Supplementary Online Appendix to

Public Goods Provision with Rent-Extracting Administrators

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## Appendix Table

### Table A1: Panel Unit Root Tests

<table>
<thead>
<tr>
<th>Variable</th>
<th>Breitung (B)</th>
<th>Levin-Lin-Chu (LLC)</th>
<th>Im-Pesaran-Shin (IPS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contribution Rate</td>
<td>-2.28**</td>
<td>-3.56***</td>
<td>-3.76***</td>
</tr>
<tr>
<td>Return Rate</td>
<td>-1.45*</td>
<td>-2.01**</td>
<td>-2.84***</td>
</tr>
</tbody>
</table>

**Notes:** Observational unit: group $n$ in period $t$; Number of observations: 396 ($N = 18$, $T = 24$); Models contain two lags selected by AIC and HQIC, panel-specific means, and exclude linear time trends; $B$ and $LLC$ assume common autoregressive parameters for all series, $IPS$ relaxes the assumption of common autoregressive parameters; $H_0$ of $B$, $LLC$, and $IPS$: All series contain a unit root; $H_1$ of $B$ and $LLC$: All series are stationary; $H_1$ of $IPS$: The fraction of panels that are stationary is nonzero. The tests reject the non-stationarity of contribution rates (aggregated to group-level) and return rates in the PTG. Cooperation and trustworthiness are stable over time. **p < 0.01, *p < 0.05, *p < 0.1
Derivation of the Panel Vector Autoregressive Model

In the following, we derive the structural form panel vector autoregressive model.\footnote{Fernández-Villaverde et al. (2007) discuss under which general conditions a model in state space representation transforms into a vector autoregressive model.}

Consider the decision rules (6) and (7) and the belief-updating rule (8) in the paper. By plugging in (8) into (6) and applying some simple transformations, we get:

\[ m_{nit} = \tau_{ni} + \rho_0 R_{nit-1} + \rho_1 m_{nit-1} + u_{nit} \]  

(A1)

where

\[
\begin{align*}
\tau_{ni} &= \alpha_2 \varphi_1 \theta_{ni} + \alpha_1 \varphi_2 \theta_{ni}, \\
\rho_0 &= \alpha_2 \varphi_2, \\
\rho_1 &= (1 - \varphi_2), \\
u_{nit} &= s_{nit} + (\varphi_2 - 1)s_{nit-1}.
\end{align*}
\]

Eq. (A1) explains a contributor’s contribution in \( t \) by the own lagged contribution and the lagged return. Although beliefs are not directly included, beliefs enter into (A1) through the decision variables. A contributor’s decision is hence in line with her underlying belief formation process. As a consequence of the transformation, \( u_{nit} \) is moving-average autocorrelated. We assume that \( s_{nit} \) is AR(1) such that the MA(1) and the AR(1) autocorrelation neutralise each other. This results in a situation where \( \text{cov}(u_{nik}, u_{njt} | R_{nit-1}, m_{nit-1}, \tau_{ni}) = 0 \) for \( k \neq j \).

Using (A1), the distributional assumption \( u_{nit} \overset{iid}{\sim} \mathcal{N}(\mu_{ni}, \sigma_{ni}^2) \), and the definition

\[ M_{nt} = r \sum_{i=1}^{4} m_{nit}, \]

we can derive the pool \( M_{nt} \) as

\[ M_{nt} = \tau_n + \rho_1 M_{nt-1} + \rho_2 R_{nt-1} + u_{nt}, \]  

(A2)
where

\[ \tau_n = r \sum_{i=1}^{4} \tau_{ni}, \]
\[ \rho_1 = (1 - \varphi_2), \]
\[ \rho_2 = 4r \alpha_2 \varphi_2, \]
\[ u_{nt} = r \sum_{i=1}^{4} u_{nit}. \]

and \( u_{nt} \overset{iid}{\sim} \mathcal{N}(\sum_{i=1}^{4} \mu_{ni}, \sum_{i=1}^{4} \sigma_{ni}^2). \) Combining (A2)) and equation (7) from the paper gives

\[ R_{nt} = \varrho_n + \rho_3 M_{nt-1} + \rho_4 R_{nt-1} + \beta_2 u_{nt} + v_{nt}, \quad \text{(A3)} \]

where

\[ \varrho_n = \beta_1 \phi_n + \beta_2 \tau_n, \]
\[ \rho_3 = \beta_2 \rho_1, \]
\[ \rho_4 = \beta_2 \rho_2, \]

and \( v_t \overset{iid}{\sim} \mathcal{N}(\mu, \sigma^2). \) Multiplying (A2) and (A3) with 5/6 gives the panel vector autoregressive model summarised by equations (9) and (10) in the paper.
Appendix Figures

Figure A1: Illustration of Shocks (One Group)

A: Contribution Rate Shocks

B: Return Rate Shocks

Notes: The Figure shows shocks in the contribution rate (Panel A) and in the return rate (Panel B) for one group. Contribution rate shocks are represented by the error term $u_{n,t}$ in equ. (9), while return rate shocks are represented by the error term $v_{n,t}$ in equ. (10) (see Section 3.2.3 in the paper). We recover the shocks using the estimated parameters from the panel vector autoregressive model. Periods outside the main interval are excluded.
Figure A2: Distributions of Shocks (All Groups)

A: Distribution of Contribution Rate Shocks

B: Distribution of Return Rate Shocks

Notes: The Figure shows the distribution of shocks in the contribution rate (Panel A) and in the return rate (Panel B) in all groups. The bin size is 5 percentage points. Contribution rate shocks are represented by the error term $u_{n,t}$ in equ. (9), while return rate shocks are represented by the error term $v_{n,t}$ in equ. (10) (see Section 3.2.3 in the paper). We recover the shocks using the estimated parameters from the panel vector autoregressive model. Periods outside the main interval are excluded.
In the following, we provide additional figures on heterogenous responses of types with different baseline attitudes with respect to trust and cooperativeness. In the paper, we focus on the behaviour of contributors. For completeness, the following figures report results on the heterogeneity in terms of administrators’ attitudes. Note also that in the public trust game, administrators do not respond to any direct signal about the trustworthiness of other agents. We, therefore, do not consider the heterogeneity in terms of trust among administrators.
Figure A3: Heterogenous Responses – Trusting vs. Non-Trusting Contributors

A: Non-Trusting Contributors  B: Trusting Contributors

**Impulse: Return Rate**

**Impulse: Contribution Rate**

**FEVD: Contribution Rate**

**FEVD: Return Rate**

Notes: The upper (lower) part of the figure shows IRFs (FEVDs). For detailed notes see Figures 5 and 6 in the paper.
Figure A4: Heterogenous Responses – Cooperative vs. Non-Cooperative Contributors

A: Non-Cooperative Contributors

Impulse: Return Rate

Impulse: Contribution Rate

FEVD: Contribution Rate

FEVD: Return Rate

Notes: The upper (lower) part of the figure shows IRFs (FEVDs). For detailed notes see Figures 5 and 6 in the paper.
Figure A5: Heterogenous Responses – Cooperative vs. Non-Cooperative Administrators

A: Non-Cooperative Administrators  B: Cooperative Administrators

**Impulse: Return Rate**

**Impulse: Contribution Rate**

**FEVD: Return Rate**

**FEVD: Contribution Rate**

**Notes:** The upper (lower) part of the figure shows IRFs (FEVDs). For detailed notes see Figures 5 and 6 in the paper.
Instructions PTG & PGG  
(PGG Instructions exclude highlighted text components)

Welcome and thank you for participating in today’s experiment. Please read the instructions carefully.

If you have any questions, please raise your hand. One of the experimenters will answer your questions. **You are not allowed to communicate with other participants of the experiment.** Violation of this rule will lead to exclusion from the experiment. Please turn off your cell phone.

This is an experiment in economic decision making. For showing up on time, you receive a one-time payment of EUR 2.5. For attending the second part of the experiment, you receive a one-time payment of EUR 6. During the experiment you will earn additional money. Your additional earnings depend on your behavior and the behavior of other participants. During the experiment, money is displayed in Experimental Currency Units (ECU). The exchange rate is 1 Euro = 40 ECU. Your entire earnings will be paid to you in cash at the end of the second part of the experiment.

You will not learn about the identity of other participants. We will not communicate your earnings or your role in the experiment to other participants. The data will be analyzed anonymously.

**Experiment**

**Duration**

The experiment is divided into periods. In each period you face the same decision-making situation. The experiment consists of **30 periods**.

**Roles**

Every participant is assigned a role, either A or B. In the following we refer to participants as **A-participant** and **B-participant**. The roles are **randomly assigned** before the first period and will not change during the experiment. All participants are treated equally during the assignment. Before the first period, every participant is informed about her role.

**Groups**

Prior to the first period, all participants are divided randomly into **independent groups** of five participants. Each group consists of **four A-participants** (in the following A1 to A4) and **one B-participant** (in the following B).

Groups remain the same throughout the experiment, meaning that you solely interact with members of your group. Decisions made by members of other groups will not affect your group.

**Sequence**

Every period follows the same sequence, illustrated in the following figure.
1) Receipt of Endowment/Receipt of Secure Income

At the beginning of every period, each of the four A-participants receives a **endowment** of 10 ECU. During the period, participants make decisions regarding the use of the endowment. The endowment is not transferable between periods, meaning that an A-participant cannot use her period-one endowment in period two.

At the beginning of every period, the B-participant receives a **secure income** of 30 ECU.

2) Decisions of A-participants

Each of the four A-participants in one group decides how much of her endowment to contribute to a joint **pool**. Specifically, A-participants choose an integer amount between 0 and 10 (indicating 0 and 10 is possible) that is contributed to the pool.

The following tables show illustrative examples. The decisions made by the participants in the actual experiment may differ from the exemplary decisions. Please take a look at the following table.

<table>
<thead>
<tr>
<th>Example 1</th>
<th></th>
<th>Example 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A-participant</strong></td>
<td><strong>B-participant</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contribution A1</td>
<td>10 ECU</td>
<td>Contribution A1</td>
<td>0 ECU</td>
</tr>
<tr>
<td>+ Contribution A2</td>
<td>10 ECU</td>
<td>+ Contribution A2</td>
<td>10 ECU</td>
</tr>
<tr>
<td>+ Contribution A3</td>
<td>10 ECU</td>
<td>+ Contribution A3</td>
<td>2 ECU</td>
</tr>
<tr>
<td>+ Contribution A4</td>
<td>10 ECU</td>
<td>+ Contribution A4</td>
<td>8 ECU</td>
</tr>
<tr>
<td><strong>Pool</strong></td>
<td><strong>40 ECU</strong></td>
<td><strong>Pool</strong></td>
<td><strong>20 ECU</strong></td>
</tr>
</tbody>
</table>

3) Multiplication of the Pool

The pool is multiplied by the **factor** 3. Please take a look at the following table.

<table>
<thead>
<tr>
<th>Example 1</th>
<th></th>
<th>Example 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pool</strong></td>
<td><strong>40 ECU</strong></td>
<td><strong>Pool</strong></td>
<td><strong>20 ECU</strong></td>
</tr>
<tr>
<td><strong>Multiplied pool</strong></td>
<td><strong>120 ECU</strong></td>
<td><strong>Multiplied pool</strong></td>
<td><strong>60 ECU</strong></td>
</tr>
</tbody>
</table>

4a) Decision of B-participant

The B-participant in every group decides which part of the multiplied pool she would like to **release** (released amount). She can release every integer amount between 0 and the multiplied pool (releasing 0 and the entire multiplied pool is
possible).

The released amount will be equally distributed among the four A-participants of a group. If the released amount is 80 ECU (see Example 1b), every A-participant receives 80/4=20 ECU. The remaining unreleased amount of 40 ECU increases the B-participant’s payoff. Please take a look at the following table.

<table>
<thead>
<tr>
<th>Example 1</th>
<th>Example 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiplied pool</td>
<td>120 ECU</td>
</tr>
<tr>
<td>a) Released amount</td>
<td>120 ECU</td>
</tr>
<tr>
<td>Every A-participant receives</td>
<td>30 ECU</td>
</tr>
<tr>
<td>The B-participant receives</td>
<td>0 ECU</td>
</tr>
<tr>
<td>b) Released amount</td>
<td>80 ECU</td>
</tr>
<tr>
<td>Every A-participant receives</td>
<td>20 ECU</td>
</tr>
<tr>
<td>The B-participant receives</td>
<td>40 ECU</td>
</tr>
</tbody>
</table>

4b) A-participants Make Estimates

While the B-participant is making her decision, every A-participant estimates the decisions made by other participants. The estimates are private information and, hence, cannot influence the behavior of other participants.

1. Every A-participant estimates the average contribution of the other A-participants. Based on this estimate, the estimated pool is calculated.

<table>
<thead>
<tr>
<th>Estimated pool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated total contribution of other A-participants’ (estimated average contribution multiplied by 3)</td>
</tr>
<tr>
<td>+ Own contribution</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Estimated pool</td>
</tr>
</tbody>
</table>

2. Every A-participant estimates the released amount (estimation of the part of the estimated pool that is released).

5) Informing A- and B-Participants

At the end of each period, all participants receive detailed information.

Every A-participant learns about
- her endowment
- her contribution
- the amount she has not paid into the pool
- the pool
- the multiplied pool
- the released amount
- the own portion of the released amount¹
- the unreleased amount
- the own period payoff
- the balance of her account (payoffs of all past periods)

Every B-participant learns about
- her secure income
- the pool
- the multiplied pool

¹ In PGG instructions: „the own portion of the multiplied pool“
Neither the A-participants nor the B-participant will be informed about the A-participants’ individual contributions to the pool.

Period Payoff
The A- and B-participants’ period payoffs are calculated as follows:

<table>
<thead>
<tr>
<th>A-participant’s payoff</th>
<th>B-Participant’s payoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endowment</td>
<td>Secure income</td>
</tr>
<tr>
<td>- Contribution</td>
<td>+ Unreleased amount</td>
</tr>
<tr>
<td>+ Portion of released amount</td>
<td></td>
</tr>
<tr>
<td>Period payoff</td>
<td>Period payoff</td>
</tr>
</tbody>
</table>

Please take a look at the following table.²

Example 1

<table>
<thead>
<tr>
<th>Multiplied pool</th>
<th>120 ECU</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Released amount</td>
<td>120 ECU</td>
</tr>
<tr>
<td>Every A-participant receives</td>
<td>30 ECU</td>
</tr>
<tr>
<td>The B-participant receives</td>
<td>0 ECU</td>
</tr>
<tr>
<td>All Participants (A and B) have a payoff of 30 ECU.</td>
<td></td>
</tr>
</tbody>
</table>

b)

<table>
<thead>
<tr>
<th>Released amount</th>
<th>80 ECU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Every A-participant receives</td>
<td>20 ECU</td>
</tr>
<tr>
<td>The B-participant receives</td>
<td>40 ECU</td>
</tr>
<tr>
<td>All A-participants have a payoff of 20 ECU. The B-participant has a payoff of 70 ECU.</td>
<td></td>
</tr>
</tbody>
</table>

Example 2

<table>
<thead>
<tr>
<th>Multiplied pool</th>
<th>60 ECU</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Released amount</td>
<td>60 ECU</td>
</tr>
<tr>
<td>Every A-participant receives</td>
<td>15 ECU</td>
</tr>
<tr>
<td>The B-participant receives</td>
<td>0 ECU</td>
</tr>
<tr>
<td>A-participants’ payoffs vary between 17 ECU and 25 ECU. The B-participant has a payoff of 30 ECU.</td>
<td></td>
</tr>
</tbody>
</table>

b)

<table>
<thead>
<tr>
<th>Released amount</th>
<th>20 ECU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Every A-participant receives</td>
<td>5 ECU</td>
</tr>
<tr>
<td>The B-participant receives</td>
<td>40 ECU</td>
</tr>
<tr>
<td>A-participants’ payoffs vary between 5 ECU and 15 ECU. The B-participant has a payoff of 70 ECU.</td>
<td></td>
</tr>
</tbody>
</table>

Example Calculations
To make sure that all participants have understood the instructions, we ask you to make some example calculations on your computer. It does not matter if you need several attempts to answer the questions.

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² Example 1 (PGG instructions): Multiplied pool = 80 ECU; Every participant receives 20 ECU from the pool; All participants have a payoff of 20 ECU.
Example 2 (PGG instructions): Multiplied pool = 40 ECU; Every participant receives 10 ECU from the pool; participants have a payoff between 10 ECU and 20 ECU.
Theoretical Analysis of the Public Trust Game

Basics

In the following, we provide a detailed theoretical analysis of the Public Trust Game. In particular, we analyze infinitely repeated interaction and reciprocity concerns. We are aware that reciprocity and effects from repeated interaction might work together in our setup. To keep the analysis simple, we examine them separately.

Consider the PTG among five players \( i = \{1, \ldots, 5\} \), where agents 1 to 4 are the contributors and agent 5 is the administrator. Contributors have similar endowments \( w_i \equiv w, i = \{1, \ldots, 4\} \), while the administrator has an endowment \( w_5 > w \). Contributions in period \( t \) are \((m_{1t}, \ldots, m_{4t})\) and \( M_t = r \sum_{i} m_{it} \) is the pool in period \( t \). Furthermore, let \( \gamma_t \in [0, 1] \) be the share of the pool kept by the administrator. Denote by \( x_{it} \) the agents’ payoffs in period \( t \). It holds that

\[
\begin{align*}
x_{it} &= w - m_{it} + \frac{1}{4} r \sum_{j=1}^{4} m_{jt} - \frac{1}{4} r \gamma_t \sum_{j=1}^{4} m_{jt}, \quad i = \{1, \ldots, 4\}, \\
x_{5t} &= w - \left(1 - \frac{1}{4} r(1 - \gamma_t)\right) m_{it} + \frac{1}{4} r(1 - \gamma_t) \sum_{j \neq i} m_{jt} \quad \text{(A4)}
\end{align*}
\]

In any equilibrium of the one-shot PTG, contributions are zero if all agents are rational payoff maximizers, and this is common knowledge among them. Consequently, any subgame perfect equilibrium of the finitely repeated game implies zero contributions in every period. The same is true if the administrator is absent and contributors play a standard PGG with an efficiency factor of \( r \). The predictions change if the PTG is infinitely repeated (or the end is unknown) or if agents have reciprocity concerns. Before turning to the details of the theoretical analysis, we provide a brief summary of the main findings.

Summary of Findings

Infinitely Repeated Interaction: Under repeated interaction with an infinite (or uncertain) horizon, agents face a tradeoff between current and future profits. This gives rise to cooperative outcomes if future profits are considered valuable enough. See Friedman (1971) and the follow-up literature on the folk theorem. In the PTG, the incentives of contributors to cooperate depend on the individual discount factor, other contributors’ behaviour, and the level of rent extraction by the administrator.\(^2\)

\(^2\)While our game is finitely repeated, it is well known that individuals do not make perfect use of backward induction (e.g., Binmore et al. 2002). This makes behaviour in our setting more closely com-
Let us focus on the conditions under which cooperative equilibria exist. First, there is no equilibrium with no or complete rent extraction. Second, increasing the extraction rate above zero raises the critical discount factor for contributors above the level that sustains cooperation in the repeated PGG. Clearly, because rent extraction reduces the true efficiency factor, it diminishes the scope for cooperation. At the same time, increasing the extraction rate decreases the critical discount factor that prevents the administrator from full rent-extraction. This points to a tradeoff in the repeated PTG: the level of anticipated rent extraction affects the incentives to cooperate and, thus, future rent extraction possibilities. As a result, the administrator chooses an intermediate level of rent extraction as long as future profits are valuable enough.

Comparing the infinitely repeated versions of the PTG and the PGG, we find that the critical discount factors that sustain cooperation are identical for both games if we hold the efficiency constant. Hence, the analysis suggests similar levels of cooperation in the PTG and the PGG. We conclude that the evidence from Figure 2 is consistent with a model involving standard preferences and repeated interaction.

**Reciprocity Concerns:** Concerns for reciprocity imply that individuals care about the intentions that accompany actions (Rabin 1993). To understand how concerns for reciprocity might affect play in the PTG, we apply Dufwenberg and Kirchsteiger's (2004) theory of sequential reciprocity to our game (see the online appendix for details). Dufwenberg and Kirchsteiger propose a simple model where agent $i$ perceives agent $j$'s action as kind (unkind) if $i$'s payoff is above (below) the average between her lowest and her highest possible material payoff resulting from $j$'s action. Dufwenberg and Kirchsteiger's utility specification implies an incentive for kindness towards others who have been kind to oneself and vice versa. As it turns out, a Sequential Reciprocity Equilibrium of the one-shot PTG with full contributions exists, if agents' reciprocity concerns are strong enough.

In the PTG extraction affects the scope for contributors’ kindness. With zero extraction, contributors’ decisions do not affect the administrator’s payoff, rendering contributors’ intentions towards her as neither kind nor unkind. As a result, the administrator cannot gain utility from reciprocating kindness. Therefore, reciprocity concerns can never induce the administrator to refrain completely from rent extraction. Furthermore, there exists a threshold level for the extraction rate: below this threshold, a Sequential Reciprocity Equilibrium with full cooperation exists. If rent extraction exceeds the threshold, i.e. if the administrator is too unkind, full cooperation cannot be sustained. Then, kind behaviour of other contributors cannot compensate for the unkind administrator’s behaviour and, thus, motivate positive contributions. Let us finally compare the PTG to a benchmark with an infinite horizon. With this in mind, and because our game is repeated 30 times, we believe that the analysis of the infinite horizon setup provides some valuable insights into the considerations (and incentives) of administrators and contributors.

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3We assume for simplicity that extraction rates are similar across all periods.
the standard PGG without administrator. Because the administrator’s kindness provides an additional motive to contribute (besides other contributors’ kindness), it is easier to sustain cooperation in the PTG than in the PGG whenever the administrator behaves kindly, and vice versa. We conclude that our findings on the overall level of cooperation are also consistent with a model of sequential reciprocity as long as contributors perceive the behaviour of the administrator as neutral.

Revised Interaction in the Public Trust Game

Let us consider repeated interactions and assume that participants share a common discount factor $\delta$. Because the infinitely repeated PTG has a continuum of equilibria (including those equilibria with zero contributions)\(^4\), we focus on conditions on $\delta$ under which full cooperation can be sustained in an equilibrium of the repeated game.

Let us first consider a standard Public Goods Game (PGG) without an administrator. The efficiency factor is $r$. It is well known that, if $\delta$ is sufficiently high, the following grim trigger strategies constitute an equilibrium of the infinitely repeated PGG:

$$m_{it} = \begin{cases} w & \text{if } m_{jt-1} = w \forall j = \{1, \ldots, 4\} \\ 0 & \text{else.} \end{cases}$$

(A6)

This is summarized in the following lemma.

**Lemma 1 (Infinitely Repeated PGG)** The infinitely repeated PGG has an equilibrium where all agents adopt the grim trigger strategy (A6) iff $\delta \geq \delta_{\text{PGG}} = \frac{4 - r}{3r}$.

**Proof.** In the PGG there is no administrator (i.e. $\gamma_t = 0$). It follows from (A4) that

$$x_{it}(m_{it}) = w - \left(1 - \frac{1}{4}r\right)m_{it} + \frac{1}{4}r \sum_{j \neq i} m_{jt}. \quad (A7)$$

Now consider player $i$’s decision to either choose the grim trigger strategies (A6) or to deviate from it given that all other players $j \neq i$ follow these strategies. Contributing $w$ in a given round (and consequently planning to do the same in all upcoming periods) yields a net present value of

$$\pi_i(w) = \sum_{t=0}^{\infty} \delta^t rw = \frac{rw}{1 - \delta}.$$ 

Deviation to $m_{it} = 0$ in a given period implies future zero contributions by all agents and

---

\(^4\)See Friedman (1971) and the follow-up literature on the folk theorem.
yields

\[ \pi_i(0) = rw + (1 - \frac{1}{4}r)w + \delta \sum_{i=0}^{\infty} \delta^i w, \]

\[ = rw + (1 - \frac{1}{4}r)w + \frac{\delta}{1-\delta} w. \]

Cooperation is sustainable if \( \pi_i(w) \geq \pi_i(0) \), i.e.

\[ \frac{rw}{1-\delta} \geq rw + (1 - \frac{1}{4}r)w + \frac{\delta}{1-\delta} w \iff \delta \geq \frac{4-r}{3r}. \]

In the PTG, the incentives of contributors to cooperate depend not only on the discount factor but also on the level of rent extraction by the administrator. Extraction rates are naturally constrained by the potential impact on future profits: an administrator who chooses full rent extraction early in the game could trigger zero future contributions and, thereby, severely limit her further opportunities to generate payoffs. In our analysis, we focus on the question under which levels of rent extraction cooperation can be sustained in equilibrium and how the possibility of rent extraction affects the critical discount factor. For simplicity, we assume that the level of rent extraction is constant \( \gamma_t = \hat{\gamma} \) and contributors expect the administrator to choose \( \hat{\gamma} \) throughout all stages. Let us consider the following grim trigger strategies:

\[
m_{it} = \begin{cases} 
  w & \text{if } m_{jt-1} = w \ \forall j = \{1, \ldots, 4\}, \text{ and } \gamma_{t-1} = \hat{\gamma} \\
  0 & \text{else,}
\end{cases} \quad (A8)
\]

\[
\gamma_t = \begin{cases} 
  \hat{\gamma} & \text{if } m_{jt-1} = w \ \forall j = \{1, \ldots, 4\}, \text{ and } \gamma_{t-1} = \hat{\gamma} \\
  1 & \text{else.}
\end{cases} \quad (A9)
\]

The following proposition states the lowest possible discount factor that sustains full cooperation by the contributors and the associated level of rent extraction by the administrator.

**Proposition 1 (Infinitely Repeated PTG)** The infinitely repeated PTG has an equilibrium where all agents adopt the grim trigger strategies (A8) and (A9) iff \( \delta \geq \delta_{PTG} = \sqrt{\frac{4}{3r} + \frac{1}{36}} - \frac{1}{6} \). In this equilibrium it holds that \( \hat{\gamma} = \hat{\gamma}^* = \frac{7}{6} - \sqrt{\frac{4}{3r} + \frac{1}{36}}. \)

**Proof.** Suppose that all players \( j \neq i \) play the proposed grim trigger strategies (A8) and (A9). A contributor \( i \)'s profit from cooperation in a given period \( t \) is

\[ x_{it}(w) = w - \left(1 - \frac{1}{4}r(1-\hat{\gamma})\right)w + \frac{1}{4}r(1-\hat{\gamma})3w = r(1-\hat{\gamma})w, \]
and her period-profit from deviation is 

\[ x_{it}(0) = w + \frac{3}{4} r(1 - \hat{\gamma})w. \]

For the administrator it holds that 

\[ x_{s\hat{t}}(\hat{\gamma}) = w_5 + 4r\hat{\gamma}w, \]
\[ x_{s\hat{t}}(1) = w_5 + 4rw. \]

The net present value of cooperation for a contributor \( i \) is 

\[ \pi_i(w) = \sum_{t=0}^{\infty} \delta^t \cdot r(1 - \hat{\gamma})w = \frac{r(1 - \hat{\gamma})w}{1 - \delta}. \]

Deviation to \( m_{it} = 0 \) in a given period implies zero contributions in the future and yields 

\[ \pi_i(0) = w + \frac{3}{4} r(1 - \hat{\gamma})w + \delta \sum_{t=0}^{\infty} \delta^t w = w + \frac{3}{4} r(1 - \hat{\gamma})w + \frac{\delta}{1 - \delta}w. \]

The administrator's net present value of choosing \( \hat{\gamma} \) is 

\[ \pi_5(\hat{\gamma}) = \sum_{t=0}^{\infty} \delta^t \cdot (w_5 + 4r\hat{\gamma}w) = \frac{w_5 + 4r\hat{\gamma}w}{1 - \delta}. \]

Deviation to \( \gamma_t = 1 \) in a given period implies zero contributions in the future and yields 

\[ \pi_5(1) = w_5 + 4rw + \delta \sum_{t=0}^{\infty} \delta^t w_5 = w_5 + 4rw + \frac{\delta}{1 - \delta}w_5. \]

Cooperation is sustainable if contributors cooperate and the administrator refrains from full rent extraction. Contributors cooperate if \( \pi_i(w) \geq \pi_i(0) \), i.e. 

\[ \frac{r(1 - \hat{\gamma})w}{1 - \delta} \geq w + \frac{3}{4} r(1 - \hat{\gamma})w + \frac{\delta}{1 - \delta}w \iff \delta \geq \frac{4 - r(1 - \hat{\gamma})}{3r(1 - \hat{\gamma})}. \]

The administrator refrains from full rent extraction if \( \pi_5(\hat{\gamma}) \geq \pi_5(1) \), i.e.

\[ \frac{w_5 + 4r\hat{\gamma}w}{1 - \delta} \geq w_5 + 4rw + \frac{\delta}{1 - \delta}w_5 \iff \delta_5 \geq 1 - \hat{\gamma}. \]

Let us define the critical discount factor of contributors and the administrator as 

\[ \delta_i(\hat{\gamma}) = \frac{4 - r(1 - \hat{\gamma})}{3r(1 - \hat{\gamma})} \quad \text{and} \quad \delta_5(\hat{\gamma}) = 1 - \hat{\gamma}. \]

Noting that \( \frac{d\delta_i}{d\hat{\gamma}} > 0 \) and \( \frac{d\delta_5}{d\hat{\gamma}} < 0 \), we can identify the level of \( \hat{\gamma} \), associated with the lowest possible discount factor that sustains cooperation.
by all parties, by solving

$$\frac{4 - r(1 - \gamma^*)}{3r(1 - \gamma^*)} = 1 - \gamma^*.$$ 

We obtain $\gamma^* = \frac{7}{6} - \frac{q}{4}$ and $\delta = \frac{1}{3}$.

The analysis points to an important tradeoff in the repeated PTG: the level of anticipated rent extraction affects the incentives to cooperate and, thus, future rent extraction possibilities. Consider the case of our experiment ($r = 3$). Whereas a critical discount factor of $\delta \geq \frac{1}{9} \approx 0.11$ sustains cooperation in the PGG, the critical discount factor in the PTG is higher: $\delta_{PTG} = \frac{p}{17} \approx 0.52$. The associated level of rent extraction is $\gamma = \frac{7 - q}{6} \approx 0.48$. Rent extraction affects the efficiency factor and, hence, diminishes the scope for cooperation.

Comparing the infinitely repeated versions of the PTG and the PGG, we find that the critical discount factor in the PTG is identical to the critical discount factor in the PGG with an exogenously given efficiency factor $\gamma = (1 - \gamma)r$. The analysis of the repeated game suggests similar levels of cooperation in the PTG and the reference PGG that we analyze in our experimental setup.

**Reciprocity Concerns in the Public Trust Game**

To shed light on how concerns for reciprocity might affect play in the PTG, we apply Dufwenberg and Kirchsteiger (2004) Theory of Sequential Reciprocity to the (one shot) stage game. Dufwenberg and Kirchsteiger assume that individuals derive utility from material payoffs and reciprocity. The utility is

$$U_i(x_1, \ldots, x_5) = x_i + Y_i \sum_{j \neq i} (\kappa_{ij} \lambda_{iij}),$$

where $x_i$ is the agent’s own material payoff, $Y_i$ is her sensitivity for reciprocity, $\kappa_{ij}$ is $i$’s kindness to agent $j$, and $\lambda_{iij}$ is $i$’s belief about $j$’s kindness to her. Both terms build on $i$’s beliefs about $j$’s behaviour, assuming that $j$’s behaviour coincides with the belief in equilibrium. $\kappa_{ij}$ is the payoff that $i$ gives to $j$ minus the average of the minimum and maximum payoff she could give to $j$. $\lambda_{iij}$ denotes $i$’s belief about her payoff from $j$ minus the average of the minimum and maximum payoff that $j$ could give to $i$. We can establish the following proposition:

**Proposition 2 (Sequential Reciprocity Equilibrium)** Suppose agents are sensitive to reciprocity as in Dufwenberg and Kirchsteiger (2004).

(i) Iff $Y_5 \geq \frac{44}{rw(4 + 15 - 3)}$ and $Y_i \geq \frac{16(1 - \frac{1}{4}(1 - \gamma)r)}{3r^2 w \left[\frac{1}{2} (1 - \gamma)^2 + 3r (1 - 2\gamma)\right]}$ for all $i = \{1, \ldots, 4\}$ a Sequential Reciprocity Equilibrium exists where $\gamma = \frac{1}{4} + \frac{1}{Y_5 rw}$ and $m_i = w$ for all $i = \{1, \ldots, 4\}$. 

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(ii) In a reciprocity equilibrium with full contributions the extraction rate \( \gamma \) is at least \( \frac{1}{4} \) and at most \( \frac{1}{11}(2 + \sqrt{15}) \approx 0.53 \).

**Proof.** For our analysis we need \( \kappa_{i5}, \kappa_{ij}, \kappa_{5i}, \lambda_{ij}, \lambda_{iij}, \) and \( \lambda_{5i5} \). To establish under which conditions a Sequential Reciprocity Equilibrium with full cooperation exists, we study one contributor \( i \)'s utility and the administrator's utility, assuming that all other contributors choose \( m_j = w \). For contributor \( i \)'s utility from reciprocity we define \( j = \{1, \ldots, 4\} \) and \( j \neq i \). For the administrator's utility from reciprocity, \( j \) denotes the group of contributors. For contributor \( i \) we get

\[
\kappa_{i5} = \gamma r m_i - \frac{1}{2} [\gamma r w] \\
= \gamma r (m_i - \frac{1}{2} w),
\]

\[
\lambda_{i5i} = \frac{1}{4} (1-\gamma) r (m_i + 3w) - \frac{1}{2} \left[ \frac{1}{4} r (m_i + 3w) \right] \\
= \frac{1}{4} (m_i + 3w) r \left( \frac{1}{2} - \gamma \right),
\]

\[
\kappa_{ij} = \frac{1}{4} (1-\gamma) r (m_i + 3w) - \frac{1}{2} \left[ \frac{3}{4} (1-\gamma) r w + (1-\gamma) r w \right] \\
= \frac{1}{4} (1-\gamma) r (m_i - \frac{1}{2} w),
\]

\[
\lambda_{ij} = \frac{1}{4} (1-\gamma) r (m_i + 3w) - \frac{1}{2} \left[ \frac{1}{4} (1-\gamma) r (m_i + 2w) + \frac{1}{4} (1-\gamma) r (m_i + 3w) \right] \\
= \frac{1}{8} (1-\gamma) r w.
\]

For the administrator we get

\[
\kappa_{5j} = (1-\gamma) r w - \frac{1}{2} [r w] \\
= (\frac{1}{2} - \gamma) r w, \\
\lambda_{5j} = 4\gamma r w - \frac{1}{2} [3\gamma r w + 4\gamma r w] \\
= \frac{1}{2} \gamma r w.
\]
The administrator’s utility is then

\[ U_5(\gamma) = w_5 + 4\gamma rw + Y_5 \left[ 4 \left( \frac{1}{2} - \gamma \right) rw \right] \left( \frac{1}{2} \gamma rw \right) \]

\[ = w_5 + 4\gamma rw + Y_5 \left[ \gamma r^2 w^2 (1 - 2\gamma) \right]. \]

Reciprocity concerns cannot induce the administrator to abstain from rent extraction. Recall from the experimental design that the administrator could choose any level of rent extraction \( \gamma \in [0, 1] \). Because for \( \gamma = 0 \) no other player can affect the administrator’s payoff, her belief about the kindness of player \( j \) towards her \( (\lambda_{5j}) \) must equal to zero if she chooses \( \gamma = 0 \). In this case, the model implies that the administrator gains no utility from being kind or unkind to the contributors. Differentiation of \( U_5(\gamma) \) with respect to \( \gamma \) yields

\[ \frac{\partial U_5}{\partial \gamma} = 4rw + Y_5 r^2 w^2 (1 - 4\gamma) \geq 0 \]

\( \Leftrightarrow \gamma \leq \frac{1}{4} + \frac{1}{Y_5 \gamma} \) or \( Y_5 \geq \frac{4}{rw(4\gamma - 1)}. \)

Thus the administrator extracts at least one fourth of the pool (if \( Y_5 \) tends to infinity) and extracts more than half of the pool if she has almost no reciprocity concerns, i.e. \( Y_5 < \frac{2}{15} \).

Contributor \( i \)'s utility and the first order condition are given by

\[ U_i(m_i, w, \gamma) = w - m_i + \frac{1}{4} (1 - \gamma) r (m_i + 3w) \]

\[ + Y_i \left[ 3 \left( \frac{1}{4} (1 - \gamma) r (m_i - \frac{1}{2} w) \right) \left( \frac{1}{8} (1 - \gamma) rw \right) \right. \]

\[ + \left( \gamma r (m_i - \frac{1}{2} w) \right) \left( \frac{1}{4} (m_i + 3w) r (\frac{1}{2} - \gamma) \right) \]

\[ = w + m_i \left( \frac{1}{4} (1 - \gamma) r - 1 \right) + \frac{3}{4} (1 - \gamma) rw \]

\[ + Y_i \left[ \frac{3}{32} (1 - \gamma)^2 r^2 w (m_i - \frac{1}{2} w) + \frac{1}{4} \gamma r^2 (m_i - \frac{1}{2} w) (m_i + 3w) (\frac{1}{2} - \gamma) \right], \]

\[ \frac{\partial U_i}{\partial m_i} = \frac{1}{4} (1 - \gamma) r - 1 + Y_i \left[ \frac{3}{32} (1 - \gamma)^2 r^2 w + \frac{1}{4} \gamma r^2 (\frac{1}{2} - \gamma) (2m_i + \frac{5}{2} w) \right] \geq 0. \]

The critical value of the contributors’ sensitivity to reciprocity depends on the level of contributions. In any equilibrium where all contributors choose \( m_i = w \), the FOC sim-
plies to
\[
\frac{\partial U_i}{\partial m_i} = \frac{1}{4}(1-\gamma)r - 1 + Y_i \left[ \frac{3}{32} (1-\gamma)^2 r^2 w + \frac{1}{4} \gamma r^2 (\frac{1}{2} - \gamma)(2w + \frac{5}{2}w) \right] \geq 0
\]
\[\iff Y_i \geq \frac{16(1 - \frac{1}{4}(1-\gamma)r)}{3r^2w[\frac{1}{2}(1-\gamma)^2 + 3\gamma(1-2\gamma)]}.
\]

Note that a Sequential Reciprocity Equilibrium where all contributions equal the endowment can only be established if the extraction rate \(\gamma\) is not too high. If \(\gamma \to \frac{1}{11}(2 + \sqrt{15}) \approx 0.53\), the critical sensitivity for reciprocity \((Y_i)\) approaches infinity. However, because of reciprocal behaviour towards other contributors, there can be non-zero contributions despite unkind administrator behaviour, i.e. \(\gamma > \frac{1}{2}\).

We finally look into the administrator’s minimal sensitivity for reciprocity that ensures an extraction of at most \(\gamma = \frac{1}{11}(2 + \sqrt{15})\), which is the highest possible extraction rate for which non-zero contributions in equilibrium are possible. Substitution of this value of \(\gamma\) into the second equation in (A11) yields a minimal sensitivity for reciprocity of \(Y_{5,\text{min}} = \frac{44}{rw(4\sqrt{15}-3)}\).

**Proposition 3 (Administrator vs. No Administrator)** Suppose agents are sensitive to reciprocity as in Dufwenberg and Kirchsteiger (2004).

(i) If in the PTG extraction behaviour is kind (i.e. \(0 < \gamma < \frac{1}{2}\)), cooperation is easier to sustain in the PTG than in a reference PGG where agents face the same true efficiency factor but no administrator.

(ii) If in the PTG the extraction behaviour is unkind (i.e. \(\gamma > \frac{1}{2}\)), cooperation is easier to sustain in a reference PGG where agents face the same true efficiency factor but no administrator.

**Proof.** Without an administrator, contributor \(i\)’s utility is
\[
U_i(m_i, w, \gamma) = w + m_i \left( \frac{1}{4}(1-\gamma)r - 1 \right) + \frac{3}{4} (1-\gamma)r w + Y_i \left[ \frac{3}{32} (1-\gamma)^2 r^2 w (m_i - \frac{1}{2}w) \right],
\]
which is the utility in (A12) without the reciprocity utility from interaction with the administrator. The FOC is
\[
\frac{\partial U_i}{\partial m_i} = \frac{1}{4}(1-\gamma)r - 1 + Y_i \left[ \frac{3}{32} (1-\gamma)^2 r^2 w \right] \geq 0 \iff Y_i \geq \frac{32(1 - \frac{1}{4}(1-\gamma)r)}{3(1-\gamma)^2 r^2 w}.
\]

To see under which conditions cooperation is easier to sustain in the PTG than in the PGG (holding the true efficiency factor constant), we compare the critical values of \(\gamma_i\)
for both games

\[
\frac{32(1 - \frac{1}{4}(1 - \gamma)r)}{3(1 - \gamma)^2r^2w} \leq \frac{16(1 - \frac{1}{4}(1 - \gamma)r)}{3r^2w[\frac{1}{2}(1 - \gamma)^2 + 3\gamma(1 - 2\gamma)]}
\]

\[
\frac{1}{\frac{1}{2}(1 - \gamma)^2} \leq \frac{1}{\frac{1}{2}(1 - \gamma)^2 + 3\gamma(1 - 2\gamma)} \leq 0.
\]

If cooperation is sustained depends on the administrator's kindness. Whenever her action is kind (i.e. \(0 < \gamma < \frac{1}{2}\)), it is easier to sustain cooperation in the game with an administrator. Whenever her action is unkind, it is easier to sustain cooperation in the absence of an administrator.\(^5\) The reason is that the administrator's kindness adds to the motivational effect of other contributors' kindness.

References


\(^5\)Note that in the case of \(\frac{1}{2}(1 - \gamma)^2 < 3\gamma(1 - 2\gamma)\) no Sequential Reciprocity Equilibrium exists because the extraction rate is too high. In this case, contributors expect excessive extraction by the administrator and therefore would not contribute if there is an administrator.