is larger in the simultaneous than in the sequential game, and they find that players contribute almost-equal amounts, in contrast to Varian's extreme theoretical prediction that one player would free ride completely off the other. The absence of a substantial first-mover advantage is explained by the second mover's unwillingness to contribute unless the first-mover does so as well. Gachter et al. (2010) extend the experimental analysis of Andreoni et al. (2002) by considering more extreme sets of parameters. They not only confirm the findings of Andreoni et al. (2002), but also explain that when first movers free-ride, second movers often punish them by contributing less than their best response. Because these experimental studies indicate that there is no advantage in pre-committing to be a free-rider, it is unclear whether contributors will actually or voluntarily choose to commit (i.e., a sequential play) even if they are given the opportunity.

To answer this question, this study analyzes *endogenous* timing in the private provision model of public goods. Several theoretical and experimental papers study voluntary contributions of a public good in the setting of endogenous timing choices. Bliss and Nalebuff (1984) are the first to investigate the endogenous timing decisions of voluntary contributions and show that in a "wars of attrition" game, where the costs of providing a public good are *heterogenous* and there is an equilibrium in private information for each individual, in which individuals choose a waiting time that is positively related to their costs, so that the lowest-cost individual supplies the public good first. Romano and Yildirim (2001) introduce warm-glow and snob effects in the utility function of donors in the sequential contribution game of Varian (1994). Hence, each donor not only cares about the total provision of the public good, but also the individual contribution levels of other donors. They show that there are *three* subgame perfect equilibria in the two-stage, action-commitment game of Hamilton and Slutsky (1990) (precisely, in the first stage, players simultaneously announce which role, i.e., leading or following, they prefer and commit to their choices of contributions. After observing the profile of announcements, players decide whether to contribute according to the resulting ordering): a simultaneous-move equilibrium where both donors simultaneously contribute and two Stackelberg equilibria where the leader and follower contribute in their respective stages. Potters, Sefton, and Vesterlund (2005) examine the voluntary provision model in which some donors do not know the quality of a public good and the sequence of contributions is endogenously determined. They show that there are two perfect Bayesian equilibria of the two-stage game, one in which the informed agent contributes first, and the uninformed second mover infers the true quality of the public good and thus mimics the action of the first mover; and the other in which both simultaneously contribute. They also experimentally confirm that donors predominantly choose to contribute sequentially. Nosenzo and Sefton (2011) incorporate Fehr and Scmidt (1999)'s inequality averse preferences into the two-stage, action commitment game of Hamilton and Slutsky (1990) and reveal the possibility that both players delay their contributions. That is, the presence of inequality averse preferences considerably expands the set of equilibrium timing outcomes, and this theoretical prediction is supported in laboratory experiments.

Nevertheless, in spite of those valuable contributions, to our knowledge there is no study that identifies the exact relationship between heterogenous incomes (or heterogenous preferences) of individuals and the endogenous timing of contributions in the *conventional* private provision model of Warr (1983) and Bergstrom, Blume, and Varian (1986) under a general utility function. This neglect stems from the fact that most of the above-mentioned authors have focused exclusively on quasi-linear utility preferences, in line with Varian (1984), which yields clear-cut results but eliminates income effects. In contrast, analyzing the impacts of *heterogenous income* among donors under a general quasi-concave utility function has formed a core research agenda in the literature on the voluntary provision of public goods. Warr's (1983) *neutrality theorem* is one such example, in which, irrespective of the form of utility functions, the Nash equilibrium provision level of a pure public good remains invariant to redistributions of income among an unchanged set of contributors. This theorem indicates that as income inequality is increased, wealthier individuals are anticipated to share disproportionately increasing burden for providing public goods and thus poorer individuals enjoy a free-ride. In fact, Konrad (1994) points out that there is a strategic advantage to being poor in a two-stage game, that is, poor individuals have strategic commitment incentives to spend more of their income on private consumption in earlier periods, they would have grounds for relying wealthier individuals to provide public goods in the future. Nevertheless, since endogenous timing choices of contributions are beyond the scope of Konrad (1994), this study would be considered as complementary to his study,

Against this background, our game departs from the above-mentioned literature in that we focus on a two-stage contribution game with *Cobb-Douglas preferences* rather than quasi-linear or linear preferences. and with heterogenous incomes across potential contributors. To maintain alignment with previous studies and endogenize the individuals' timing choices of contributions, we also use the two-stage, action commitment game of Hamilton and Slutsky (1990) and investigate how heterogenous income and preferences of potential contributors affect the choice to become a leader (or a follower) in providing public goods. These aspects of our model allow us to pinpoint the role of heterogenous incomes and preferences across individuals in determining the timing choices of contributions, assuming away other potential explanations such as reciprocity, signaling, fairness, income inequality aversion preferences, etc. We further conduct the same analysis in the model of *multiple* voluntarily supplied public goods in which individuals with heterogenous incomes and preferences may choose *different orders of moves for different public goods*. This extension serves in highlighting the role of heterogenous preferences toward *different* public goods in determining the timing choices of contributing to those public goods.

This paper presents the following theoretical and empirical results. First, when the inequality of income among individuals becomes sufficiently large, all potential contributors are indifferent between the timing choices of moving first and later in spite of their heterogenous preferences towards a single public good. Second, as the income gap is reduced, contributors with higher incomes remain indifferent toward timing choices, while those with lower incomes prefer to move first, so that the sequential contribution game in which a higher-income individual acts as a follower may emerge. A more equal distribution of income increases the likelihood that the simultaneous-move game emerges because they are more alike and thus have similar incentives to enjoy a first-mover advantage and thus both high- and low-income individuals prefer to move first in the timing game. Third, in the presence of *multiple* public goods, the higher-valuation contributors for a particular public good may well prefer to act as a follower. Hence, the findings obtained in the model of a single public good may not apply.

Experimental results suggest that a narrower income gap does not necessarily result in simultaneous-move games in which all participants prefer to act as a leader. Instead, they prefer to act as a leader when they are relatively low-income, while they also prefer to act as a follower when they are relatively high-income, which is not consistent with the above theoretical predictions. We also explore several possible reasons for this observed behavior, and we infer that the participants' timing choices may depend on their risk attitude toward "strategic uncertainty" regarding the opponent's timing decisions.

The present paper is organized as follows. Section 2 presents a single public-good model with Cobb-Douglas preferences coupled with endogenous timing choices of individuals. Section 3 investigates how the distribution of income between two individuals affects the timing choices of their contributions. In Section 4, we investigate a contribution game in which individuals simultaneously contribute to multiple public goods. Section 5 presents the experimental design. Section 6 concludes with a brief discussion on possible extensions of the present model.

2 The model

In the model, we consider two individuals indexed by $i = 1, 2$ (we could easily extend the present model to the one with an arbitrary number of *heterogenous* individuals). Each individual divides income between private consumption, c_i, and contributions, g_i, toward the public good, G. The preferences of individual i are given by $u^i(x_i, G)$ for $i = 1, 2$. Individuals are assumed to make contributions $g_i \geq 0$, voluntarily and noncooperatively. Individual i's budget constraint is expressed by

$$x_i + g_i = m_i, \quad i = 1, 2, \tag{1}$$

where m_i is the exogenously given income (or wealth) of individual i, and the relative price (the unit cost of production) of the public good G relative to the private (numeraire) good is fixed and normalized to one. Assuming that the two individuals have *non-identical Cobb-Douglas preferences* and *different income levels*, they will noncooperatively solve the following maximization problems in either a simultaneous-move or sequential-move game:[1]

$$\max U_1 = \ln x_1 + \beta \ln G, \quad \text{s.t. } x_1 + g_1 = \rho \text{ and } g_1 \geq 0, \text{ and} \tag{2}$$

$$\max U_2 = \ln x_2 + \delta \ln G, \quad \text{s.t. } x_2 + g_2 = 1 - \rho \text{ and } g_2 \geq 0, \tag{3}$$

where $G \equiv g_1 + g_2$, and the parameters $\beta \in (0,1)$ and $\delta \in (0,1)$ represent the weights on the public good toward which individuals 1 and 2, respectively, place. We set $m_1 = \rho$ and $m_2 = 1 - \rho$ to highlight the effect of varying income distribution between the two individuals. It is important to note that the solution for this game depends on the choice of timing made by the respective individuals and the income distribution. Indeed, we consider the *endogenous* timing-choice model in the subsequent sections. For simplicity, we further assume

- **Assumption 1: (i)** $1 < \beta(1+\delta)$ and **(ii)** $\beta > \delta$.

Assumption 1 implies that individual 1 prefers the public good G more so than individual 2.

2.1 The structure of the game

The present contribution game consists of two stages. The two individuals simultaneously determine their timings for the choices of contributions in stage 1. Hence, the strategy set for each individual in stage 1 is given by $\{L, F\}$, where L (F) denotes individual i acts as a leader (follower). If the announced timings match (i.e., either the strategy profile (L, L) or (F, F) is announced), a simultaneous-move contribution game between the two individuals is played in stage 2. Alternatively, a sequential-move game is played in stage 2 if their announced

[1] When an individual has CES preferences, the realized Nash equilibrium allocation is the same as that of log-linear preferences. See Appendix A for further details.

timings differ (i.e., either the strategy profile (L, F) or (F, L) is announced). In stage 2, each individual contributes to a single public good *before or after* the other player. The structure of the two-stage contribution game is summarized as follows:

- **stage 1**: Each individual decides the timing of her contribution.
- **stage 2**: Each individual chooses her optimal contribution to the public good **simultaneously**, or **after the other individual** in stage 2, according to the timing chosen in stage 1.

Their announced timings must be *credibly committed*. In other words, in each stage game, the two potential contributors find it in their own best interests to select contribution strategies according to their announcement, which should constitute a subgame perfect Nash equilibrium of the two-stage game.

2.2 Equilibrium

To find a subgame perfect equilibrium (i.e., a backward induction solution), we first solve the stage 2's problem of identifying optimal contributions according to the predetermined timing decisions.

2.3 Simultaneous contribution

We first consider a case where all individuals make contributions to the single public good G *simultaneously* in stage 2. Solving this problem, the following first-order conditions are derived:

$$\frac{x_1\beta}{G} \leq 1 \qquad \text{with equality if } \ g_1 > 0,$$
$$\frac{x_2\delta}{G} \leq 1 \qquad \text{with equality if } \ g_2 > 0.$$

Elementary manipulations reveal that the resulting allocation in a Nash equilibrium would fall into one of the following three patterns depending on the distribution of income between the two individuals. Table 1 summarizes the results:

Income distribution	x_1	x_2	g_1	g_2	G
$0 \leq \rho \leq \frac{\delta}{\beta(1+\delta)+\delta}$	ρ	$\frac{1-\rho}{1+\delta}$	0	$\frac{\delta(1-\rho)}{1+\delta}$	$\frac{\delta(1-\rho)}{1+\delta}$
$\frac{\delta}{\beta(1+\delta)+\delta} \leq \rho \leq \frac{\delta(1+\beta)}{\beta(1+\delta)+\delta}$	$\frac{\delta}{\beta(1+\delta)+\delta}$	$\frac{\beta}{\beta(1+\delta)+\delta}$	$\rho - \frac{\delta}{\beta(1+\delta)+\delta}$	$\frac{\delta(1+\beta)}{\beta(1+\delta)+\delta} - \rho$	$\frac{\beta\delta}{\beta(1+\delta)+\delta}$
$\frac{\delta(1+\beta)}{\beta(1+\delta)+\delta} \leq \rho \leq 1$	$\frac{\rho}{1+\beta}$	$1-\rho$	$\frac{\beta\rho}{1+\beta}$	0	$\frac{\beta\rho}{1+\beta}$

Table 1. The profile of equilibrium allocation in the simultaneous move game.

2.4 Sequential contribution

Next, we examine a case where each individual contributes to the public good G *sequentially* in stage 2. There are two possibilities, namely individual 1 contributes *before* 2 in stage 2, and vice versa.

(i) Individual 1 contributes before 2 in stage 2

First, we consider a case where individual 1 contributes to the public good *before* 2 in stage 2. Given this predetermined order of moves, individual 1 must take the best-reaction function of individual 2 into account when choosing her optimal contribution level:

$$U_1 = \ln(\rho - g_1) + \beta \ln(g_1 + \max\{R^2(g_1; 1-\rho), 0\}), \tag{4}$$

where $R^2(g_1; 1-\rho)$ represents the best-reaction function of individual 2 and is given by

$$R^2(g_1; 1-\rho) = \begin{cases} \frac{\delta(1-\rho)-g_1}{1+\delta}, & \text{if } \delta(1-\rho) \geq g_1, \\ 0, & \text{if } \delta(1-\rho) \leq g_1. \end{cases} \tag{5}$$

When $\delta(1-\rho) \geq g_1$, after substitution of the first equation in (5) into g^2 (i.e., $R^2(g_1; 1-\rho)$) in (4), maximizing the resultant utility function with respect to g_1 leads to

$$g_1 = \begin{cases} \rho - \frac{1}{1+\beta}, & \text{if } \rho \geq \frac{1}{1+\beta}, \\ 0, & \text{if } \rho \leq \frac{1}{1+\beta}. \end{cases} \tag{6}$$

When $\delta(1-\rho) \leq g_1$, on the other hand, after substitution of $g^2 = 0$ into (4), maximizing the resultant utility function with respect to g_1 yields

$$g_1 = \frac{\beta}{1+\beta}\rho. \tag{7}$$

By substituting (6) and (7) into (5) we obtain, respectively, the corresponding optimal contributions below g_2. To sum up,

$$g_1 = \begin{cases} 0, & \text{if } 0 \leq \rho \leq \frac{1}{1+\beta}, \\ \rho - \frac{1}{1+\beta}, & \text{if } \frac{1}{1+\beta} \leq \rho \leq \frac{1+\delta(1+\beta)}{(1+\delta)(1+\beta)}, \\ \frac{\beta}{1+\beta}\rho, & \text{if } \frac{1+\delta(1+\beta)}{(1+\delta)(1+\beta)} \leq \rho \leq 1, \end{cases} \tag{8}$$

and

$$g_2 = \begin{cases} \frac{\delta(1-\rho)}{1+\delta}, & \text{if } 0 \leq \rho \leq \frac{1}{1+\beta}, \\ \frac{1+\delta(1+\beta)}{(1+\delta)(1+\beta)} - \rho, & \text{if } \frac{1}{1+\beta} \leq \rho \leq \frac{1+\delta(1+\beta)}{(1+\delta)(1+\beta)}, \\ 0, & \text{if } \frac{1+\delta(1+\beta)}{(1+\delta)(1+\beta)} \leq \rho \leq 1. \end{cases} \tag{9}$$

Combining (8) and (9) together with (1) yields each individual's private consumption and voluntary contribution, as well as the total provision of the public good G, depending on income distribution. The results are summarized in Table 2:

Income distribution	x_1	x_2	g_1	g_2	G
$0 \leq \rho \leq \frac{1}{1+\beta}$	ρ	$\frac{1-\rho}{1+\delta}$	0	$\frac{\delta(1-\rho)}{1+\delta}$	$\frac{\delta(1-\rho)}{1+\delta}$
$\frac{1}{1+\beta} \leq \rho \leq \frac{1+\delta(1+\beta)}{(1+\delta)(1+\beta)}$	$\frac{1}{1+\beta}$	$\frac{\beta}{(1+\delta)(1+\beta)}$	$\rho - \frac{1}{1+\beta}$	$\frac{\delta(1+\beta)+1}{(1+\delta)(1+\beta)} - \rho$	$\frac{\beta\delta}{(1+\delta)(1+\beta)}$
$\frac{1+\delta(1+\beta)}{(1+\delta)(1+\beta)} \leq \rho \leq 1$	$\frac{\rho}{1+\beta}$	$1-\rho$	$\frac{\beta\rho}{1+\beta}$	0	$\frac{\beta\rho}{1+\beta}$

Table 2. The profile of equilibrium allocation when individual 1 acts as a leader while 2 a follower.

(ii) Individual 1 contributes after 2 in stage 2

On the contrary, let us assume that individual 2 contributes to the public good *before* 1 in stage 2. Following the same procedure as in case (i), we have

$$g_1 = \begin{cases} 0, & \text{if } 0 \leq \rho \leq \frac{\delta}{(1+\beta)(1+\beta)}, \\ \rho - \frac{\delta}{(1+\beta)(1+\delta)}, & \text{if } \frac{\delta}{(1+\beta)(1+\ \delta)} \leq \rho \leq \frac{\delta}{1+\delta}, \\ \frac{\beta}{1+\beta}\rho, & \text{if } \frac{\delta}{1+\beta} \leq \rho \leq 1, \end{cases}$$

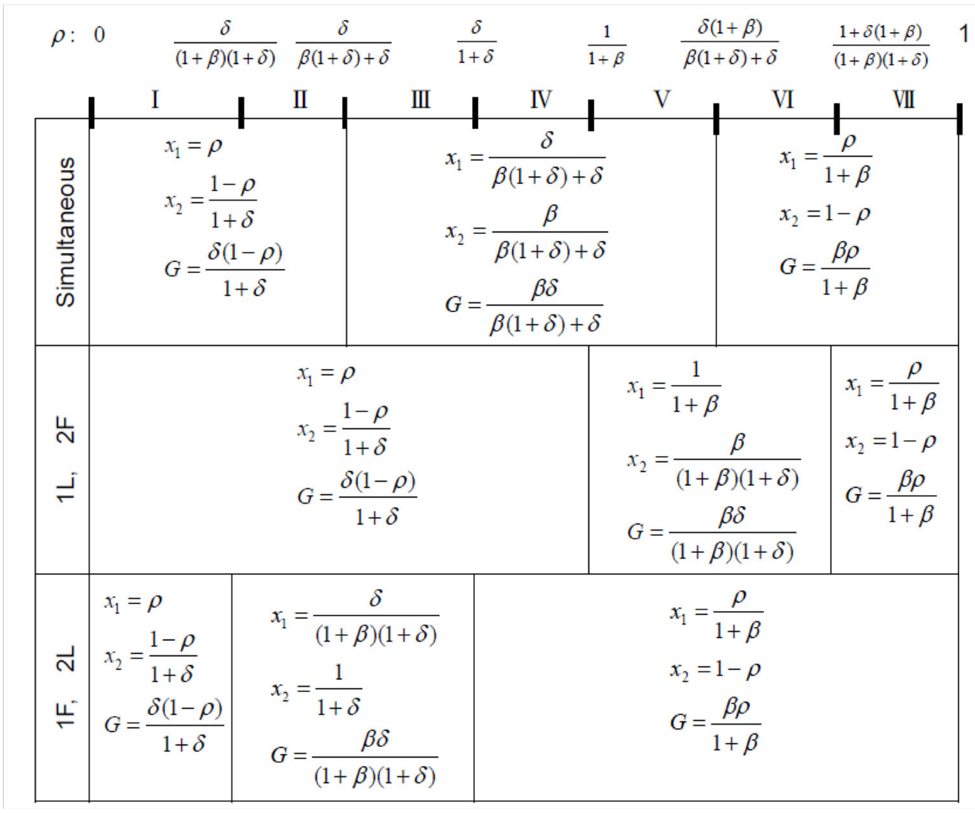

Figure 1: Income distribution and equilibrium allocation, where the expression $1L$ represents a case in which individual 1 acts as a leader, and so on.

and

$$g_2 = \begin{cases} \frac{\delta}{1+\delta}(1-\rho), & \text{if } 0 \leq \rho \leq \frac{\delta}{(1+\beta)(1+\beta)}, \\ \frac{\delta}{1+\delta} - \rho & \text{if } \frac{\delta}{(1+\beta)(1+\delta)} \leq \rho \leq \frac{\delta}{1+\delta}, \\ 0, & \text{if } \frac{\delta}{1+\beta} \leq \rho \leq 1. \end{cases}$$

Table 3 summarizes the resulting equilibrium allocations:

Income distribution	x_1	x_2	g_1	g_2	G
$0 \leq \rho \leq \frac{\delta}{(1+\delta)(1+\beta)}$	ρ	$\frac{1-\rho}{1+\delta}$	0	$\frac{\delta(1-\rho)}{1+\delta}$	$\frac{\delta(1-\rho)}{1+\delta}$
$\frac{\delta}{(1+\delta)(1+\beta)} \leq \rho \leq \frac{\delta}{1+\delta}$	$\frac{\delta}{(1+\delta)(1+\beta)}$	$\frac{1}{1+\delta}$	$\rho - \frac{\delta}{(1+\delta)(1+\beta)}$	$\frac{\delta}{(1+\delta)} - \rho$	$\frac{\beta\delta}{(1+\delta)(1+\beta)}$
$\frac{\delta}{1+\delta} \leq \rho \leq 1$	$\frac{\rho}{1+\beta}$	$1-\rho$	$\frac{\beta\rho}{1+\beta}$	0	$\frac{\beta\rho}{1+\beta}$

Table 3. The profile of equilibrium allocation when 1 acts as a follower, while 2 a leader.

3 Income distribution and endogenous timing

In Section 2, we have solved the utility maximization problem in stage 2 to derive each individual's optimal contribution and private consumption, *given the predetermined timing of* *contributions*. The results summarized in Tables 1, 2, and 3 clearly show how the equilibrium allocations of public goods and private consumption are affected by the distribution of income. With these results, we identify Nash equilibria in the timing games of stage 1 associated with varying distributions of income. For ease of comparison, we integrate Tables 1, 2, and 3 into Figure 1, which displays how the range of income distribution between the two individuals is segmented into *seven* regions over the interval $[0, 1]$ corresponding to the different timings chosen by individuals. In each region, we calculate the payoffs associated with the chosen timings. More precisely, when both contributors choose to be a leader (or a follower), the resulting game is simultaneous, so the payoffs to the respective individuals (=utilities (2) and (3)) can be calculated from the corresponding allocations in Table 1. (See the first row of Figure 1.) In contrast, when the individuals choose different timings, the resulting game is sequential, and the payoffs can be calculated from the corresponding allocations in Tables 2 and 3. (See also the second and third rows of Figure 1.)

(i) Region I : $0 \leq \rho \leq \frac{\delta}{(1+\beta)(1+\delta)}$

The payoff matrix for this timing game is given by:

Individual 1 (extremely poor)		Individual 2 (extremely rich)	
		L	F
	L	$V_1^*,\ V_2^*$	$V_1^*,\ V_2^*$
	F	$V_1^*,\ V_2^*$	$V_1^*,\ V_2^*$

,

where $V_1 \equiv \ln \rho + \beta \ln \frac{\delta(1-\rho)}{1+\delta}$ and $V_2 \equiv \ln \frac{1-\rho}{1+\delta} + \delta \ln \frac{\delta(1-\rho)}{1+\delta}$. The first (second) entry of payoff cells denotes the payoff to individual 1 (2). The above table indicates that *all strategy profiles constitute Nash equilibria* whose pairs of payoffs are marketed with the symbol *, because the pairs of payoffs in all cells of the above matrix are the same.

Since the income gap between the individuals is sufficiently large, the extremely low-income individual (i.e., individual 1) always *stops* contributing to the public good due to too little income *irrespective of her chosen timing of contribution*, and thus the extremely high-income (individual 2) always is a sole provider of the public good. Hence, individual 2 ends up choosing her *standalone* contribution level (=the total provision) to maximize her own utility, which in turn yields that individual's contribution level and the same level of private consumption, *irrespective of the timing choices of any individuals* (see Region I in Figure 1). As a result, the payoffs appearing in all cells of the payoff matrix become *identical*, implying that all strategy profiles are Nash equilibria.

(ii) Region II : $\frac{\delta}{(1+\beta)(1+\delta)} \leq \rho \leq \frac{\delta}{\beta(1+\delta)+\delta}$

The payoff matrix for this game is given by:

Individual 1 (relatively poor)		Individual 2 (relatively wealthy)	
		L	F
	L	$V_1^*,\ V_2^*$	$V_1^*,\ V_2^*$
	F	W_1, W_2	$V_1,\ V_2$

,

where $W_1 \equiv \ln \frac{\delta}{(1+\beta)(1+\delta)} + \beta \ln \frac{\beta\delta}{(1+\beta)(1+\delta)}$ and $W_2 \equiv \ln \frac{1}{1+\delta} + \delta \ln \frac{\beta\delta}{(1+\beta)(1+\delta)}$.

Lemma 1 *$V_1 > W_1$ and $W_2 > V_2$ for $\rho \in \left[\frac{\delta}{(1+\beta)(1+\delta)}, \frac{\delta}{\beta(1+\delta)+\delta}\right]$.*

Proof. Define $F(\rho) \equiv V_1 - W_1 = \left(\ln \rho + \beta \ln \frac{\delta(1-\rho)}{1+\delta}\right) - \left(\ln \frac{\delta}{(1+\beta)(1+\delta)} + \beta \ln \frac{\beta\delta}{(1+\beta)(1+\delta)}\right) = \ln \rho - \ln \frac{\delta}{(1+\beta)(1+\delta)} + \beta \left(\ln \frac{\delta(1-\rho)}{1+\delta} - \ln \frac{\beta\delta}{(1+\beta)(1+\delta)}\right)$. Because $\frac{\partial F(\rho)}{\partial \rho} = \frac{1}{\rho} - \frac{\beta}{1-\rho} > 0$ due to $\rho \leq \frac{\delta}{\beta(1+\delta)+\delta} < \frac{1}{1+\beta}$ (i.e., $F(\rho)$ is an increasing function of ρ) and because $F\left(\frac{\delta}{(1+\beta)(1+\delta)}\right) = \beta \ln \frac{1+\beta(1+\delta)}{(1+\delta)\beta} > 0$, $F(\rho) \equiv V_1 - W_1 > 0$ for all $\rho \in \left[\frac{\delta}{(1+\beta)(1+\delta)}, \frac{\delta}{\beta(1+\delta)+\delta}\right]$. Define $G(\rho) \equiv W_2 - V_2 = \left(\ln \frac{1}{1+\delta} + \delta \ln \frac{\beta\delta}{(1+\beta)(1+\delta)}\right) - \left(\ln \frac{1-\rho}{1+\delta} + \delta \ln \frac{\delta(1-\rho)}{1+\delta}\right)$. Although $\frac{\partial G(\rho)}{\partial \rho} = \frac{1}{1-\rho} + \frac{\delta}{1-\rho} > 0$, $G\left(\frac{\delta}{(1+\beta)(1+\delta)}\right) = \ln \frac{(1+\beta)(1+\delta)}{1+\beta+\beta\delta} + \delta \ln \frac{\beta(1+\delta)}{1+\beta+\beta\delta} \gtreqless 0$ because the first term is positive while the second term is negative. Nevertheless, since it can be verified that $\left|\ln \frac{(1+\beta)(1+\delta)}{1+\beta+\beta\delta}\right| > \left|\ln \frac{\beta(1+\delta)}{1+\beta+\beta\delta}\right| > \delta \left|\ln \frac{\beta(1+\delta)}{1+\beta+\beta\delta}\right|$, we obtain $G(\frac{\delta}{(1+\beta)(1+\delta)}) > 0$. Taken together, $G(\rho) \equiv W_2 - V_2 > 0$ for all $\rho \in \left[\frac{\delta}{(1+\beta)(1+\delta)}, \frac{\delta}{\beta(1+\delta)+\delta}\right]$. ■

It follows from Lemma 1 and the above payoff matrix that only the strategy profiles (L, L) and (L, F) are Nash equilibria in the timing game. The relatively lower-income individual 1 always prefers to act as a leader because she can fully exploit the first-mover advantage and supply nothing; otherwise, she will provide a positive amount, which is motivated by a positive income effect on the public good, resulting in a lower well-being of individual 1. As a result, L is a **strictly dominant strategy** for 1. Anticipating 1's choice of zero supply, 2 always becomes the sole provider of the public good and thus chooses the *same* standalone contribution level *irrespective of 2's own choices of timing,* as shown in Region II of Figure 1. Hence, the higher-income individual 2 will be indifferent between the strategies L and F.

(iii) Region III : $\frac{\delta}{\beta(1+\delta)+\delta} \leq \rho \leq \frac{\delta}{1+\delta}$

The payoff matrix is given by

Individual 1		Individual 2	
		L	F
	L	$X_1^*,\ X_2^*$	$V_1,\ V_2$
	F	$W_1,\ W_2$	$X_1,\ X_2$

,

where $X_1 \equiv \ln \frac{\delta}{\beta(1+\delta)+\delta} + \beta \ln \frac{\beta\delta}{\beta(1+\delta)+\delta}$ and $X_2 \equiv \ln \frac{\beta}{\beta(1+\delta)+\delta} + \delta \ln \frac{\beta\delta}{\beta(1+\delta)+\delta}$.

Lemma 2 *$X_1 > W_1$, $X_2 > V_2$, $W_2 > X_2$, and $V_1 > X_1$ for $\rho \in \left[\frac{\delta}{\beta(1+\delta)+\delta}, \frac{\delta}{1+\delta}\right]$.*

Proof. $X_1 - W_1 = \left(\ln \frac{\delta}{\beta(1+\delta)+\delta} + \beta \ln \frac{\beta\delta}{\beta(1+\delta)+\delta}\right) - \left(\ln \frac{\delta}{(1+\beta)(1+\delta)} + \beta \ln \frac{\beta\delta}{(1+\beta)(1+\delta)}\right) = (1+\beta) \ln \frac{(1+\beta)(1+\delta)}{\beta(1+\delta)+\delta} > 0$. $X_2 - V_2 = \left(\ln \frac{\beta}{\beta(1+\delta)+\delta} + \delta \ln \frac{\beta\delta}{\beta(1+\delta)+\delta}\right) - \left(\ln \frac{1-\rho}{1+\delta} + \delta \ln \frac{\delta(1-\rho)}{1+\delta}\right) = (1+\delta) \ln \frac{\beta(1+\delta)}{(\beta(1+\delta)+\delta)(1-\rho)} > 0$ so long as $\rho > \frac{\delta}{\beta(1+\delta)+\delta}$. $W_2 - X_2 = \left(\ln \frac{1}{1+\delta} + \delta \ln \frac{\beta\delta}{(1+\beta)(1+\delta)}\right) - \left(\ln \frac{\beta}{\beta(1+\delta)+\delta} + \delta \ln \frac{\beta\delta}{\beta(1+\delta)+\delta}\right) = \underset{(+)}{\ln \frac{\beta(1+\delta)+\delta}{\beta(1+\delta)}} + \delta \underset{(-)}{\ln \frac{\beta(1+\delta)+\delta}{(1+\beta)(1+\delta)}} \gtreqless 0$. Since $\left|\ln \frac{\beta(1+\delta)+\delta}{\beta(1+\delta)}\right| > \left|\ln \frac{\beta(1+\delta)+\delta}{(1+\beta)(1+\delta)}\right| > \delta \left|\ln \frac{\beta(1+\delta)+\delta}{(1+\beta)(1+\delta)}\right|$, we have $W_2 > X_2$. Define $H(\rho) \equiv V_1 - X_1 = \left(\ln \rho + \beta \ln \frac{\delta(1-\rho)}{1+\delta}\right) - \left(\ln \frac{\delta}{\beta(1+\delta)+\delta} + \beta \ln \frac{\beta\delta}{\beta(1+\delta)}\right.$ $\ln \frac{\rho(\beta(1+\delta)+\delta)}{\delta} + \beta \ln \frac{(1-\rho)(\beta(1+\delta)+\delta)}{(1+\delta)\beta}$. Because $H(\rho)$ is decreasing in ρ as long as $\rho \leq \frac{\delta}{1+\delta} < \frac{1}{1+\beta}$ and because $H(\frac{\delta}{\beta(1+\delta)+\delta}) = \beta \ln \beta < 0$, we have $V_1 < X_1$. ■

It immediately follows from Lemma 2 and the payoff matrix that only the strategy profile $(L,\, L)$ constitutes a Nash equilibrium. In this region, since the income levels of the individuals are similar, both have the same incentive to enjoy a first-mover advantage by committing to free ride as a first mover. This is because if either of them were to be a follower, the other will free ride by contributing nothing (or less) thereby forcing the follower to make a positive amount of contribution (or to contribute more); consequently, the well-being of the follower is reduced. Hence, both players are no longer indifferent between the strategies L and F, and thus only L is a dominant strategy for them.

(iv) Region IV : $\frac{\delta}{1+\delta} \leq \rho \leq \frac{1}{1+\beta}$

The payoff matrix is given by

Individual 1		Individual 2	
		L	F
	L	$X_1^*,\, X_2^*$	$V_1,\ V_2$
	F	$Z_1,\, Z_2$	$X_1,\ X_2$

,

where $Z_1 \equiv \ln \frac{\rho}{1+\beta} + \beta \ln \frac{\beta\rho}{1+\beta}$ and $Z_2 \equiv \ln(1-\rho) + \delta \ln \frac{\beta\rho}{1+\beta}$.

Lemma 3 $X_1 > Z_1$ *and* $Z_2 > X_2$ *for* $\rho \in \left[\frac{\delta}{1+\delta}, \frac{1}{1+\beta}\right]$.

Proof. $X_1 - Z_1 = \ln \frac{\delta}{\beta(1+\delta)+\delta} + \beta \ln \frac{\beta\delta}{\beta(1+\delta)+\delta} - \left(\ln \frac{\rho}{1+\beta} + \beta \ln \frac{\beta\rho}{1+\beta}\right) = (1+\beta) \ln \frac{(1+\beta)\delta}{(\beta(1+\delta)+\delta)\rho} > 0$ so long as $\rho \left(\leq \frac{1}{1+\beta}\right) < \frac{(1+\beta)\delta}{\beta(1+\delta)+\delta}$. Define $R(\rho) \equiv Z_2 - X_2 = \ln(1-\rho) + \delta \ln \frac{\beta\rho}{1+\beta} - \left(\ln \frac{\beta}{\beta(1+\delta)+\delta} + \delta \ln \frac{\beta\delta}{\beta(1+\delta)+\delta}\right) = \ln \frac{(\beta(1+\delta)+\delta)(1-\rho)}{\beta} + \delta \ln \frac{(\beta(1+\delta)+\delta)\rho}{(1+\beta)\delta}$. $R'(\rho) = \frac{-1}{1-\rho} + \frac{\delta}{\rho} < 0$ for $\rho \in \left[\frac{\delta}{1+\delta}, \frac{1}{1+\beta}\right]$. $R(\frac{1}{1+\beta}) = \ln \frac{\beta(1+\delta)+\delta}{(1+\beta)} + \delta \ln \frac{\beta(1+\delta)+\delta}{(1+\beta)^2\delta} > 0$, because $\left|\ln \frac{\beta+\delta+\beta\delta}{1+\beta}\right| > \left|\ln \frac{\beta+\delta+\beta\delta}{(1+\beta)^2\delta}\right| > \delta \left|\ln \frac{\beta+\delta+\beta\delta}{(1+\beta)^2\delta}\right|$ due to $(1+\beta)\delta > 1$ (i.e., **Assumption 1**). Taken together, $R(\rho) \equiv Z_2 - X_2 > 0$ is obtained. ■

Lemma 3, together with the above payoff matrix, implies that only the strategy profile $(L,\, L)$ constitutes a Nash equilibrium in this timing game. For the same reason stated for

Region III, both individuals have the same incentive to enjoy first mover advantage (see Region IV in Figure 1). Hence, only L is a dominant strategy for both individuals. As a result, a simultaneous-move game emerges.

(v) Region V : $\frac{1}{1+\beta} \leq \rho \leq \frac{\delta(1+\beta)}{\beta(1+\delta)+\delta}$

The payoff matrix for this game is represented by

Individual 1		Individual 2	
		L	F
	L	$X_1^*,\ X_2^*$	Y_1, Y_2
	F	$Z_1,\ Z_2$	$X_1,\ X_2$

,

where $Y_1 \equiv \ln\frac{1}{1+\beta} + \beta\ln\frac{\beta\delta}{(1+\delta)(1+\beta)}$ and $Y_2 \equiv \ln\frac{\beta}{(1+\delta)(1+\beta)} + \delta\ln\frac{\beta\delta}{(1+\delta)(1+\beta)}$.

Lemma 4 *$Y_1 > X_1$, $X_2 > Y_2$, and $V_1 > X_1$ $\rho \in \left[\frac{1}{1+\beta}, \frac{\delta(1+\beta)}{\beta(1+\delta)+\delta}\right]$.*

Proof. $Y_1 - X_1 = \ln\frac{1}{1+\beta} + \beta\ln\frac{\beta\delta}{(1+\delta)(1+\beta)} - \left(\ln\frac{\delta}{\beta(1+\delta)+\delta} + \beta\ln\frac{\beta\delta}{\beta(1+\delta)+\delta}\right) = \ln\frac{\beta(1+\delta)+\delta}{(1+\beta)\delta} + \beta\ln\frac{\beta(1+\delta)+\delta}{(1+\beta)(1+\delta)}$. Since $\left|\ln\frac{\beta(1+\delta)+\delta}{(1+\beta)\delta}\right| | > \left|\ln\frac{\beta(1+\delta)+\delta}{(1+\beta)(1+\delta)}\right| > \beta\left|\ln\frac{\beta(1+\delta)+\delta}{(1+\beta)(1+\delta)}\right|$, we have $Y_1 > X_1$. $X_2 - Y_2 = \ln\frac{\beta}{\beta(1+\delta)+\delta} + \delta\ln\frac{\beta\delta}{\beta(1+\delta)+\delta} - \left(\ln\frac{\beta}{(1+\delta)(1+\beta)} + \delta\ln\frac{\beta\delta}{(1+\delta)(1+\beta)}\right) = (1+\delta)\ln\frac{(1+\beta)(1+\delta)}{\beta(1+\delta)+\delta} > 0$. ■

Lemma 4, together with the payoff matrix, implies that only the strategy profile (L, L) constitutes a Nash equilibrium. In Region V, although the income levels are reversed, they are close enough to have the same incentive to enjoy the first-mover advantage as in Regions III and IV. Consequently, their dominant strategy is L.

(vi) Region VI :$\frac{\delta(1+\beta)}{\beta(1+\delta)+\delta} \leq \rho \leq \frac{1+\delta(1+\beta)}{(1+\beta)(1+\delta)}$

The payoff matrix for this game is given by the following table:

Individual 1 (relatively rich)		Individual 2 (relatively rich)	
		L	F
	L	$Z_1^*,\ Z_2^*$	Y_1, Y_2
	F	$Z_1^*,\ Z_2^*$	$Z_1,\ Z_2$

.

Lemma 5 *$Y_1 > Z_1$ and $Z_2 > Y_2$ for* $\rho \in \left[\frac{\delta(1+\beta)}{\beta(1+\delta)+\delta}, \frac{1+\delta(1+\beta)}{(1+\beta)(1+\delta)}\right]$.

Proof. $Y_1 - Z_1 = \ln\frac{1}{1+\beta} + \beta\ln\frac{\beta\delta}{(1+\delta)(1+\beta)} - (\ln\frac{\rho}{1+\beta} + \beta\ln\frac{\beta\rho}{1+\beta}) = \ln\frac{1}{\rho} + \delta\ln\frac{\delta}{(1+\delta)\rho} < 0$. Define $Q(\rho) \equiv Z_2 - Y_2 = \ln(1-\rho) + \delta\ln\frac{\beta\rho}{1+\beta} - \left[\ln\frac{\beta}{(1+\delta)(1+\beta)} + \delta\ln\frac{\beta\delta}{(1+\delta)(1+\beta)}\right] = \ln\frac{(1-\rho)(1+\delta)(1+\beta)}{\beta} + \delta\ln\frac{\rho(1+\delta)}{\delta}$, $\frac{\partial Q(\rho)}{\partial\rho} = \frac{-1}{1-\rho} + \frac{\delta}{\rho} < 0$ as long as $\rho \geq \frac{\delta(1+\beta)}{\beta(1+\delta)+\delta} > \frac{\delta}{1+\delta}$. $Q\left(\frac{1+\delta(1+\beta)}{(1+\beta)(1+\delta)}\right) = \delta\ln\frac{1+\delta(1+\beta)}{(1+\beta)\delta} > 0$. Taken together, $Q(\rho) = Z_2 - Y_2 > 0$ for all $\rho \in \left[\frac{\delta(1+\beta)}{\beta(1+\delta)+\delta}, \frac{1+\delta(1+\beta)}{(1+\beta)(1+\delta)}\right]$. ■

Lemma 5, together with the payoff matrix, implies that the strategy profiles (L, L) and (F, L) constitute Nash equilibria. The Nash equilibrium profiles emerge symmetrically as those in the case of Region II. The same economic reasoning as in Region II applies here except that individual 2 acts a leader and 1 is indifferent between the strategies L and F.

(vii) Region VII : $\frac{1+\delta(1+\beta)}{(1+\beta)(1+\delta)} \leq \rho \leq 1$

The payoff matrix for this game is given as follows:

		Individual 2 (extremely wealthy)	
Individual 1 (extremely wealthy)		L	F
	L	$Z_1^*,\ Z_2^*$	$Z_1^*,\ Z_2^*$
	F	$Z_1^*,\ Z_2^*$	$Z_1^*,\ Z_2^*$

This game corresponds to the one opposite to Region I with the income levels of the two individuals being reversed. Hence, all strategy profiles are Nash equilibria of the timing game, so that either a simultaneous- or sequential-move game emerges.

To summarize, we have

Proposition 1 *Consider a two-person economy where individuals have different Cobb-Douglas preferences and different income levels:*

(i) When the income inequality is extremely wide, only the wealthier individual contributes to a public good, and both individuals are indifferent between timing choices. Hence, either a sequential- or simultaneous-move game emerges.

(ii) When the income inequality is reduced to a moderate extent, the poorer individual prefers to act as a leader, while the wealthier individual is indifferent between earlier and later moves. Hence, either a sequential- or simultaneous-move game emerges..

(iii) When the wealth levels of the two individuals are similar or equal, both prefer to act as a leader. Hence, only the simultaneous-move game emerges.

It follows from Figure 1 and Proposition 1 that three remarks are in order. First, we need to distinguish two causes for free-riding behavior. The first is that the marginal rate of substitution between private and public goods is *less* than the marginal cost of the public good for an extremely low-income individual, while the second is the strategic incentive to enjoy a first-mover advantage.[2] The first cause is emphasized by the standard literature such as Bergstrom, Blume, and Varian (1986) in which free riding is caused by the suboptimality of a Nash equilibrium arising from ignorance (or underestimation) of the beneficial externality accrued to all other individuals (which may be called "a *static* free-riding behavior"), while for the second cause, stressed by Varian (1994), a first mover strategically commits to contribute nothing so that this commitment forces the other individual to contribute more, which in turn improves the well-being of the first mover (which may be called "a *dynamic* free-riding behavior"). A low-income individual in Region I and II in Figure 1 contributes nothing because of the static free-riding motive, which is independent of the order of moves. Second, comparing the total provision under a simultaneous-move game with the two sequential-move

[2]The term *"free rider",* which is used rather loosely in the literature, applies to at least *three* distinct phenomena. First, it refers to the suboptimality that typically characterizes a Nash equilibrium. In this case, free-riding relates to the negative slope of the Nash reaction curve and indicates one agent's reliance on the public good provision of the other. Second, free riding relates to the failure of individuals to reveal their true preferences for public goods through their contributions. Third, it denotes the tendency for public contributions to decline as group size increases (Olson 1965). Cornes and Sandler (1996), on the other hand, claim that the term *easy riding* is more appropriate for the suboptimality associated with pure public good provision that does not entail an individual's contribution of zero, since individuals seldom free ride completely. In this paper, we additionally have introduced the fourth type of free-riding behavior suggested by Varian (1994) (i.e., a dynamic free-riding behavior).

games yields the following table:

Region	I	II	III	IV	V	VI	VII
Provision level	$G^S = G^{1L} = G^{1F}$	$G^S = G^{1L} > G^{1F}$	$G^S > G^{1L} > G^{1F}$	$G^S > G^{1L} \gtreqless G^{1F}$	$G^S > G^{1F} > G^{1F}$	$G^S = G^{1F} > G^{1L}$	$G^S = G^{1F} = G^{1L}$

,

Table 4. Comparison of total contributions

where G^S represents the total contributions in the simultaneous-move game, and G^{1L} and G^{1F}, respectively, represent the sequential-move game when 1 acts as a leader or a follower. This result is consistent with Varian (1994) in that the total contribution is larger under the simultaneous-move game than under the sequential-move game, independent of the profile of income distribution. Note that Varian's result based on quasi-linear preferences remains valid under a more general utility function which allows for the presence of an income effect.

Third, the larger the preference parameter β (δ), the narrower the range of income distribution within which individual 1 (2) free ride, as seen in Figure 1 where the boundary line $1/(1+\beta)$ moves to the left, while the boundary line $\delta/(1+\delta)$ moves to the right. As a result, the strategy profile (L, L), and thus a simultaneous-move game, are more likely to emerge for larger values of β or δ. Intuitively, as the preferences of an individual for the public good is enhanced, she prefers a larger amount of the public good. In either case, therefore, even the lower-income individual is more willing to supply a positive amount rather than supplying zero by committing to free ride.

Fourth, Varian (1964) shows that a high-valuation individual moves first, and a low-valuation individual moves later, while our model shows that a lower-income individual moves first, and a higher-income individual may well move later. Under Cobb-Douglas preferences, the lower-income individual is likely to contribute nothing due to the negative income effect coupled with the underestimation of benefits generated by the public good in a Nash equilibrium, whereas the higher income individual will be indifferent toward timing.

4 Multiple public goods

In this section, we consider the model with multiple public goods. For simplicity, we focus on the case of *two* public goods, denoted G and H. Each individual divides her income between private consumption, c_i, and contributions toward the two public goods, G and H, denoted g_i and h_i, respectively. As in the previous sections, we consider two cases where individuals either *simultaneously* or *sequentially* make contributions g_i and h_i. Two individuals with the following *non-identical* Cobb-Douglas preferences and different income levels solve the following optimization problem in either a simultaneous- or sequential-move game:[3]

$$\text{Max } U_1 = \ln x_1 + \beta_1 \ln G + \beta_2 \ln H, \quad \text{s.t. } x_1 + g_1 + h_1 = \rho, \; g_1 \geq 0, \; h_1 \geq 0, \; \text{ and}$$

$$\text{Max } U_2 = \ln x_2 + \delta_1 \ln G + \delta_2 \ln H, \quad \text{s.t. } \; x_2 + g_2 + h_2 = 1 - \rho, \; g_2 \geq 0, \; h_2 \geq 0,$$

where $G \equiv g_1 + g_2$ and $H \equiv h_1 + h_2$, and $\beta_i > 0$ and $\delta_i > 0$ represent individual i's preference towards the public goods G and H, respectively. We first solve the Nash equilibrium profile for each contribution in the simultaneous-move game and obtain the following first-order conditions:

$$\begin{aligned}
\frac{x_1\beta_1}{G} &\leq 1 \qquad \text{with equality if } \; g_1 > 0, \\
\frac{x_1\beta_2}{H} &\leq 1 \qquad \text{with equality if } \; h_1 > 0, \\
\frac{x_2\delta_1}{G} &\leq 1 \qquad \text{with equality if } \; g_2 > 0, \text{ and} \\
\frac{x_2\delta_2}{H} &\leq 1 \qquad \text{with equality if } \; h_2 > 0.
\end{aligned}$$

Each individual has four strategies for timing choices, namely, LL, LF, FL, and FF, where the first letter is the timing of the move when providing the public good G, and the second

[3] Under CES preferences, the equilibrium level is the same as that under log-linear preferences because we obtain the same first order conditions.

is the timing of the move when providing the public good H. (For example, FL implies an individual acts as a follower when providing the public good G and a leader when providing the public good H.) Unfortunately, we need to further specify parameter values of preferences and income levels of the respective individuals because of the analytical complexities. We employ a numerical analysis focusing on *five* profiles of income distribution between the two individuals, namely $\rho = 0.1$, $\rho = 0.25$, $\rho = 0.5$, $\rho = 0.75$, and $\rho = 0.9$. We further set the preference parameters of both individuals at $\beta_1 = 1.6$, $\beta_2 = 0.4$, $\delta_1 = 0.4$, and $\delta_2 = 1.6$ and then examine the payoff matrixes associated with $\rho = 0.1$, $\rho = 0.25$, $\rho = 0.5$,, $\rho = 0.75$, and $\rho = 0.9$, respectively. Note that the strategy profiles corresponding to the pairs of payoffs in bold type represent Nash equilibria in the following tables.

When $\rho = 0.1$ (individual 1 is extremely low-income relative to 2),

	LL	FF	FL	LF
LL	$\mathbf{-6.20^*, -3.15^*}$	$-5.99, -3.23$	$-5.99, -3.23$	$\mathbf{-6.20^*, -3.15^*}$
FF	$-7.22, -3.10$	$-6.20, -3.15$	$-6.39, -3.14$	$-6.39, -3.14$
FL	$-7.22, -3.10$	$-6.20, -3.15$	$-6.39, -3.14$	$-7.22, -3.10$
LF	$\mathbf{-6.20^*, -3.15^*}$	$-5.99, -3.23$	$-5.99, -3.23$	$\mathbf{-6.20^*, -3.15^*}$

Table 5. The payoff matrix when $\rho = 0.1$.

When $\rho = 0.25$ (individual 1 is moderately low-income relative to 2),

	LL	FF	FL	LF
LL	$\mathbf{-5.65^*, -3.22^*}$	$-5.44, -3.77$	$-5.48, -3.68$	$\mathbf{-5.65^*, -3.22^*}$
FF	$\mathbf{-5.65^*, -3.22^*}$	$-5.65, -3.22$	$-5.65, -3.22$	$\mathbf{-5.65^*, -3.22^*}$
FL	$\mathbf{-5.65^*, -3.22^*}$	$-5.65, -3.22$	$-5.65, -3.22$	$\mathbf{-5.65^*, -3.22^*}$
LF	$\mathbf{-5.65^*, -3.22^*}$	$-5.44, -3.77$	$-5.48, -3.68$	$\mathbf{-5.65^*, -3.22^*}$

Table 6. The payoff matrix when $\rho = 0.25$.

When $\rho = 0.5$ (the income levels of individuals 1 and 2 are equal),

	LL	FF	FL	LF
LL	$\mathbf{-4.01}^{*}, \mathbf{-4.01}^{*}$	$\mathbf{-4.01}^{*}, \mathbf{-4.01}^{*}$	$\mathbf{-4.01}^{*}, \mathbf{-4.01}^{*}$	$\mathbf{-4.01}^{*}, \mathbf{-4.01}^{*}$
FF	$\mathbf{-4.01}^{*}, \mathbf{-4.01}^{*}$	$\mathbf{-4.01}^{*}, \mathbf{-4.01}^{*}$	$\mathbf{-4.01}^{*}, \mathbf{-4.01}^{*}$	$\mathbf{-4.01}^{*}, \mathbf{-4.01}^{*}$
FL	$\mathbf{-4.01}^{*}, \mathbf{-4.01}^{*}$	$\mathbf{-4.01}^{*}, \mathbf{-4.01}^{*}$	$\mathbf{-4.01}^{*}, \mathbf{-4.01}^{*}$	$\mathbf{-4.01}^{*}, \mathbf{-4.01}^{*}$
LF	$\mathbf{-4.01}^{*}, \mathbf{-4.01}^{*}$	$\mathbf{-4.01}^{*}, \mathbf{-4.01}^{*}$	$\mathbf{-4.01}^{*}, \mathbf{-4.01}^{*}$	$\mathbf{-4.01}^{*}, \mathbf{-4.01}^{*}$

Table 7. The payoff matrix when $\rho = 0.5$

When $\rho = 0.75$ (individual 2 is moderately low-income relative to 1),

	LL	FF	FL	LF
LL	$\mathbf{-3.23}^{*}, \mathbf{-5.65}^{*}$	$\mathbf{-3.23}^{*}, \mathbf{-5.65}^{*}$	$\mathbf{-3.23}^{*}, \mathbf{-5.65}^{*}$	$\mathbf{-3.23}^{*}, \mathbf{-5.65}^{*}$
FF	$-3.78, -5.44$	$-3.23, -5.65$	$-3.78, -5.44$	$-3.23, -5.65$
FL	$\mathbf{-3.23}^{*}, \mathbf{-5.65}^{*}$	$\mathbf{-3.23}^{*}, \mathbf{-5.65}^{*}$	$\mathbf{-3.23}^{*}, \mathbf{-5.65}^{*}$	$\mathbf{-3.23}^{*}, \mathbf{-5.65}^{*}$
LF	$-3.78, -5.44$	$-3.23, -5.65$	$-3.68, -5.34$	$-3.23, -5.65$

Table 8. The payoff matrix when $\rho = 0.75$

When $\rho = 0.9$ (individual 1 is extremely high-income relative to 2),

	LL	FF	FL	LF
LL	$\mathbf{-3.15}^{*}, \mathbf{-6.20}^{*}$	$-3.10, -7.22$	$\mathbf{-3.15}^{*}, \mathbf{-6.20}^{*}$	$-3.10, -7.22$
FF	$-3.23, -5.99$	$-3.15, -6.20$	$-3.23, -5.99$	$-3.15, -6.20$
FL	$\mathbf{-3.15}^{*}, \mathbf{-6.20}^{*}$	$-3.10, -7.22$	$\mathbf{-3.15}^{*}, \mathbf{-6.20}^{*}$	$-3.10, -7.22$
LF	$-3.23, -5.99$	$-3.14, -6.38$	$-3.23, -5.99$	$-3.14, -6.38$

Table 9. The payoff matrix when $\rho = 0.9$.

Inspection of Tables 5-9 reveals two features. First, unlike the case of a single public good, the timing choices of the respective individuals display a variety of results, including: both individuals may be indifferent between the strategies L and F toward *at least* one public good even if the incomes of the two individuals are close or equal, which never occurs in the previous single public-good contribution game. Second, if an individual has stronger preferences toward a particular public good, she tends to be indifferent between the timing choices of contribution. That is, they may choose the strategy F.

More specifically, we consider how *heterogeneous* preferences across the two individuals affect their timing choices of contributions. To do this, we fix the distribution of income at $\rho = 0.5$ in the following discussion and simultaneously vary the preferences parameters of individuals 1 and 2 towards the public goods G and H, respectively. We obtain the following payoff matrixes:

	LL	FF	FL	LF
LL	$\mathbf{-3.47^*, -3.47^*}$	$-3.75, -3.91$	$-3.75, -3.81$	$\mathbf{-3.47^*, -3.47^*}$
FF	$-3.91, -3.75$	$\mathbf{-3.47^*, -3.47^*}$	$-3.91, -3.75$	$\mathbf{-3.47^*, -3.47^*}$
FL	$\mathbf{-3.47^*, -3.47^*}$	$\mathbf{-3.47^*, -3.47^*}$	$\mathbf{-3.47^*, -3.47^*}$	$\mathbf{-3.47^*, -3.47^*}$
LF	$-3.47, -3.47$	$-4.13, -3.09$	$-3.75, -3.91$	$\mathbf{-3.47^*, -3.47^*}$

Table 10. The payoff matrix when $\beta_1 = 1, \beta_2 = 0.5, \delta_1 = 0.5,$ and $\delta_2 = 1$.

	LL	FF	FL	LF
LL	$\mathbf{-4.54^*, -4.54^*}$	$\mathbf{-4.54^*, -4.54^*}$	$\mathbf{-4.54^*, -4.54^*}$	$\mathbf{-4.54^*, -4.54^*}$
FF	$\mathbf{-4.54^*, -4.54^*}$	$\mathbf{-4.54^*, -4.54^*}$	$\mathbf{-4.54^*, -4.54^*}$	$\mathbf{-4.54^*, -4.54^*}$
FL	$\mathbf{-4.54^*, -4.54^*}$	$\mathbf{-4.54^*, -4.54^*}$	$\mathbf{-4.54^*, -4.54^*}$	$\mathbf{-4.54^*, -4.54^*}$
LF	$\mathbf{-4.54^*, -4.54^*}$	$\mathbf{-4.54^*, -4.54^*}$	$\mathbf{-4.54^*, -4.54^*}$	$\mathbf{-4.54^*, -4.54^*}$

Table 11. The payoff matrix when $\beta_1 = 2, \beta_2 = 0.5, \delta_1 = 0.5,$ and $\delta_2 = 2$.

	LL	FF	FL	LF
LL	$\mathbf{-3.23^*, -5.65^*}$	$\mathbf{-3.23^*, -5.65^*}$	$\mathbf{-3.23^*, -5.65^*}$	$\mathbf{-3.23^*, -5.65^*}$
FF	$-3.78, -5.44$	$-3.23, -5.65$	$-3.78, -5.44$	$-3.23, -5.65$
FL	$\mathbf{-3.23^*, -5.65^*}$	$\mathbf{-3.23^*, -5.65^*}$	$\mathbf{-3.23^*, -5.65^*}$	$\mathbf{-3.23^*, -5.65^*}$
LF	$-3.78, -5.44$	$-3.23, -5.65$	$-3.68, -5.34$	$-3.23, -5.65$

Table 12. The payoff matrix when $\beta_1 = 3, \beta_2 = 0.5, \delta_1 = 0.5,$ and $\delta_2 = 3$.

Inspection of Tables 10-12 reveals that even when the distribution of income is equal, all strategy profiles constitute Nash equilibria *only if the preference parameters of both individuals are set to particular values such as in Table 11,* which stands in sharp contrast with the previous single public-good model. In addition, it is seen from Tables 10-12 that when an individual has stronger preferences towards particular public goods, she may well act as a follower, which is in sharp contrast with the theoretical result of Varian (1984). This difference is caused by the presence of an income effect in our multiple public-good model.

5 Experimental Design

This section describes the design of our experiment. We test if the relationship between the timing choices of individuals and the distribution of income in the theoretical model with *a single public good* (i.e., Section 3) emerges in experiments.

We conducted seven sessions of experiments from December 6 to 15 in the Center of Experimental Research in Social Science (CERSS) at Hokkaido University, Japan. We recruited 110 students on campus, most of them freshmen from various academic backgrounds. Each session consists of 14 to 16 participants. The experiment was conducted using the z-Tree software (Fischbacher, 2007).

Upon arrival, participants were asked to draw from a lottery to determine their workstations, which are separated by boards from each other. It was announced that their identities would not be revealed before, during, or after the experiment. They were then given instructions. (See Appendix A for details.) After reading the instructions, subjects were given two minutes to consider how to make decisions in the experiment. Then, ten rounds were conducted.

At the beginning of each round, participants were randomly paired with another participant, with whom they matched only once through the experiment. They were then given ten tokens, and these were randomly distributed to the pair. For instance, participant 1 may be given nine tokens, while participant 2 is given one token. Participants were then asked to choose either "Lead" or "Follow."

If both participants choose "Lead" or "Follow," both participants make contribution decisions *simultaneously* in the following stage. On the other hand, if one participant chooses

"Lead" while the other chooses "Follow," the participant who chooses "Lead" makes the contribution decision first, and then the participant who chooses "Follow" decides how much to contribute to the public account. Before the follower contributes, they are informed of the leader's decision.

In the following stage, participants were asked to allocate their tokens between their private account, corresponding to the spending for private goods x_i, and public account, corresponding to the spending for public goods g_i. Their payoffs are determined according to the number of tokens placed in their private account (x_i) and public account ($G = g_1 + g_2$); i.e., $U_1 = x_1 G^\beta$ and $U_2 = x_2 G^\delta$. We set $\beta = \delta = 0.9$ in the experiment. This payoff structure is summarized in the "Payoff Table" in Appendix A, and participants could refer to this table during the experiment.

At the end of each round, the allocations of tokens and the resulting payoffs for both participants were revealed. Each experiment consisted of ten rounds, at the end of which the payoff of one of the ten rounds was randomly chosen by the software, and the corresponding payoff plus a show-up fee were paid in cash to participants. Participants were also asked to complete post-experiment questionnaires, including tasks for measuring the ability of backward induction[4] as well as social value orientation (SVO).[5]

6 Results

In this section, we first focus on the aggregate data to identify the percentage of cases resulting in simultaneous- versus sequential-move games. We then proceed to individual data to identify

[4] This variable is measured by asking participants to solve five questions regarding "race to 100 games" following Levitt & Sadoff (2011).

[5] The idea of social value orientation was developed in the field of social Psychology and captures the various motivations of participants in social dilemma. We follow Van Lange et al. (2007) and ask participants to complete twelve tasks, in each of which they choose their preferable income distribution. We then classified participants into five categories: first, "Individualists" who prefer to maximize their own payoffs; second, "Equalitarians" who prefer to minimize their payoff difference; third, "Competitors" who prefer to maximize their payoff difference; fourth, "Utilitarians" who maximize their joint-payoffs; and the rest were classified as "Not classifiable."

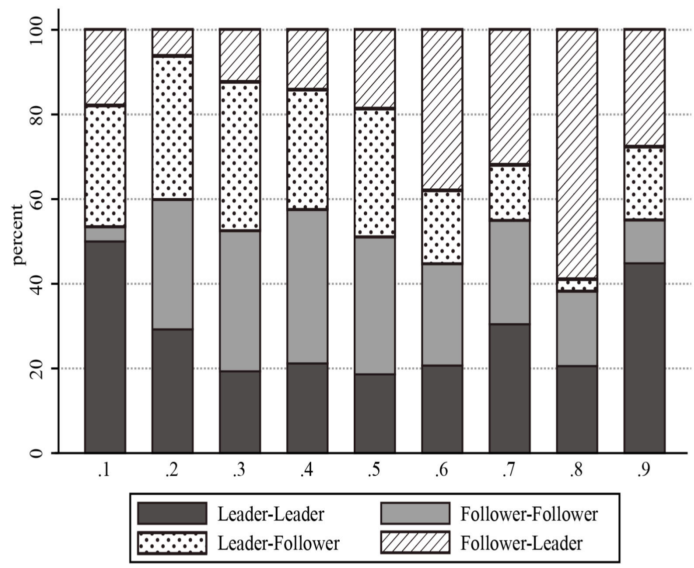

Figure 2: The composition of realized games by ρ

how income inequality among participants affects individual choices of timing. We also conduct multivariate regressions to identify whether there are determinants of timing choices other than income inequality.

6.1 Realized timing choices

Figure 2 summarizes the relationship between income inequality and the timing choices of individuals observed in the laboratory. The horizontal axis indicates ρ, that is, the proportion of tokens endowed to individual 1. The vertical axis indicates the percentage of the games resulting from the *actual* timing choices of individuals; namely, the simultaneous-move game corresponds to the strategy profile (L, L) or (F, F), while the sequential-move game corresponds to the strategy profile (L, F) or (F, L).

We see from Figure 2 that the percentage of (L, L) decreases as ρ approaches 0.5, that is, the income inequality among participants becomes small, while the percentage of (L, L) increases as ρ gets extremely high or low values, that is, the income inequality among participants becomes large. Table 13 also shows that the strategy profile (L, L) represents only 20.09%

in Regions III, IV, and V, while the pair (L, L) represents 28.97% of other regions.[6] These observations are *inconsistent* with our theoretical prediction in that *only* the strategy profile (L, L) emerges in equilibrium when the income inequality among participants is small (i.e. more equal).

	LL Games			Other Games			Total		
		Rounds			Rounds			Rounds	
	Overall	1 to 5	6 to 10	Overall	1 to 5	6 to 10	Overall	1 to 5	6 to 10
Region III, IV, V	46	21	25	183	96	87	229	117	112
	20.09%	17.95%	22.32%	79.91%	82.05%	77.68%	100.00%	100.00%	100.00%
Other Regions	93	42	51	228	116	112	321	158	163
	28.97%	26.58%	31.29%	71.03%	73.42%	68.71%	100.00%	100.00%	100.00%
Total All Regions	139	63	76	411	212	199	550	275	275
	25.27%	22.91%	27.64%	74.73%	77.09%	72.36%	100.00%	100.00%	100.00%

Note: Table entries are the numbers and the compositions of realized games under regions.

Table 13. The percentages of realized (L, L) by region

Figure 3 further shows the percentages of $(L,\ L)$ in the realized games from rounds 1 to 10. Although the percentage of $(L,\ L)$ is slightly increasing as the rounds increase, the percentage in regions III, IV, and V is almost always less than in other regions.

6.2 Individual timing choices

We next focus on the individual choices of timing. Figure 4 summarizes the results for the relationship between income inequality and the respective timing choices for those labelled Individual 1 (left) and 2 (right). The horizontal axis indicates ρ, while the vertical axis indicates the percentages of individual timing choices (i.e., L or F).

It is immediately seen from Figure 4 that for both individuals 1 and 2, the higher their endowment, the more likely they are to choose acting as a follower rather than as a leader. *This finding is also inconsistent with the theory as a larger number of participants choose acting as a follower even when the endowment levels are similar.* Interestingly, however, the above

[6] In our parameter settings, ρ falls into Region 1 when $\rho = 0.1$ or $\rho = 0.2$; Region 2, 3, 4, 5, and 6 when $\rho = 0.3$, $\rho = 0.4$, $\rho = 0.5$, $\rho = 0.6$, and $\rho = 0.7$, respectively; and Region 7 when $\rho = 0.8$ or $\rho = 0.9$.

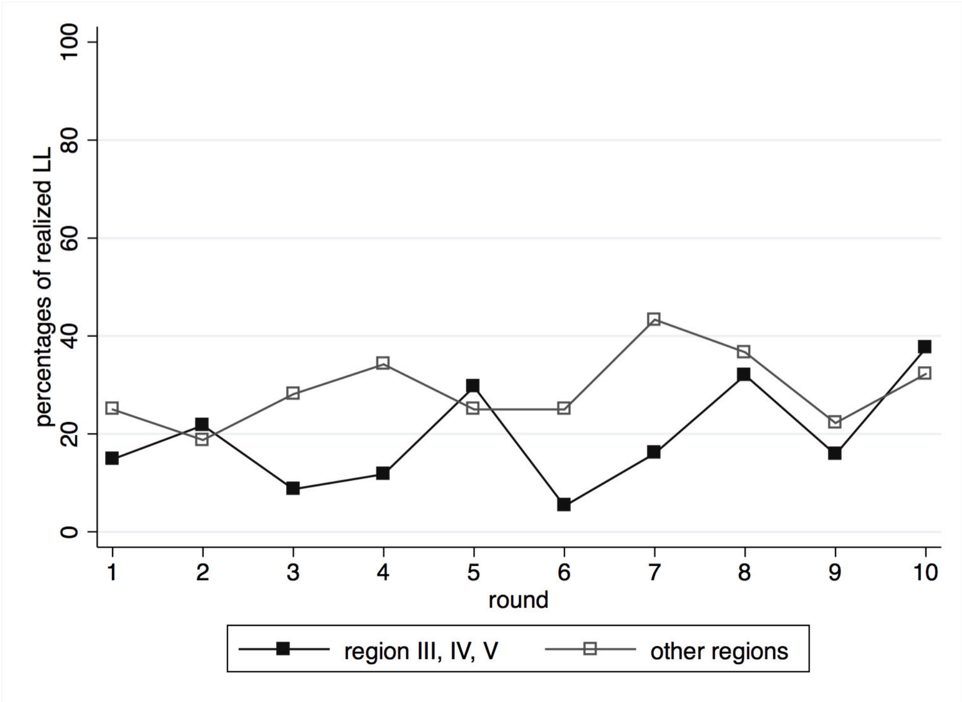

Figure 3: The percentages of realized (L, L) by round

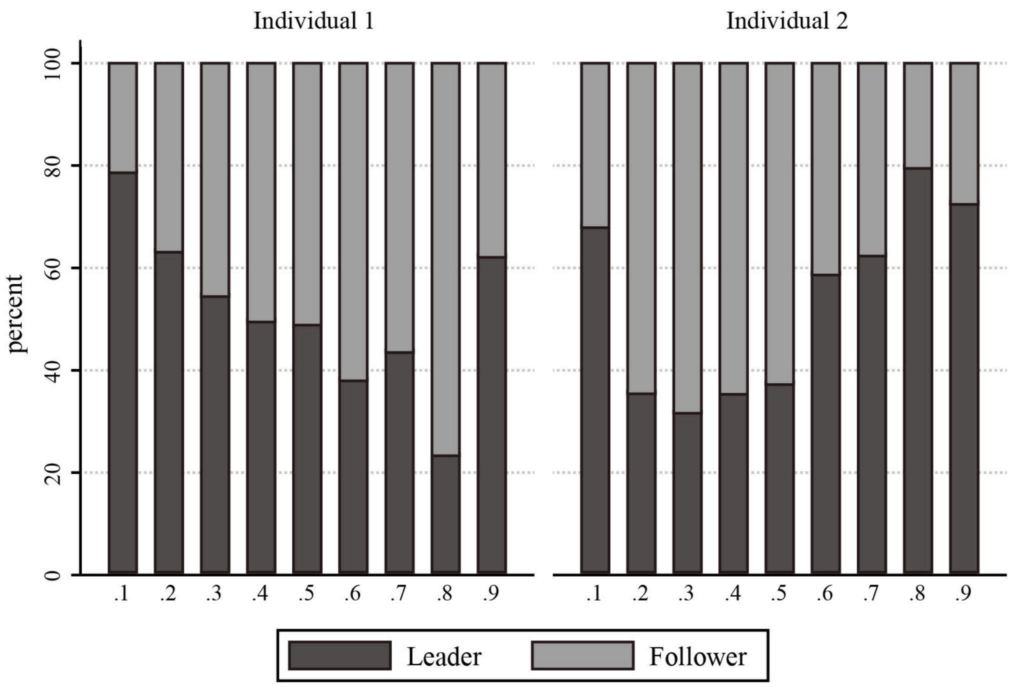

Figure 4: The composition of timing choices

pattern does not emerge in the case where participants are extremely "high-income" ($\rho = 0.9$ for individual 1, $\rho = 0.1$ for Individual 2). In this case, participants are likely to choose acting as a leader.

Table 13 summarizes the estimates of probit models explaining the participants' choices of acting as a leader. Model 1 estimates the effect of dummy variable for Regions III, IV, and V on participants' choices of acting as a leader with individual fixed effects. We see that the sign of the estimate is negative at the 1% significance level; that is, participants are less likely to choose acting as a leader in Regions III, IV, and V, which apparently contradicts with our theoretical predictions.

To test the robustness of our empirical results, we also conducted three regressions of the probability of participants choosing L on several independent variables related to the participants' traits. These variables include a Female Dummy (Model 2), Individualist Dummy that equals 1 when the participant's SVO is "Individualist" (Model 3), participant's ability of backward induction (the number of correct answers regarding the questions on the centipede game) (Model 4), and all of these variables combined (Model 5).

	Model 1	Model 2	Model 3	Model 4	Model 5
Region III, IV, V Dummy	-0.228***	-0.0867	-0.124	-0.223	-0.193
	(0.0876)	(0.109)	(0.104)	(0.146)	(0.178)
Female Dummy		-0.263*			-0.272*
		(0.151)			(0.148)
Region III, IV, V Dummy × Female Dummy		-0.0724			-0.0467
		(0.189)			(0.189)
Individualist Dummy			-0.0822		-0.108
			(0.142)		(0.138)
Region III, IV, V Dummy × Individualist Dummy			0.00495		0.0169
			(0.177)		(0.178)
Ability of Backward Induction				0.0210	0.0138
				(0.0610)	(0.0606)
Region III, IV, V Dummy × Ability of Backward Induction				0.0579	0.0511
				(0.0670)	(0.0673)
Constant	-0.0515	0.146*	0.105	0.0280	0.179
	(0.133)	(0.0847)	(0.0893)	(0.117)	(0.142)
Observations	1,100	940	940	940	940
Pseudo R2	0.00739	0.0105	0.00239	0.00357	0.0128
Wald Chi2	7.807	7.284	2.793	3.036	9.328
Fixed Effect	YES	NO	NO	NO	NO

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 14. Estimates of timing choices (Probit)

Table 14 summarizes the results. From Models 2 to 5, we derive the following conclusions. First, the estimates of the Regions III, IV, and V dummy are *statistically insignificant*. Together with the results obtained in Model 1, we see that the effect of an equalized income distribution on timing decisions, more precisely, the Regions III, IV, and V dummy, is negative but **not** significant regarding the participant's choice of L. Second, the estimated coefficient on the Female dummies in Models 2 and 5 is negative at the 10% significance level. The result is consistent with other experimental studies on the endogenous timing choices of public goods provision, e.g., Nosenzo and Sefton (2011), suggesting gender as well as the degree of risk aversion matter. Third, other variables are statistically insignificant.

In summary, it is hard to say that we have convincing evidence that supports our theoretical predictions presented in Section 3. To further identify the determinants of participants' choices of acting as a leader, we conduct multivariate probit regressions apart from the game theoretic model. Table 15 summarizes the estimates of the probit models explaining participants' choices of acting as a leader other than income inequality among participants. Model 1 controls income inequality by including endowments, while Model 2 controls it by including ρ and an individual 2 dummy, and Model 3 controls it by including a Region and an individual 2 dummy.

	Model 1	Model 2	Model 3
Endowment	-0.127***		
	(0.0274)		
ϱ		-0.144	
		(0.234)	
ϱ × Individual 2 Dummy		0.504***	
		(0.152)	
Region			-0.0183
			(0.0256)
Region × Individual 2 Dummy			0.0707***
			(0.0190)
Chose Acting as a Leader in *t*-1	0.230**	0.234**	0.233**
	(0.104)	(0.105)	(0.106)
Opponent Chose Acting as a Leader in *t*-1	-0.125	-0.139	-0.139
	(0.109)	(0.111)	(0.111)
Average # of Opponent Acting as a Leader	0.141	0.165	0.172
	(0.276)	(0.269)	(0.269)
Female Dummy	-0.233**	-0.210*	-0.211*
	(0.118)	(0.118)	(0.119)
Individualist Dummy	-0.0615	-0.0517	-0.0485
	(0.106)	(0.106)	(0.106)
Ability of Backward Induction	0.0442	0.0356	0.0361
	(0.0439)	(0.0450)	(0.0452)
Degree of Comprehension: Timing Choice	0.00267	0.0119	0.0119
	(0.0573)	(0.0558)	(0.0558)
Degree of Comprehension: First Stage	-0.155**	-0.152**	-0.154**
	(0.0646)	(0.0658)	(0.0660)
Degree of Comprehension: Second Stage	0.215***	0.209***	0.211***
	(0.0747)	(0.0737)	(0.0742)
Degree of Comprehention: Experiment as a Whole	0.0901	0.0819	0.0811
	(0.111)	(0.115)	(0.115)
Constant	0.00134	-0.676	-0.692
	(0.503)	(0.511)	(0.511)
Observations	920	920	920
Pseudo R2	0.0712	0.0447	0.0477
Wald Chi2	58.93	54.14	58.66

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 15. Determinants of timing choices (Probit)

The results in Table 14 illuminate how participants choose acting as a leader in their timing choices. First, the dummy variables (equal to one when participants choose acting as a leader in the previous period, $t-1$) have positive effects (5% significance level) in all three models. This observation indicates not only the possibility that participants do not behave in a way predicted by the theory, but also that their behaviors may reflect some sort of bounded rationality.

Second, the coefficients of the female dummies (Female Dummy) are negative in all three models (5% significance level in Model 1, and 10% significance level in Models 2 and 3). As depicted in Table 14, the participants' gender matters in their timing choices. Nosenzo and Sefton (2011) point out that, for those who are risk averse, typically female participants, committing to contribute in stage 1 may be a risky decision (i.e., *strategic uncertainty*), because mis-coordination among other participants may lead to considerable losses in payoffs.

Third, the estimates regarding the degree of comprehension in stage 1 (Degree of Comprehension: First stage), in both simultaneous and sequential games, are significant at the 5% level in Models 1 to 3. However, the directions of these effects are counterintuitive. The more the participants are to comprehend the consequences of their action in stage 1, the less likely they are to choose acting as a leader. On the other hand, the estimates regarding the degree of comprehension in stage 2 (Degree of Comprehension: Second stage) are positively significant at the 1% level in Models 1 to 3. The more the participants comprehend in stage 2, the more likely they are to choose acting as a leader.

6.3 Public goods provision

The results in the previous subsection would indicate that participants' timing choices are not entirely compatible with our theoretical predictions and somewhat depend on bounded rationality as well as participants' characteristics. Does this mean that the present rational choice model based on a game-theoretical approach explains nothing?

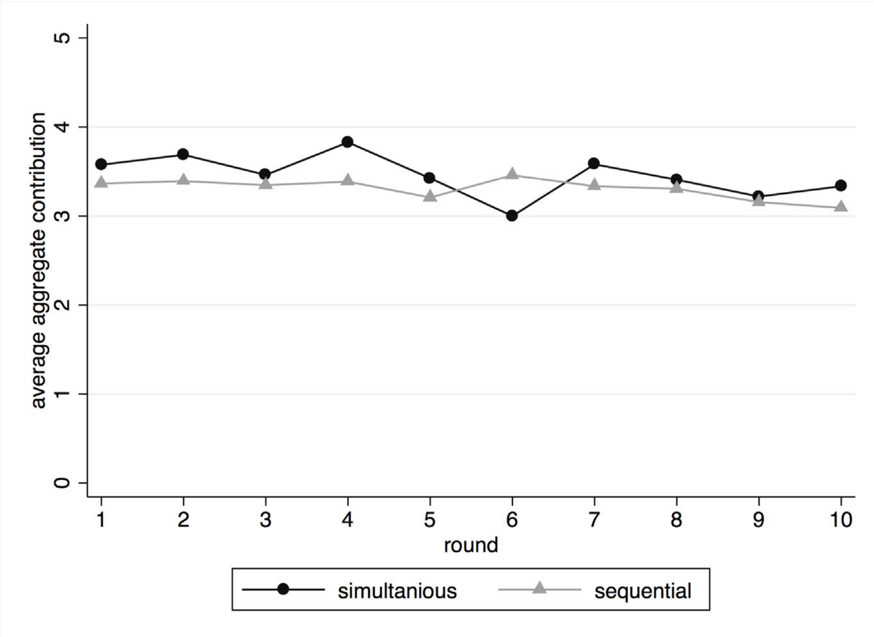

Figure 5: The average contribution of tokens by round

The answer is no. Table 15 shows the average contribution per pair in 10 rounds as well as the first five and last five rounds. The overall average contribution in the sequential-move games is 3.31 tokens, while the average in the simultaneous-move games is 3.47 tokens; hence the former is less than the latter (p=0.015). This result is consistent with Varian's (1994) as well as our theoretical prediction. (See Table 4.) In addition, Figure 5 also confirms our theoretical prediction that the average contribution of tokens in the simultaneous-move game almost always exceeds the average contribution in the sequential-move game in rounds 1 to 10.

		Rounds	
	Overall	1 to 5	6 to 10
Sequential	3.31	3.33	3.28
(n=265)	0.06	0.08	0.08
Simultaneous	3.47	3.60	3.34
(n=285)	0.05	0.07	0.07

Note: Table entries are average contributions per game with standard deviations.

Table 15. The average contribution of tokens by timing

On the other hand, Figures 6 shows the mean contributions of participants labelled indi-

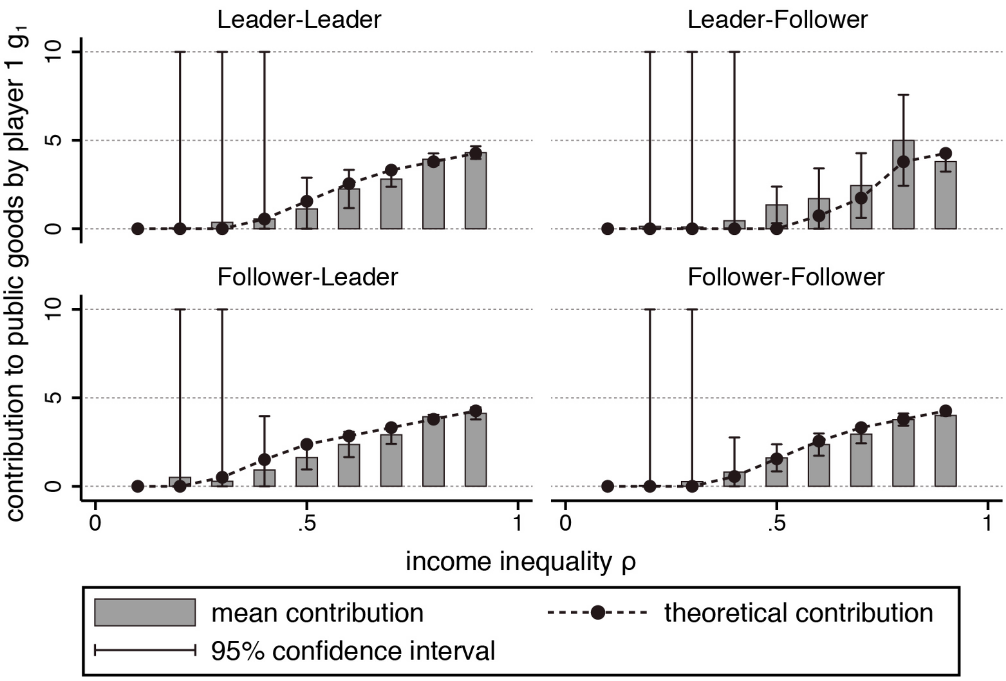

Figure 6: Average contributions to public goods by Individual 1

viduals 1 and 2 for the public good. The horizontal axis indicates ρ, and the vertical axis indicates the number of tokens dedicated to the public good. Bars indicate the average numbers of tokens and error bars indicate 95% confidence intervals. The dotted lines indicate the Nash equilibrium contributions calculated from our theoretical model. As seen from these figures, the *actual* amounts of tokens dedicated to the "public account" in stage 2 almost coincide with our theoretical predictions associated with the entire range of ρ. In short, although the experimental results in stage 2 are almost *consistent* with the theoretical predictions, the results of stage 1 are *inconsistent* with the theoretical predictions.

7 Concluding remarks

Our theoretical and empirical studies are a first attempt to isolate the effects of heterogenous income and preferences across individuals on the individual's timing choices of contributions from reciprocity, signalling effects, inequality aversion preferences, etc. This paper clearly reveals that the timing of providing public goods depends critically on the distribution of income in addition to the preferences toward public goods, unlike Varian's (1994). Nevertheless, although the actual individuals' and aggregate contributions observed in the laboratory are consistent with the theoretical predictions, most of our theoretical predictions regarding the timing choices of individual contributions in the single public good model are *not* consistent with our experimental results. The results of this study indicate not only that the heterogeneity of income levels and preferences which allow for an income effect are not sufficient to explain the actual timing choices of contributions, but also that these factors would be sufficient to explain the actual choices of contributions (i.e., individual and total provisions), *given the timing choices of individuals.* We can infer that the participants' timing choices may be dependent on the underlying factors such as warm-glow preferences (e.g., Romano and Yildirim, 2001), fieriness (Nosenzo and Sefton, 2011), signaling (Porters et al., 2005), gender, or participants' risk attitudes toward the strategic uncertainty of the timing game, etc., which may cause timing choices to deviate from our theoretical predictions. We need to test the effects of these other factors on the timing choice with more rigorous methodologies.

The theoretical results obtained and tested in this paper critically rely on the restrictive structure of the present model (such as a two-individual model, perfect information and Cobb-Douglas preferences). Hence, future research should address the robustness of the results under more general utility functions. In addition, an equally important extension is to investigate theoretically and experimentally the relationship between income inequality and the timing decisions of contributors in a *multiple* public-good provision model in a rigorous and exhaustive manner. Owing to the intrinsic complexity of the determinants of timing of public good contributions, we need to resort to numerical analysis.

Appendix A

Welcome to our experiment. This is an experiment on decision-making. The amount of reward you will receive depends on the performance of you and the other participants. Experiments will be conducted anonymously so that no one can recognize your decisions during the experiment.

Please refrain from talking in the laboratory. Please turn off your mobile phone, or set it in silent mode. You can take notes on this written instruction and its appendix; however, you cannot take this out outside the laboratory. This instruction consists of the following three parts:

1. Outline of the experiment,
2. Determination of payoffs,
3. Detailed instruction by using PC screen.

A.1. Outline of the experiment

This experiment consists of ten rounds, and each round consists of three stages. Before starting each round, you will be randomly paired with another participant. The pair will be randomly re-matched at the beginning of each round, and you will never be matched with whom you have already matched once.

After you are matched with your opponent, ten "tokens" are given to your pair; the distribution of these tokens is random and not necessarily equal; e.g., you may receive two tokens, while your partner receives eight tokens. The distributions of tokens change round by round.

- Stage 1 - In stage 1, you can choose whether you make a decision in stage 2 or stage 3.[7] The situation you will face in the following stage depends on which stage you chose and your opponent chooses in stage 1. (See Figure 7.)

For example, suppose you choose stage 2 and your opponent also chooses stage 2. In this case, you and your opponent will make decisions simultaneously in stage 2. On the other hand, suppose you choose stage 2 while your opponent chooses stage 3. In this case, you will make a decision in stage 2, and your opponent makes a decision in stage 3 after observing your decision in stage 2.

The relationship between your choice in stage 1 and the timing of the subsequent stages can be summarized as in the following table:

		Your opponent	
		stage 2	stage 3
You	stage 2	Simultaneous	Sequential (you move first)
	stage 3	Sequential (your opponent moves first)	Simultaneous

[7] In the experiment, we divide stage 2 into stage 2 and stage 3, where choosing stage 2 corresponds to the choice of earlier move (or the choice of "Lead"), while choosing stage 3 corresponds to the choice of later move (or the choice of "Follow"). We label the timing choice game as stage 1 as before.

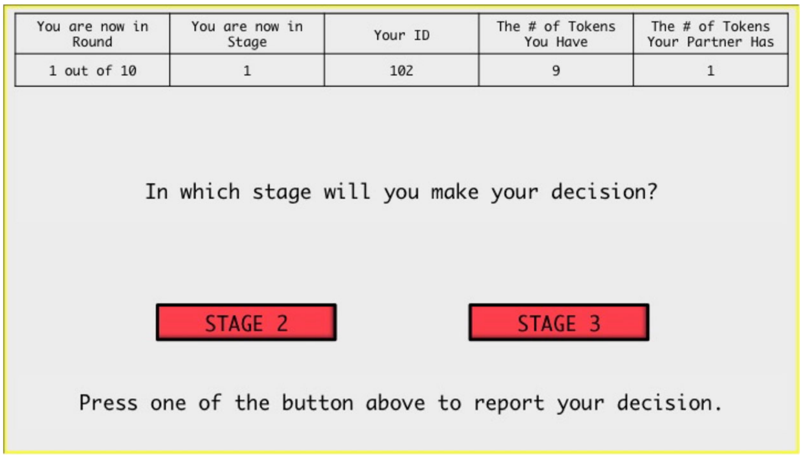

Figure 7: Timing choices in stage 1

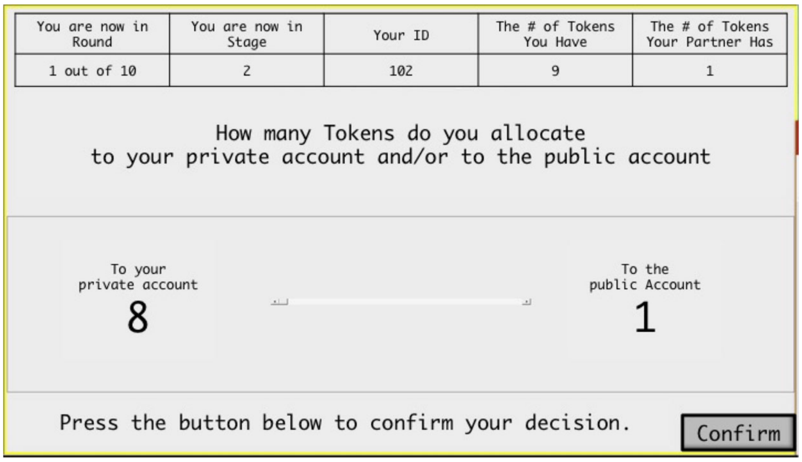

Figure 8: Allocation of tokens in stage 2

- Stage 2 - What you need to do in stage 2 is to allocate your tokens in your "private account" and "public account." (See Figure 8.) Notice that your opponent can also allocate his/her tokens in the "public account." For instance, if you and your opponent have chosen stage 2, you will allocate your tokens simultaneously with your opponent.

On the other hand, if you have chosen stage 2 while your opponent has chosen stage 3, your opponent can allocate his/her tokens in stage 3 after observing the number of tokens you have allocated in stage 2.

- Stage 3 - What you need to do in stage 3 is almost the same as in stage 2, that is, allocate your tokens in your "private account" and "public account," per the timing you and your opponent choose. (See Figure 8.) As in stage 2, if you and your opponent have chosen stage 3 in stage 1, you will allocate your tokens simultaneously with your opponent.

On the other hand, if you have chosen stage 3 while your opponent has chosen stage 2, you can allocate your tokens in stage 3 after observing the number of tokens your opponent has allocated in stage 2. After finishing stage 3, the payoffs are displayed, and a new round starts. We repeat ten rounds in total.

A. 2. Determination of payoffs

The payoffs you receive from this experiment are dependent on the number of tokens placed in your "private account" and the number of tokens in the "public account" of your pair. Roughly speaking, the more you allocate your tokens in your "private account," and the more tokens are placed on "public accounts," the more payoff you can receive.

Notice that it is not the tokens you added to the "public account," but the sum of tokens placed in "public account" which is jointly funded by you and your opponent. The number of tokens can be positive even when you allocate nothing to "public account" if only your opponent allocates a positive number of tokens.

The relationship between the payoffs you receive and the number of tokens allocated to your "private account" and the "public account" is summarized in the table named "Payoff Table" on your desk. (See Table 16.) For example, when there are three tokens on your "private account" and three tokens on the "public account," the Payoff Table tells you that your payoff in this round is 970 JPY.

	Number of Tokens in Public Account										
Number of Tokens in Your Private Account	0	1	2	3	4	5	6	7	8	9	10
0	0	0	0	0	0	0	0	0	0	0	0
1	0	120	220	320	420	510	600	690	780	870	
2	0	240	450	650	840	1020	1200	1380	1560		
3	0	360	670	970	1250	1530	1810	2070			
4	0	480	900	1290	1670	2040	2410				
5	0	600	1120	1610	2090	2550					
6	0	720	1340	1940	2510						
7	0	840	1570	2260							
8	0	960	1790								
9	0	1080									
10	0										

Table 16. Payoff Table

After the tenth round is finished, the computer program randomly chooses one round out of ten. The reward you will receive is the amount of payoff in the chosen round plus a 500 JPY show-up fee. To summarize,

$$\text{Your Reward} = \text{Payoff in selected round} + 500JPY.$$

Notice that every round is equally important, as you never know which round will be chosen ex-ante.

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