Managing the Tragedy of the Commons: A Partial Output-Sharing Approach*

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Abstract

This study investigates partial output-sharing as an incentive-based mechanism to mitigate over-extraction in common-pool resource (CPR) environments. Sharing arrangements among resource users can induce free-riding behavior, which may offset over-extraction and promote socially optimal outcomes. In this framework, individuals are pooled into a single group and required to share a proportion of their output evenly with other members. I conduct a laboratory experiment using CPR games with varying levels of mandatory sharing to assess the effectiveness of the partial output-sharing model. The results show that higher levels of sharing significantly reduce appropriation effort, with the treatment aligned with the symmetric Nash equilibrium yielding outcomes statistically indistinguishable from the social optimum. These findings confirm theoretical predictions and demonstrate the behavioral viability of partial output-sharing as a sustainable CPR management tool. Compared to traditional regulatory interventions, this mechanism may be more politically acceptable and directly addresses the core issue of the commons problem—misaligned economic incentives. This study provides novel experimental evidence and lays the groundwork for future research on the practical implementation of partial output-sharing in CPR settings.

Keywords: Common Pool Resource, Collective Action, Group Behavior, Experiments
JEL Codes: C71, C92, Q28

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1 Introduction

Common-pool resources (CPRs) are defined to be natural or man-made resources that are non-excludable and rivalrous. Anyone can extract resources and enjoy its benefits since the resources are open to everyone. One's extraction[1] of resources can exclude others from obtaining benefits from it since the resources are finite. Thus, individuals have the incentive to exploit the resources as much as possible before someone else takes them. Such behavior generates negative externalities, as each individual's appropriation imposes implicit costs on others by making the resource scarcer, raising the marginal cost of extraction, and reducing the marginal benefit due to declining market prices. These externalities can ultimately lead to the depletion of the resource. Since Hardin's (1968) seminal paper, the phenomenon is called '*Tragedy of the Commons*,' where individuals' rational decisions result in sub-optimal outcomes for the community. The most common examples are fishery, forestry, and groundwater irrigation. However, the '*Tragedy of the Commons*' problems are not limited to replenishable resources, but could also apply to non-replenishable resources such as crude oil, natural gas, and other underground resources. Further, the commons dilemma could also be found in environmental resources such as clean air, since excessive pollution leads to environmental damage, biodiversity loss, and global warming (Barrett, 1994).

Several approaches have been proposed to mitigate the tragedy of the commons. Many countries have implemented individual quotas and individual transferable quotas (ITQs) to regulate the harvesting of marine resources by setting a total allowable catch and distributing it among resource users. Territorial user rights for fisheries (TURFs[2]) and Forest User Groups (FUGs[3]) are other top-down approaches to managing resource extraction. In these systems, governments assign area-based property rights to resource users, thereby internalizing incentives for sustainable management.

[1] In this paper, terms such as "extraction," "harvesting," "exploitation," and "appropriation" are used as equivalent terms for devoting effort to obtaining the product of a CPR.

[2] Examples are Maine lobster fishery and Chile shellfish fishery (Steneck et al., 2017).

[3] In Napal, property rights are allocated to communities that have a traditional claim to the forest (Bartlett and Malla, 1992).

While these top-down interventions have shown success in certain settings, an alternative line of research highlights the potential of bottom-up, community-driven solutions that empower resource users to self-organize and manage shared resources collaboratively. Ostrom, Gardner, and Walker (1994) summarize various community-based strategies for overcoming CPR dilemmas. In particular, mechanisms such as face-to-face communication (Ostrom and Walker, 1991), communication with sanctions (Ostrom et al., 1992), and rule proposals with group voting (Walker et al., 2000) exemplify decentralized, participatory approaches.

In addition to both regulatory and community-based governance, another class of solutions, that typically implemented through top-down design, seeks to alter the underlying economic incentives that drive CPR overuse. These incentive-based mechanisms, while centrally imposed, aim to harness individual decision-making rather than restrict it. One such approach is the use of a sharing arrangement. Heintzelman et al. (2009) provides a theoretical framework for how such arrangements can reduce over-extraction. The sharing arrangement induces free-riding behavior, which in turn reduces individuals' incentives to extract excessively. The reduced appropriation could be beneficial in the context of CPRs where resource users tend to over-harvest. Building on this idea, Heintzelman et al. (2009) proposed the full output-sharing model[4] that a socially optimum level of harvesting could be induced by dividing the set of resource users into partnerships in such a way that individual's tendency to over-extract is exactly offset by a tendency to free-ride on others' efforts.

Similarly, Tilman et al. (2018) proposed the partial output-sharing model, in which a socially optimal level of extraction can be achieved by pooling all resource users into a single group and sharing a fraction of the revenue among its members. In this setting, individuals who voluntarily join the output-sharing group are required to share a certain proportion of their output to the group, then the shared outputs are distributed equally among all group members. This arrangement reduces the marginal benefit of extraction by converting part of the private benefit into a public benefit.

[4]Also known as the Partnership Solution (Schott et al., 2007; Heintzelman et al., 2009; Cherry et al., 2015; Buckley et al., 2018).

The resulting incentive structure resembles that of a Pigouvian tax on harvests, in that it imposes an implicit cost on each unit extracted and uses the collected revenue to compensate others. However, unlike a Pigouvian tax, which is typically levied by an external authority and remitted to a government, the output-sharing mechanism is structured as an internal redistribution within the group of resource users. This distinction matters both institutionally and behaviorally: the burden of the intervention is less likely to be perceived as punitive, and the proceeds remain within the community, potentially increasing political acceptability and social cohesion. Despite the theoretical appeal of this mechanism, its behavioral implications, particularly whether individuals respond to internally redistributed sharing rules remain unexplored in experimental settings.

In this study, I conduct a laboratory experiment to evaluate the effectiveness of the partial output-sharing model in addressing the CPR problem. To the best of my knowledge, this is the first laboratory experiment to test the behavioral effects of the model proposed by Tilman et al. (2018). This experimental approach provides novel behavioral evidence on how partial output-sharing influences individual appropriation decisions, offering empirical insight into its practical viability as a CPR management tool.

This study contributes to the literature on CPR management by advancing our understanding of incentive-based solutions, particularly through the lens of partial output-sharing. Sharing arrangements offer several advantages over traditional approaches, such as community-based rule changes. While these methods have proven effective in certain settings, their success often depends on context-specific social norms, trust, and the ability of users to self-organize. In contrast, sharing arrangements directly address the core issue of the commons problem—economic incentives—by modifying payoff structures to encourage sustainable management, even in non-cooperative scenarios. In addition, sharing arrangements are often more politically acceptable, as they allow resource rents to remain within the user group, making them more appealing than taxes. The partial output-sharing model, in particular, introduces a centralized structure that includes all resource users in a single group. By providing behavioral evidence on the performance of this model, my study offers new insights into its potential as a viable and scalable tool for managing CPRs.

The results show that *partial* output-sharing effectively reduces resource appropriation, with appropriation levels approaching socially optimal benchmarks and aligning with theoretical Nash equilibrium predictions. These findings are consistent with prior results from *full* output-sharing studies (Schott et al., 2007; Cherry et al., 2015; Buckley et al., 2018), reinforcing the potential of output-sharing mechanisms as viable strategies for managing common-pool resources.

The remainder of the paper is organized as follows. Section 2 outlines CPR model in detail. Section 3 describes the experimental design and procedures. I present results in Section 4, followed by conclusion and discussion in Section 5. Subject instructions and decision screens are included in the appendix.

2 The common-pool resource model

In the CPR games[5], there are n appropriators with access to the CPR. Each appropriator i has an endowment of e which can be invested either in the CPR or a safe, outside activity. The marginal payoff of the outside activity is equal to w. The payoff to an individual appropriator from investing in the CPR depends on the aggregate group investment in the CPR and on the appropriator investment as a percentage of the aggregate. Let x_i denote appropriator i's investment in the CPR, where $0 \leq x_i \leq e$. The group return to investment in CPR is given by the production function $F(\sum_{j=1}^{n} x_j)$, where F is a concave function, with $F(0) = 0$, $F'(0) > w$, and $F'(ne) < 0$. Initially, investment in the CPR pays better than the opportunity cost of the forgone safe investment $[F'(0) > w]$; but if the appropriators invest all resources in the CPR, the outcome is counterproductive $[F'(ne) < 0]$. Thus, the yield from the CPR reaches a maximum net level when individuals invest some, but not all, of

[5] See Ostrom et al. (1994) for more details.

their endowments in the CPR (See figure 1).

$$
\begin{aligned}
u_i(x) &= we \text{ if } x_i = 0 \\
&= w(e - x_i) + (x_i / \textstyle\sum_{j=1}^{n} x_j) F(\textstyle\sum_{j=1}^{n} x_j) \text{ if } x_i > 0
\end{aligned} \tag{1}
$$

Let the payoff in Equation 1 be the payoff function in a symmetric, non-cooperative game. There is a symmetric Nash equilibrium, with each player investing x_i^* in the CPR, where

$$
-w + (1/n)F'(nx_i^*) + F(nx_i^*)[(n-1)/x_i^* n^2] = 0 \tag{2}
$$

For the optimal solution to the group, summing across individual payoffs $u_i(x)$ for all appropriators i, we have the group payoff function

$$
U(X) = nwe - wX + F(X), \text{ where } X = \textstyle\sum_{j=1}^{n} x_j
$$

which is to be maximized subject to the constraint $0 \leq X \leq ne$. Given the production function F, the group maximization problem has a unique solution characterized by the condition:

$$
-w + F'(X) = 0 \tag{3}
$$

According to Equation 3, the marginal return from the CPR should equal the opportunity cost of the outside alternative for the last unit invested in the CPR. Note that neither the Nash equilibrium investment nor the optimal group investment depends on the endowment e, as long as e is sufficiently large. However, out of equilibrium, a larger e means players are capable of generating larger negative yields when appropriating too much from the CPR.

In experiments that use CPR games, the CPR scenario is modeled using quadratic production functions denoted as $F(X)$, where $F(X) = aX - bX^2$, with conditions $F'(0) = a > w$ and $F'(ne) = a - 2bne < 0$. This quadratic specification leads to a payoff function where the investment level at the symmetric Nash equilibrium $x_i = (a-w)/(n+1)b$ falls between the maximal net yield (the group optimum) condition $x_i = (a-w)/2nb$ and the zero net yield condition $x_i = (a-w)/nb$.

$$\begin{aligned} u_i(x) &= we \text{ if } x_i = 0 \\ &= w(e - x_i) + \big(\frac{x_i}{X}\big)\big(aX - bX^2\big) \text{ if } x_i > 0 \end{aligned} \tag{4}$$

2.1 CPR games and partial output-sharing treatments

I use the CPR game as the baseline game, following the seminal work of Ostrom et al. (1992). In CPR games, subjects are randomly assigned into the group size of n. After the group assignment, subjects are given an endowment e by the experimenter, and they must allocate this endowment between two possible investments. One option is to invest in a safe, outside activity which gives a fixed rate of return, w. The other option is to invest in the CPR which gives variable returns depending on the aggregate group investment in the CPR, X. As the aggregated group investment in the CPR increases, the marginal rate of return from investment in the CPR decreases. The individual payoff for CPR games in each round is expressed in equation 5.

$$\pi_i = w(e - x_i) + x_i(a - bX), \text{ where } X = \textstyle\sum_{j=1}^{n} x_j \tag{5}$$

For the partial output-sharing treatments, two components are added from the baseline CPR games to operationalize the partial sharing among group members. One component is the percentage of sharing arrangement, $\lambda \in [0, 1]$, and the other component is the additional income source from the equal distribution of the shared output from the group. In the partial output-sharing treatments, similar to the CPR games, subjects are randomly assigned into the group size of n. Then, they are given an endowment e to allocate between two possible investments. However, they must share λ percentage of their output from the investment into the CPR. The shared output will be distributed equally to the group members. For example, each player i keeps $(1-\lambda)x_i(a-bX)$ from their own CPR appropriation and shares λ percentage of their output, $\lambda x_i(a-bX)$, then the total shared output is $\lambda X(a-bX)$ which is equally distributed among group members. The λ is the key parameter of the partial output-sharing model since it controls the individual's final payoff, and thus it governs the individual's behavior. As the sharing arrangement λ increases, the benefit of appropriation from CPR decreases, while the benefit from the shared income increases, which results in reduced appropriation of CPR. For example, if an individual decides not to appropriate CPR and stays home, the individual earns $w * e$ plus the amount shared from the group. An individual who decides to appropriate x_i, earns $w * (e - x_i)$ plus their own portion of the output from the appropriation of CPR plus the amount shared from the group (See equation 6).

$$\pi_i = w(e - x_i) + (1 - \lambda)x_i(a - bX) + \frac{\lambda}{n}X(a - bX) \tag{6}$$

We can set the percentage of sharing arrangement, λ to satisfy the investment level at symmetric Nash equilibrium in equation 7 to meet the group optimum condition $x_i = (a - w)/2nb$.

$$x_i = \frac{(1 - \lambda + \lambda/n)a - w}{\big((n+1) - \lambda(n-1)\big)b} \quad \text{or}$$

$$\lambda = \frac{n-1}{n}\Big(\frac{a - (n+1)bx_i}{a + nbx_i}\Big) \tag{7}$$

To calibrate λ so that the symmetric Nash equilibrium appropriation level in Equation

7 coincides with the socially optimal level, we substitute $x_i = (a - w)/2nb$, which yields:

$$\lambda = \frac{a - w}{a + w} \tag{8}$$

This closed-form solution allows us to determine the precise level of sharing needed to induce optimal behavior under self-interested assumptions.

2.2 Parameter choices

I focus on experiments that use the parameter values shown in Table 1. The number of subjects and the individual token endowment are based on the experimental designs of Ostrom et al. (1992), Walker and Gardner (1992), and Ostrom et al. (1994). Other parameters, such as the production function for CPR investment and the fixed return from outside activities, are selected to ensure that both the Nash equilibrium and the socially optimal group investment levels are close to integer values. The parameters are also calibrated to produce a meaningful divergence between individual earnings under the Nash equilibrium and the group maximum. Specifically, the relative payoff difference is approximately 20%[6] on average. The optimal sharing arrangement, denoted by λ, is set to 0.6. This implies that self-interested[7] subjects under a partial output-sharing treatment with $\lambda = 0.6$ will choose to appropriate at the socially optimal level. Figure 2 illustrates the theoretical predictions for individual appropriation levels in the CPR as a function of the sharing arrangement parameter λ, given the chosen parameters.

[6]Computed as the average of two ratios: $(185 - 151)/185 \approx 18.4\%$ and $(185 - 151)/151 \approx 22.5\%$.
[7]Assuming individuals care only about maximizing their own payoffs.

3 Experiments

3.1 Experimental design

The experiment consists of three different CPR games, each varying in the intensity of the sharing arrangement, denoted by λ. For clarity, I refer to these treatments as Game S_{60}, Game S_{30}, and Game S_0 corresponding to 60%, 30%, and 0% output-sharing, respectively.

Game S_0 serves as the baseline and represents the natural CPR environment without any sharing mechanism ($\lambda = 0$). This captures subjects' behavior in the absence of institutional intervention.

Game S_{60} implements a 60% partial output-sharing rule. In this treatment, all subjects are required to participate in the sharing group and contribute 60% of their CPR earnings to the group account, which is then equally redistributed. The choice of $\lambda^* = 0.6$ is based on theoretical predictions: under standard Nash equilibrium assumptions with self-interested agents, this level of sharing leads to socially optimal appropriation.

Game S_{30} introduces a moderate level of output-sharing ($\lambda = 0.3$). Although it is not predicted to induce socially optimal behavior under Nash assumptions, this intermediate treatment serves two purposes. First, it reflects the practical reality that identifying and implementing the precise optimal sharing level may be difficult in the field. Second, it offers insight into how individuals respond behaviorally to moderate versus strong redistribution. While full sharing ($\lambda = 0.6$) is theoretically optimal, it may be perceived as excessive or unfair by some participants, potentially reducing cooperation. In contrast, a moderate level of sharing, such as $\lambda = 0.3$, may feel more acceptable and elicit stronger behavioral responses. Comparing appropriation levels between S_{30} and S_{60} thus allows us to test whether intermediate sharing can perform better than its theoretically superior counterpart due to behavioral resistance to higher redistribution.

There are three different treatment sessions in the experiment. All subjects will play game S_0 first, then subjects play one of the three games-—$S_6$0, S_{30}, or S_0 for the second game. Thus, the experimental design is S_0S_{60}, S_0S_{30}, and S_0S_0. The design has both within-session variation and between-session variation. There are several advantages to this design. First, the institutional changes take place after the natural state, which resembles the real-world implementation. We can observe how subjects react to policy changes that potentially provide insights into how we should implement a partial output-sharing model. Second, playing the baseline game first alleviates the concern for learning during the session. Subjects will gain a sufficient understanding of the game by playing the baseline game for 10 rounds. This will allow me to estimate the treatment effect by comparing the result from the second game S_0, S_{60}, and S_{30}.

3.2 Implementation

The experiment was conducted at the Experimental Economics Center Laboratory at Georgia State University (GSU) in Fall 2024. A total of 144 subjects participated across six experimental sessions, which included three session types: 60% sharing (S_0S_{60}), 30% sharing (S_0S_{30}), and No-sharing (S_0S_0). Each session consisted of three groups of eight participants, totaling 24 subjects per session. Table 3 summarizes the number of sessions, groups, and subjects for each treatment condition. Subjects were recruited using an automated system that randomly invites participants from a pool of around 1,000 students who signed up to participate in economic experiments. Undergraduate students at GSU were invited to participate in this experiment via email. Upon arriving at the lab, subjects were randomly assigned to a laboratory computer terminal. Subjects earned experimental dollars (E$), which was converted to U.S. dollars at the rate of E$200 = U.S. $1 at the end of the session. The experiment was programmed using o-Tree (Chen et al., 2016). Each session lasted approximately one hour. The average payment per subject was $18.93 including a $3 participation fee.

3.3 Procedures

Each session of the experiment had two parts, each with 10 rounds: first game S_0, followed by one of the three games, S_0, S_{60}, or S_{30}. After completing the games, subjects filled out a survey. Subjects were told that their final payoff would be the total of their earnings from both parts.

The session proceeded as follows. At the beginning of a session, subjects read on-screen instructions detailing the experiment. After all subjects completed reading the instructions, the experimenter summarized them and answered any questions. Before starting the experiment, subjects took a short quiz to ensure they understood the consequences of their choices for their payoffs. The computer did not allow subjects to proceed to the next screen until they achieved a perfect score on the quiz. After the quiz, subjects played three practice rounds against the computer. Next, subjects were randomly assigned to a group of eight. They then played 10 rounds of Game S_0 as part 1, followed by either Game S_0, S_{60}, or S_{30} as part 2. Groups remained fixed within each part, but subjects were randomly reassigned to new groups at the beginning of part 2. During the game, subjects decided how much to appropriate from the CPR, denoted as x_i, for each round. After all group members submitted their decisions privately, payoffs for the round were determined. Subjects received information on their own payoffs, including a breakdown of earnings from appropriation, other work, and group sharing. They also received information on the total appropriation by the group and a history of their earnings for each round.

Once they completed part 2, subjects filled out a questionnaire on demographics, strategies, preferences over two games, and questions about Big-Five personality traits using Ten-Item Personality Inventory (Gosling et al., 2003). On top of the payoffs from the games, subjects received a $3 bonus for filling out the questionnaire at the end of the experiment to avoid the income effect of the participation fee. Table 2 shows the experimental procedures.

3.4 Hypotheses

This section outlines three testable hypotheses derived from the theoretical predictions of the partial output-sharing model.

Hypothesis 1 (H1) *Output-sharing reduces over-appropriation compared to no sharing.*

The null hypothesis is that there is no difference in the group (individual) appropriation X (x_i) between the output-sharing treatments, S_{30}, S_{60}, and the no-sharing baseline, S_0.

$$H_0^1 : X^{S_{30}} = X^{S_0} \quad \text{and} \quad X^{S_{60}} = X^{S_0}$$
$$x_i^{S_{30}} = x_i^{S_0} \quad \text{and} \quad x_i^{S_{60}} = x_i^{S_0} \tag{9}$$

with alternative hypothesis is that the group (individual) appropriation X (x_i) in output-sharing treatments, S_{30}, S_{60}, is lower than in the no-sharing baseline, S_0.

$$H_A^1 : X^{S_{30}} < X^{S_0} \quad \text{and} \quad X^{S_{60}} < X^{S_0}$$
$$x_i^{S_{30}} < x_i^{S_0} \quad \text{and} \quad x_i^{S_{60}} < x_i^{S_0} \tag{10}$$

Hypothesis 2 (H2) *Stronger output-sharing further reduces over-appropriation.*

The null hypothesis is that there is no difference in group (individual) appropriation X (x_i) between the strong-sharing treatment, S_{60}, and the weak-sharing treatment, S_{30}.

$$H_0^2 : X^{S_{60}} = X^{S_{30}}$$
$$x_i^{S_{60}} = x_i^{S_{30}} \tag{11}$$

The alternative hypothesis is that group (individual) appropriation X (x_i) is lower in the stronger-sharing treatment, S_{60}, than in S_{30}.

$$H_A^2 : X^{S_{60}} < X^{S_{30}}$$
$$x_i^{S_{60}} < x_i^{S_{30}} \tag{12}$$

Hypothesis 3 (H3) *Subjects will appropriate at the socially optimum level in the partial output-sharing model.*

The null hypothesis is that the observed group (individual) appropriation X (x_i) and earnings u_i in the S_{60} treatment are equal to the theoretical social optimum and the corresponding maximum payoff.

$$H_0^3 : X^{S_{60}} = X^{\text{opt}} \quad \text{and} \quad u_i^{S_{60}} = u_i^{\text{max}} \tag{13}$$

The alternative hypothesis is that group (individual) appropriation and earnings in the S_{60} treatment differ significantly from the social optimum and maximum payoff.

$$H_A^3 : X^{S_{60}} \neq X^{\text{opt}} \quad \text{or} \quad u_i^{S_{60}} \neq u_i^{\text{max}} \tag{14}$$

To evaluate the hypotheses, I compare average appropriation and earnings across treatments and game phases. For Hypotheses H1 and H2, I analyze mean appropriation in the second half of the CPR games. For Hypothesis H1, I test whether average group and individual appropriation in the output-sharing treatments (S_{30} and S_{60}) is significantly lower than in the baseline (S_0). A rejection of the null hypothesis supports the claim that output-sharing reduces over-appropriation. For Hypothesis H2, I test whether appropriation in the strong-sharing treatment (S_{60}) is significantly lower than in the weak-sharing treatment (S_{30}). A rejection of the null in this case would indicate that higher levels of sharing further reduce appropriation. To evaluate Hypothesis H3, I compare observed group appropriation and individual earnings in the S_{60} treatment to the theoretical social optimum and corresponding maximum payoff. If the observed values are statistically indistinguishable from these optimal benchmarks, I fail to reject the null hypothesis, indicating that subjects under strong output-sharing behave in accordance with socially optimal outcomes.

I also estimate the average treatment effect of the partial output-sharing model using both between-subjects and within-subjects comparisons. To account for potential learning dynamics, the initial rounds of each part are excluded from the main analysis.

4 Results

4.1 Aggregate appropriation

This section reports the aggregate group appropriation of CPR across periods and compares it to the group's Nash equilibrium benchmarks for each treatment. Figure 3 plots mean group-level appropriation over time (solid lines) against Nash equilibrium predictions (dashed lines) for the three treatments: No Sharing (black circles), 30% Sharing (green squares), and 60% Sharing (red triangles). The observed mean appropriations are 117.3, 99.8, and 65.3 for the no-sharing, 30%, and 60% sharing treatments, respectively. These values closely align with the theoretical Nash predictions of 112, 96, and 64. In the no-sharing treatment, mean aggregate group appropriation appears to oscillate between 100 and 120, consistent with findings reported by Ostrom et al. (1994) for CPR games. In the sharing treatments, mean aggregate appropriation appears to converge to the Nash equilibrium levels of 96 and 64 for the 30% and 60% sharing treatments, respectively, results that are consistent with those reported by Schott et al. (2007) for full output-sharing treatments. The right panel of Figure 3 shows the mean aggregate appropriation for periods 4–9, excluding potential noise from early learning effects and end-of-period behavior. The overall pattern remains consistent: both sharing treatments lead to reduced appropriation, with the 60% sharing treatment yielding the most substantial decline.

The reduction in aggregate group appropriation is more evident when examining the between-subjects mean comparison by treatment. Figure 4 presents the mean aggregate group appropriation across treatments. The left panel shows mean appropriation during the first (baseline) games, and the right panel shows mean appropriation during the second (treatment) games. The lack of differences across treatments in the baseline (left panel) indicates that randomization of subjects across treatments was successful, as baseline behavior does not differ systematically across treatment groups. It also reflects a consistent pattern of higher appropriation in the absence of sharing incentives, characteristic of over-extraction behavior in CPR environments. In contrast, the right panel shows a notable reduction in mean appropriation under both sharing treatments, supporting Hypothesis H1: subjects appropriate less in the partial output-sharing model than in the baseline model.

Table 4 presents OLS regression estimates of aggregate group appropriation by treatment assignment. The results confirm that both sharing treatments significantly reduce appropriation compared to the no-sharing baseline, with the 60% sharing treatment associated with the largest reduction. These findings reinforce the experimental evidence that stronger sharing incentives lead to more restrained use of common-pool resources.

Result 1: Hypothesis H1 is supported. Group appropriation is significantly reduced under the output-sharing treatments compared to the baseline (i.e., no sharing).

Result 2: Hypothesis H2 is supported. The 60% sharing treatment achieved the lowest aggregate appropriation, indicating stronger restraint from over-extraction compared to the 30% sharing group. This trend aligns with Hypothesis H2, which suggested that higher sharing intensity leads to lower overall appropriation.

4.2 Individual appropriation

Figure 5 depicts mean individual appropriation across treatments. The left panel shows mean appropriation during the first (baseline) games, and the right panel shows mean appropriation during the second (treatment) games. Consistent with the group-level results, individual appropriation remains high across all treatments in the baseline games (left panel) and decreases following the introduction of the sharing treatments (right panel). This provides evidence that partial output-sharing induces behavioral changes at the individual level, leading to reduced resource extraction.

Table 5 presents OLS regression estimates of individual appropriation by treatment assignment. The results confirm that both sharing treatments significantly reduce individual appropriation compared to the no-sharing baseline, with the 60% sharing treatment associated with the largest reduction.

To further assess the consistency between observed behavior and theoretical predictions, Figure 6, it compares the observed average individual appropriation in each treatment with theoretical benchmarks—specifically the symmetric Nash equilibrium for no sharing baseline and social optimum levels, as illustrated in Figure 2. The theory predicts that as the proportion of sharing (λ) increases, average individual appropriation declines, reaching the social optimum at 60% sharing. The observed mean individual appropriations—14.1 for no sharing, 12.4 for 30% sharing, and 9.1 for 60% sharing—–closely align with the theoretical predictions of 14, 12, and 8, respectively. The observed behaviors are not statistically different from the theoretical predictions at the 95% confidence level, suggesting that participants adjusted their behavior in response to the sharing incentives in a manner consistent with theoretical expectations.

Result 3: Hypothesis H3 is supported. The mean individual appropriation in the 60% sharing treatment is 9.1, which is not statistically different from the socially optimal appropriation level of 8 at a 95% confidence level.

4.3 Earnings

Figure 7 displays the distribution of individual earnings during the treatment phase across the three treatments. Mean individual earnings (indicated by dotted lines) are highest under the 60% sharing treatment and lowest under the no-sharing baseline. Additionally, the 60% sharing treatment exhibits the lowest variance in earnings, suggesting a more equitable distribution of payoffs among participants by design. These findings support Hypothesis H3, which posits that the social optimum is achieved under the 60% sharing treatment. The lower mean earnings in the no-sharing condition reflect the inefficiencies associated with CPR over-extraction. In contrast, the upward trend in mean earnings with increasing sharing intensity implies that partial output-sharing not only mitigates over-extraction but also improves overall earnings, benefiting participants collectively. Table 6 and Table 7 present OLS regression estimates of total individual earnings over 10 periods and mean individual earnings per period, respectively.

4.4 Subgroup Analysis: Gender and Big Five Personality Traits

This section explores treatment heterogeneity by gender and Big Five personality traits, using both between-subjects and within-subjects comparisons. Personality traits were measured using the Ten-Item Personality Inventory (TIPI; Gosling et al., 2003). Participants rated themselves on a 1–7 Likert scale for two items per trait: one positively worded and one negatively worded (reverse-coded). Trait scores were calculated as the average of the non-reverse minus reverse item responses. A subject is categorized as high in a given trait (i.e., Extraversion, Agreeableness, Conscientiousness, Openness, or Neuroticism) if their score was equal to or greater than one.

Figure 8 presents the between-subjects results. The left panel displays treatment effects for the 60% sharing condition, while the right panel shows results for the 30% sharing treatment. In this specification, treatment effects are estimated by comparing average appropriation behavior during the second phase of the experiment across different treatment sessions. The results suggest that male participants reduced their appropriation more than female participants in both treatment conditions. In the 60% sharing treatment, differences across personality traits are small and statistically insignificant. In contrast, in the 30% sharing treatment, Extraverted individuals appear to reduce their appropriation more than others, although this difference is only marginally significant.

Figure 9 presents the within-subjects analysis. The left and right panels show estimated treatment effects for the 60% and 30% sharing treatments, respectively. In this approach, treatment effects are computed as the difference in appropriation between the first (baseline) and second (treatment) phases within the same subject. Consistent with the between-subjects results, male participants reduced their appropriation more than female participants. Among the personality subgroups, no statistically significant differences were observed in either treatment condition. However, similar to the between-subjects results, Extraverted participants in the 30% sharing treatment appear to reduce their appropriation more than others, though the differences are not statistically significant.

5 Conclusion and Discussion

5.1 Conclusion

This study examined the effectiveness of partial output-sharing as a mechanism for managing CPRs. Using a laboratory experiment, I tested the impact of different levels of output-sharing on individuals' resource extraction behavior. The results indicate that partial output-sharing significantly reduces over-extraction and leads to higher collective earnings, thereby supporting socially optimal outcomes.

Specifically, the findings show that increasing the proportion of output shared among participants reduces the incentive to over-extract. The 60% sharing treatment yielded appropriation levels that were not statistically different from the social optimum, while also generating the highest individual earnings and the lowest variance across participants. These results suggest that the partial output-sharing model can effectively align individual incentives with the collective interest in resource sustainability.

The results further demonstrate the potential of partial output-sharing as a viable policy tool for enhancing the sustainability of common resources. While it is difficult to draw definitive conclusions about real-world effectiveness from a single laboratory experiment, the evidence presented here offers valuable insights into a promising approach to CPR management.

The implications of these findings are substantial for the design of CPR management policies. Partial output-sharing presents a promising alternative to traditional top-down regulatory approaches, as it retains resource rents within the community and enhances political acceptability. Future research should explore practical avenues for implementation, such as testing voluntary participation and alternative governance structures.

Overall, this study suggests that partial output-sharing is an effective institutional tool for mitigating the 'Tragedy of the Commons' and improving sustainability outcomes in CPR settings, ultimately benefiting all participants.

5.2 Discussion

While the full output-sharing model, often referred to as the Partnership Solution, has demonstrated effectiveness in laboratory settings, its applicability in real-world environments remains questionable. For instance, Cherry et al. (2015) show that full output-sharing can reduce appropriation effort and promote socially optimal outcomes under controlled conditions. However, whether these results translate into field settings is less clear, particularly given the complexity of real-world motivations.

Platteau and Seki (2001) highlights this concern through a study of Japanese fishery communities that implement pooling arrangements within small groups. Interestingly, in interviews with fishermen, the dominant rationale for joining output-sharing groups was not to insure against low catches or reduce individual effort, as predicted by free-riding logic.

Instead, the primary motivation was to avoid congestion at lucrative fishing spots. This suggests that the behavioral mechanisms underpinning full output-sharing in theory may not fully align with those observed in practice. In some cases, such arrangements may even reinforce extractive behaviors, as partnerships are formed to maximize access rather than to limit it.

By contrast, the partial output-sharing model explored in this study may offer a more behaviorally robust and field-relevant solution. Unlike full output-sharing, partial sharing maintains individual autonomy while still modifying incentives through shared redistribution. This design preserves a clear link between individual effort and earnings, while simultaneously internalizing the social cost of over-extraction. Furthermore, its centralized structure, in which all users belong to a single sharing group, offers administrative simplicity and stability, avoiding the coordination issues that can arise in forming and maintaining smaller, dynamic partnerships.

5.3 Future Work

The partial output-sharing model can be further explored in laboratory settings that more closely mimic real-world environments. Once sufficient behavioral insights are gained through controlled experiments, the model can be tested in field settings, such as fisheries, to evaluate its practical implementation and effectiveness in natural contexts.

One promising extension involves introducing voluntary participation. In the current experiment, all participants were required to join the sharing group. In a follow-up study, subjects could begin each round in the natural (non-sharing) state and choose whether to opt into the partial output-sharing group. To incentivize participation, mechanisms such as sign-up bonuses could be introduced. Once a subject chooses to join, they would remain in the group for the remainder of the experiment. This design would provide valuable insight into voluntary engagement with sustainability initiatives and help inform real-world implementation strategies.

Another direction is to examine how decisions about the sharing level are made—specifically, comparing centralized versus decentralized governance structures. In a centralized setting, subjects could vote to elect a leader who decides the sharing proportion on behalf of the group. In a decentralized setting, group members would collectively discuss and reach a consensus on the sharing level. This experiment would offer insight into whether participants or designated leaders are better able to identify and implement optimal sharing arrangements, and whether such systems can still support socially optimal appropriation outcomes. These extensions would contribute to a more nuanced understanding of how partial output-sharing can be adapted and scaled for practical use.

References

Barrett, Scott (1994), "Self-enforcing international environmental agreements." *Oxford economic papers*, 46, 878–894.

Bartlett, AG and YB Malla (1992), "Local forest management and forest policy in nepal." *Journal of World Forest Resource Management*, 6, 99–99.

Buckley, Neil J, Stuart Mestelman, R Andrew Muller, Stephan Schott, and Jingjing Zhang (2018), "The effects of communication on the partnership solution to the commons." *Environmental and Resource Economics*, 70, 363–380.

Chen, Daniel L, Martin Schonger, and Chris Wickens (2016), "otree—an open-source platform for laboratory, online, and field experiments." *Journal of Behavioral and Experimental Finance*, 9, 88–97.

Cherry, Josh, Stephen Salant, and Neslihan Uler (2015), "Experimental departures from self-interest when competing partnerships share output." *Experimental Economics*, 18, 89–115.

Gosling, Samuel D, Peter J Rentfrow, and William B Swann Jr (2003), "A very brief measure of the big-five personality domains." *Journal of Research in personality*, 37, 504–528.

Hardin, Garrett (1968), "The tragedy of the commons: the population problem has no technical solution; it requires a fundamental extension in morality." *science*, 162, 1243–1248.

Heintzelman, Martin D, Stephen W Salant, and Stephan Schott (2009), "Putting free-riding to work: a partnership solution to the common-property problem." *Journal of Environmental Economics and Management*, 57, 309–320.

Ostrom, Elinor, Roy Gardner, James Walker, James M Walker, and Jimmy Walker (1994), *Rules, games, and common-pool resources*. University of Michigan Press.

Ostrom, Elinor and James Walker (1991), "Communication in a commons: cooperation without external enforcement." *Laboratory research in political economy*, 287–322.

Ostrom, Elinor, James Walker, and Roy Gardner (1992), "Covenants with and without a sword: Self-governance is possible." *American political science Review*, 86, 404–417.

Platteau, Jean-Philippe and Erika Seki (2001), "Community arrangements to overcome market failures: pooling groups in japanese fisheries." In *Communities and markets in economic development*, 344–402, Oxford Univerity Press; Oxford.

Schott, Stephan, Neil J Buckley, Stuart Mestelman, and R Andrew Muller (2007), "Output sharing in partnerships as a common pool resource management instrument." *Environmental and Resource Economics*, 37, 697–711.

Steneck, Robert, Ana M Parma, Billy Ernst, and James A Wilson (2017), "Two lobster tales: lessons from the convergent evolution of turfs in maine (usa) and the juan fernández islands (chile)." *Bulletin of Marine Science*, 93, 13–33.

Tilman, Andrew R, Simon Levin, and James R Watson (2018), "Revenue-sharing clubs provide economic insurance and incentives for sustainability in common-pool resource systems." *Journal of theoretical biology*, 454, 205–214.

Walker, James M and Roy Gardner (1992), "Probabilistic destruction of common-pool resources: experimental evidence." *The Economic Journal*, 102, 1149–1161.

Walker, James M, Roy Gardner, Andrew Herr, and Elinor Ostrom (2000), "Collective choice in the commons: Experimental results on proposed allocation rules and votes." *The Economic Journal*, 110, 212–234.

Figures and Tables

Figure 1: Production function for CPRs

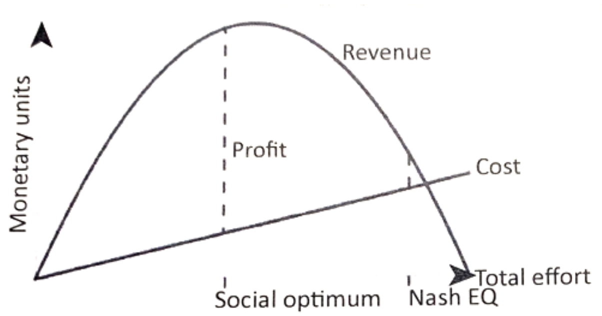
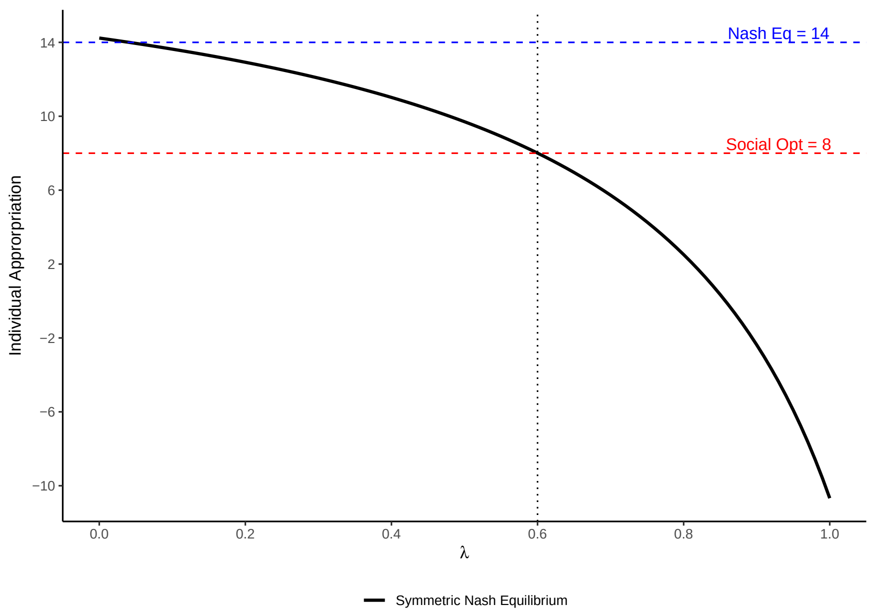
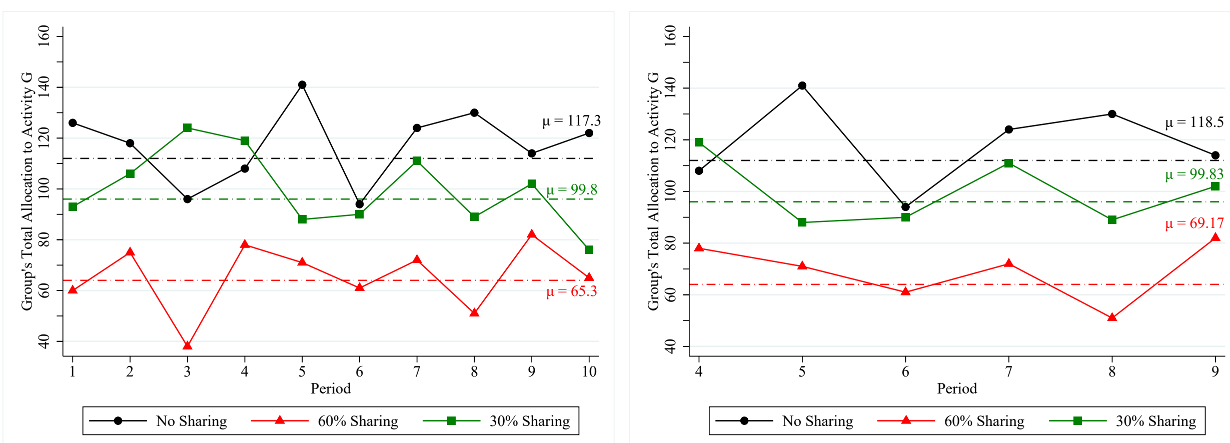


Figure 2: Individual Appropriation Theoretical Benchmark



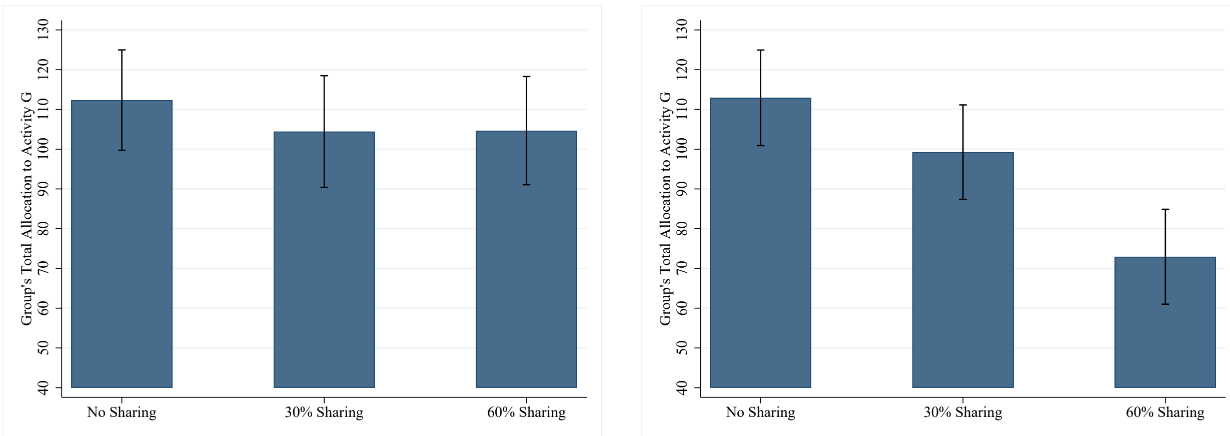
Notes: The figure illustrates theoretical individual appropriation levels as a function of the sharing parameter λ. The curve represents the predicted individual appropriation under the symmetric Nash equilibrium. Dashed horizontal lines indicate the Nash equilibrium level for no sharing baseline (blue, 14) and the social optimum (red, 8).

Figure 3: Aggregate Group Appropriation by Treatment



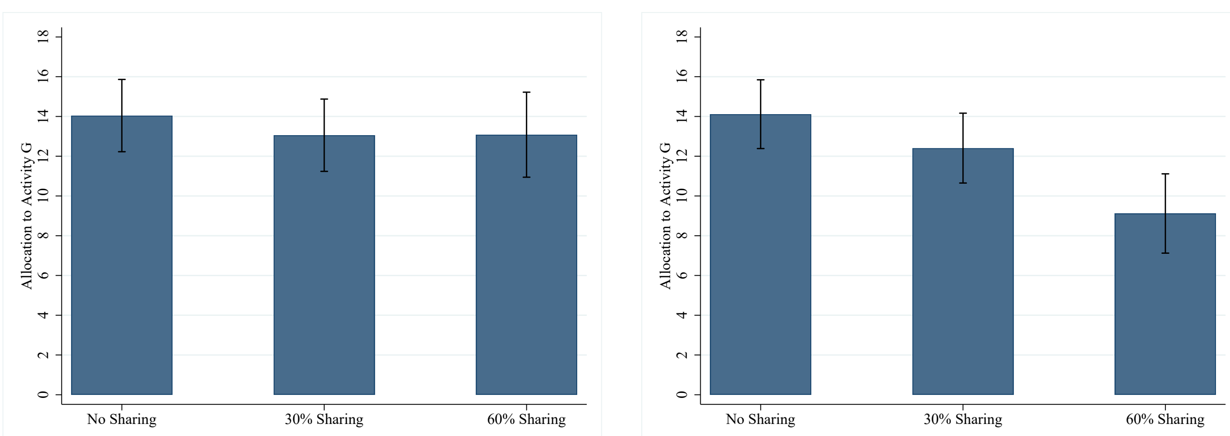
Notes: The left panel shows aggregate group appropriation by treatment over periods 1–10, and the right panel focuses on periods 4–9. Solid lines represent group appropriation in each period, while dashed lines indicate the group's Nash equilibrium for each treatment: 112 for the no-sharing treatment, 96 for the 30% sharing treatment, and 64 for the 60% sharing treatment. Red triangles correspond to the 60% sharing treatment, green squares to the 30% sharing treatment, and black circles to the no-sharing treatment.

Figure 4: Mean Aggregate Group Appropriation by Treatment (Between-Subjects Comparison)



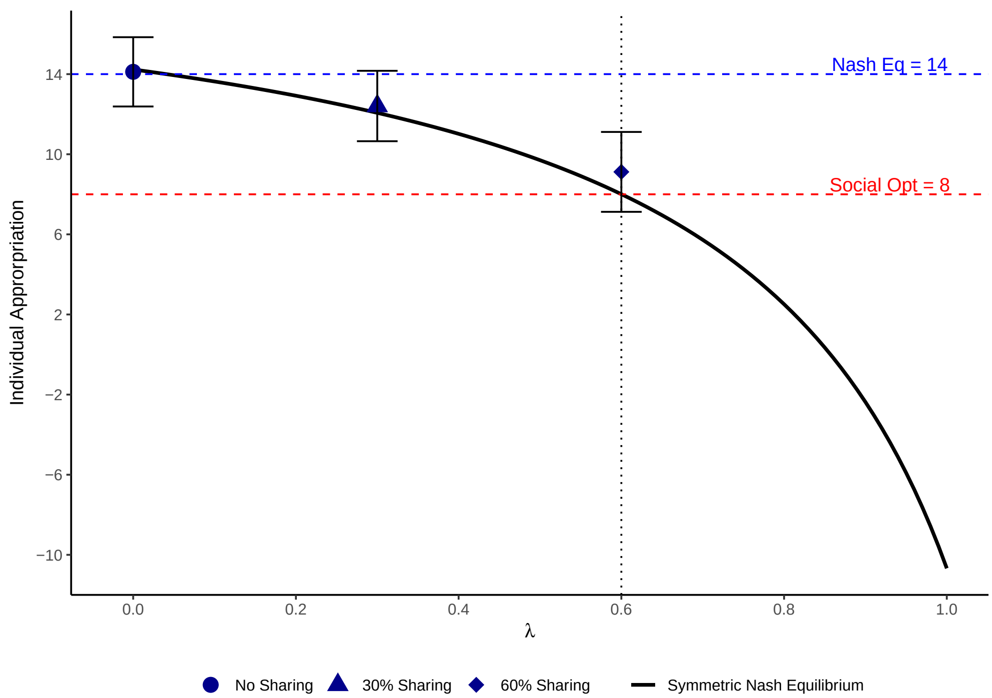
Notes: The left panel shows the mean aggregate group appropriation in the first (baseline) games by treatment. The right panel shows the mean aggregate group appropriation in the second (treatment) games by treatment. Error bars represent 95% confidence intervals.

Figure 5: Mean Individual Appropriation by Treatment (Between-Subjects Comparison)



Notes: The left panel shows the mean individual appropriation in the first (baseline) games by treatment. The right panel shows the mean individual appropriation in the second (treatment) games by treatment. Error bars represent 95% confidence intervals.

Figure 6: Theory Prediction vs. Mean Individual Appropriation by Treatment

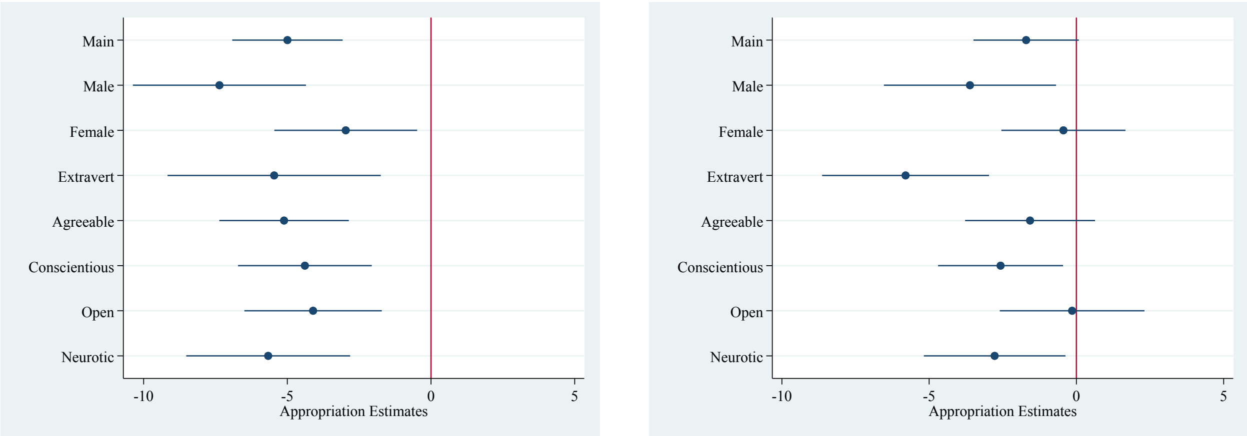


Notes: The figure compares mean individual appropriation across treatments with theoretical benchmarks. Circle represents the no-sharing treatment, triangle represents the 30% sharing treatment, and diamond represents the 60% sharing treatment. The x-axis shows the level of the sharing parameter λ, and the y-axis shows individual appropriation levels. Dashed lines indicate the symmetric Nash equilibrium for no sharing baseline (blue, 14) and the social optimum (red, 8). Error bars represent 95% confidence intervals.

Figure 7: Distributions of Individual Earnings by Treatment

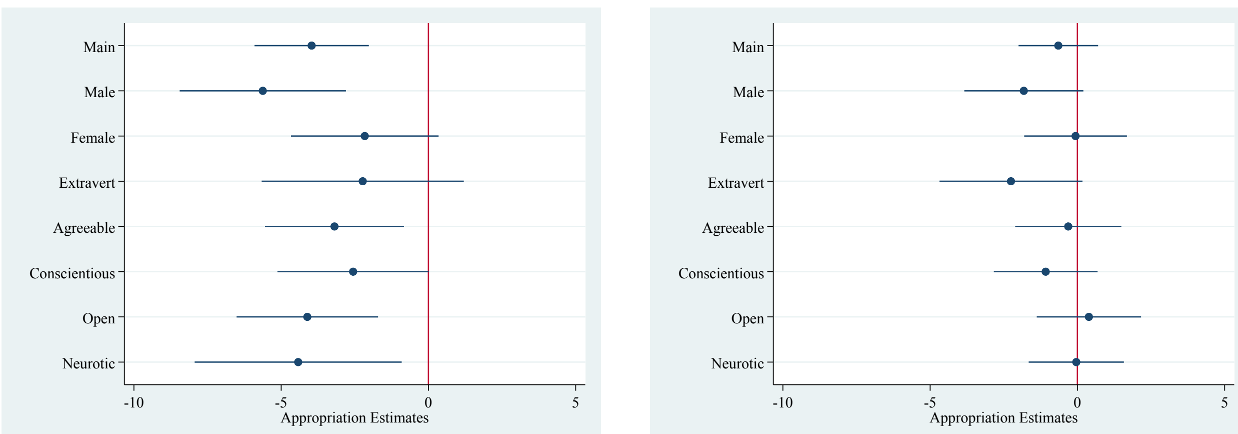
Notes: The figure shows kernel density estimates of individual earnings across treatments. Earnings are measured in hundreds of experimental dollars. The black, green, and red lines represent the no sharing, 30% sharing, and 60% sharing treatments, respectively. Vertical dashed lines indicate the mean earnings for each treatment.

Figure 8: Treatment Effects by Gender and Big Five Personality Traits (Between-Subjects Comparison)



Notes: Treatment effects are based on a between-subjects comparison and are stratified by gender and Big Five personality traits. The left panel displays the effect of the 60% sharing treatment, and the right panel displays the effect of the 30% sharing treatment. Error bars represent 95% confidence intervals.

Figure 9: Treatment Effects by Gender and Big Five Personality Traits (Within-Subjects Comparison)



Notes: Treatment effects are based on a within-subjects comparison and are stratified by gender and Big Five personality traits. The left panel displays the effect of the 60% sharing treatment, and the right panel displays the effect of the 30% sharing treatment. Error bars represent 95% confidence intervals.

Table 1: Parameters for a Given Decision Round

	Notations	Parameters
Number of subjects	N	8
Individual effort endowment	e	25
Production function	$aX - bX^2$	$20X - 0.1171X^2$
Activity A return/ unit of output	w	E$ 5
Nash equilibrium allocation in Activity B		14
Group optimal allocation in Activity B		8
Earnings/ subject at group maximum		E$ 185
Earnings/ subject at Nash equilibrium		E$ 151
Earnings difference: Nash vs Group max (%)		20%
Optimum sharing arrangement	λ^*	0.60

Table 2: Experimental Procedures

Part 1	Common-Pool Resource Game S_0
	Instructions for CPR Game S_0
	Quiz and Practice
	Game S_0: 10 Rounds
Part 2	Common-Pool Resource Game S_0 or S_{60} or S_{30}
	Instructions for CPR Game S_0 *or* S_{60} *or* S_{30}
	Quiz and Practice
	Game S_0 or S_{60} or S_{30}: 10 Rounds
	Payoff: Pay all sequentially.
Post-Survey	Demographics, Strategies, Big-Five personality traits
	Payoff: $3

Table 3: Experiment Details

	Session Types		
	No Sharing	30% Sharing	60% Sharing
Number of sessions	2	2	2
Group size	8	8	8
Number of groups	6	6	6
Number of subjects	48	48	48

Table 4: OLS Regression of Group Total Appropriation of CPR

	Group Total Appropriation			
	Between	Within		
	(1)	(2)	(3)	(4)
60% Sharing	-39.97***	-31.72***		
	(2.445)	(3.815)		
30% Sharing	-13.65***		-5.183*	
	(3.362)		(2.541)	
No Sharing				0.567
				(1.436)
Constant	112.9***	104.7***	104.5***	112.3***
	(1.582)	(1.908)	(1.271)	(0.718)
Observations	180	120	120	120

Notes: The dependent variable is group total appropriation on CPR. “60% Sharing,” “30% Sharing,” and “No Sharing” are dummy variables equal to 1 if the subject is in the corresponding treatment condition, and 0 otherwise. Controls include gender, race, school year, average GPA, and STEM majors. Column (1) presents between-subjects estimates by comparing group total appropriation during the second phase of the experiment across treatment sessions. Columns (2), (3), and (4) report within-subjects estimates, comparing the change in group total appropriation between the first (baseline) and second (treatment) phases within the same session; Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: OLS Regression of Individual Appropriation of CPR

	Individual Appropriation			
	Between	Within		
	(1)	(2)	(3)	(4)
60% Sharing	-4.996***	-3.965***		
	(0.980)	(0.990)		
30% Sharing	-1.706*		-0.648	
	(0.912)		(0.690)	
No Sharing				0.0708
				(0.400)
Constant	14.11***	13.08***	13.06***	14.04***
	(0.643)	(0.495)	(0.345)	(0.200)
Fixed Effects		X	X	X
Observations	1440	960	960	960

Notes: The dependent variable is individual appropriation on CPR. "60% Sharing," "30% Sharing," and "No Sharing" are dummy variables equal to 1 if the subject is in the corresponding treatment condition, and 0 otherwise. Controls include gender, race, school year, average GPA, and STEM majors. Column (1) presents between-subjects estimates by comparing individual appropriation during the second phase of the experiment across treatment sessions. Columns (2), (3), and (4) report within-subjects estimates, comparing the change in individual appropriation between the first (baseline) and second (treatment) phases within the same session. All within-subjects specifications include individual fixed effects. Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: OLS Regression of Individual Earnings over 10 Periods

	Individual Earnings over 10 Periods				
	Between		Within		
	(1)	(2)	(3)	(4)	(5)
60% Sharing	338.4***	321.6***	262.6***		
	(15.09)	(17.74)	(25.44)		
30% Sharing	168.8***	164.6***		70.18***	
	(19.35)	(21.26)		(23.71)	
No Sharing					-4.683
					(13.64)
Constant	1467.9***	1373.7***	1543.7***	1566.6***	1472.6***
	(14.156)	(60.958)	(12.718)	(11.855)	(6.819)
Controls		X			
Fixed Effects			X	X	X
Observations	144	144	96	96	96

Notes: The dependent variable is total individual earnings over 10 periods. "60% Sharing," "30% Sharing," and "No Sharing" are dummy variables equal to 1 if the subject is in the corresponding treatment condition, and 0 otherwise. Controls include gender, race, school year, average GPA, and STEM majors. Column (1) presents between-subjects estimates by comparing total individual earnings during the second phase of the experiment across treatment sessions. Columns (2), (3), and (4) report within-subjects estimates, comparing the change in total individual earnings between the first (baseline) and second (treatment) phases within the same session. All within-subjects specifications include individual fixed effects. Standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7: OLS Regression of Mean Individual Earnings per Period

	Individual Earnings for Periods				
	Between		Within		
	(1)	(2)	(3)	(4)	(5)
60% Sharing	33.84***	32.16***	23.96***		
	(2.260)	(2.471)	(2.778)		
30% Sharing	16.88***	16.46***		7.018***	
	(3.954)	(4.009)		(2.360)	
No Sharing					-0.468
					(1.357)
Constant	146.8***	137.4***	156.7***	156.7***	147.3***
	(2.098)	(5.009)	(1.389)	(1.180)	(0.679)
Controls		X			
Fixed Effects			X	X	X
Observations	1440	1440	960	960	960

Notes: The dependent variable is individual earnings per period. "60% Sharing," "30% Sharing," and "No Sharing" are dummy variables equal to 1 if the subject is in the corresponding treatment condition, and 0 otherwise. Controls include gender, race, school year, average GPA, and STEM majors. Column (1) presents between-subjects estimates by comparing individual earning per period during the second phase of the experiment across treatment sessions. Columns (2), (3), and (4) report within-subjects estimates, comparing the change in individual earning per period between the first (baseline) and second (treatment) phases within the same session. All within-subjects specifications include individual fixed effects. Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Appendix A. Subject Instructions

General Information

Welcome

No Talking Allowed
Now that the experiment has begun, we ask that you do not communicate with other participants. If you have any questions after we finish reading the instructions, please raise your hand and the experimenter will answer your question in private.

Complete Privacy
This experiment is structured so that no one, including the experimenters, the monitor, and the other subjects will ever know the personal decision of anyone in the experiment. Every person's privacy is guaranteed because neither his/her name nor student ID number will appear on any form that records decisions in this experiment.

Random Matching and Anonymity
In this experiment, you will be randomly assigned to a group of 8 people. The group you are assigned to will stay the same throughout each part. The group will be reassigned randomly at the beginning of Part 2.

Two Parts: 10 Rounds Each
In this experiment, there will be two parts, each consisting of ten rounds. Your final earnings will be the sum of the earnings from both parts.

Cash Payoffs
Your earnings in this experiment are expressed in EXPERIMENTAL Dollars (E$), which we will refer to as E$. At the conclusion of the experiment you will be paid in U.S. dollars using a conversion rate of $1 for every E$ 200 of earnings from the experiment.

E$ 200 = $1

If you read the instructions carefully and act wisely, you can earn a considerable amount of money. Your earnings in this experiment depend both on your decisions and the decisions of others.

If you have any questions, please raise your hand and wait for the experimenter to come and help you.

Part 1: S_0-Baseline

Settings
You will be playing an **effort allocation game** in a group of 8 people. In each round, you will decide how to allocate efforts between two different activities. Each round, you are endowed with **25 efforts** and must decide how many to allocate to **Activity F** and **Activity G**.

- **Activity F**: For each effort allocated to Activity F, you will receive a **fixed return of E$5**.
- **Activity G**: The return on efforts allocated to Activity G is **variable** and depends on the **total efforts allocated by the entire group, including yours**.

  The return for each effort allocated to Activity G is:

  $$\mathbf{20 - 0.1171 * (group's\ total\ effort\ allocated\ to\ Activity\ G)\ E\$\ per\ effort}$$

Note that the return from Activity G **decreases** as the total efforts allocated to Activity G by the group **increases**.

Your earnings for each round will depend on both **your own decisions** and the decisions of **others in your group**.

Multiple Rounds
The part 1 consists of **10 decision rounds**. In each round, you will face the same decision task, where you will allocate efforts between Activity F and Activity G.

Earnings
After everyone has submitted, the earnings of the round will be calculated and shown to you. For each round, your earnings are:

- Earnings from **Activity F**
- Earnings from **Activity G**

Your final earnings will be the sum of every round's earnings.

Example Calculations

Situation 1:
In round 1, assume the group's total allocation to Activity G is **80 efforts**. The return for each effort allocated to Activity G will be:

$$20 - 0.1171 \times 80 = 10.632 \ \textbf{E\$ per effort}$$

If you allocate **10 efforts** to Activity G, your earnings from Activity G will be:

$$10 \times 10.632 = \textbf{E\$}\ 106.32$$

For your remaining **15 efforts** allocated to Activity F, your earnings from Activity F will be:

$$15 \times 5 = \textbf{E\$}\ 75$$

Thus, your total earnings for this round will be:

$$106.32 + 75 = \textbf{E\$}\ 181.32$$

Situation 2:
In round 2, assume the group's total allocation to Activity G is **150 efforts**. The return for each effort allocated to Activity G will be:

$$20 - 0.1171 \times 150 = 2.435\ \textbf{E\$ per effort}$$

If you allocate **10 efforts** to Activity G, your earnings from Activity G will be:

$$10 \times 2.435 = \textbf{E\$}\ 24.35$$

For your remaining **15 efforts** allocated to Activity F, your earnings from Activity F will be:

$$15 \times 5 = \textbf{E\$}\ 75$$

Thus, your total earnings for this round will be:

$$24.35 + 75 = \textbf{E\$}\ 99.35$$

After everyone has submitted, the earnings of the round will be calculated and shown to you.

Rules

- The game consists of **10 rounds**.
- You will be **given 25 efforts** in every round and submit how much to allocate in Activity G.
- The return on Activity G is decided by the group's total allocation in Activity G.

$$\textbf{20} - \textbf{0.1171} * \textbf{(group's total effort allocated to Activity G) E\$ per effort}$$

- The return on Activity A is **E$ 5** per effort.
- Your earnings for the round is:
  - Earnings from **Activity F**
  - Earnings from **Activity G**

- After everyone submitted, you will see your earnings.

Part 2: S_{60}-60% Partial-Output Sharing

Settings
You will be playing an **effort allocation game** in a group of 8 people. In each round, you will decide how to allocate efforts between two different activities.

But the following is new in this game:

Sharing Rule
Now you are **sharing 60% of returns from Activity G** with the group members. You will only keep 40% of returns from Activity G. This means that you will also **receive an equal amount from the group's share**. You will **not be sharing the returns from Activity F**.

Each round, you are endowed with **25 efforts** and must decide how many to allocate to **Activity F** and **Activity G**.

- **Activity F**: For each effort allocated to Activity A, you will receive a **fixed return of E$ 5**. You will **not be sharing the returns from Activity F** with anyone.
- **Activity G**: The return on efforts allocated to Activity G is **variable** and depends on the **total efforts allocated by the entire group, including yours**. In this game, you are **sharing 60% of the returns from Activity G** with the group members.

  The return for each effort allocated to Activity G is 40% of the following:

  $$\mathbf{20 - 0.1171 * (\text{group's total effort allocated to Activity G})\ E\$\ \text{per effort}}$$

Note that the return from Activity G **decreases** as the total efforts allocated to Activity G by the group **increases**.

Your earnings for each round will depend on both **your own decisions** and the decisions of **others in your group**, as well as **the sharing rule for Activity G**.

Multiple Rounds
The part 2 consists of **10 decision rounds**. In each round, you will face the same decision task, where you will allocate efforts between Activity F and Activity G.

Earnings
After everyone has submitted, the earnings of the round will be calculated and shown to you. For each round, your earnings are:

- Earnings from **Activity F**

- **40%** of the Earnings from **Activity G**
- Earnings from the **group's sharing**

Your final earnings will be the sum of every round's earnings.

Example Calculations

Situation 1:
In round 1, assume the group's total allocation to Activity G is **80 efforts**. The return for each effort allocated to Activity G will be:

$$20 - 0.1171 \times 80 = 10.632 \textbf{ E\$ per effort}$$

If you allocate **10 efforts** to Activity G, your earnings from Activity G will be:

$$10 \times 10.632 = \textbf{E\$ } 106.32$$

Since you only keep **40%** of your returns, your personal earnings from Activity G will be:

$$10.632 \times 0.4 = 42.528 \approx \textbf{E\$ } 42.53$$

For your remaining **15 efforts** allocated to Activity F, your earnings from Activity F will be:

$$15 \times 5 = \textbf{E\$ } 75$$

You will also receive **1/8 of the group's 60% share** of Activity G returns, which is:

$$(10.632 \times 80) \times 0.6 \div 8 = 63.792 \approx \textbf{E\$ } 63.79$$

Thus, your total earnings for this round will be:

$$42.53 + 75 + 63.79 = \textbf{E\$ } 181.32$$

Situation 2:
In round 2, assume the group's total allocation to Activity G is **150 efforts**. The return for each effort allocated to Activity G will be:

$$20 - 0.1171 \times 150 = 2.435 \textbf{ E\$ per effort}$$

If you allocate **10 efforts** to Activity G, your earnings from Activity G will be:

$$10 \times 2.435 = \textbf{E\$ } 24.35$$

Since you only keep **40%** of your returns, your personal earnings from Activity G will be:

$$24.35 \times 0.4 = \textbf{E\$ } 9.74$$

For your remaining **15 efforts** allocated to Activity F, your earnings from Activity F will be:

$$15 \times 5 = \textbf{E\$ } 75$$

You will also receive **1/8 of the group's 60% share** of Activity G returns, which is:

$$(2.435 \times 150) \times 0.6 \div 8 = 27.393 \approx \textbf{E\$ } 27.39$$

Thus, your total earnings for this round will be:

$$9.74 + 75 + 27.39 = \textbf{E\$ } 112.13$$

After everyone has submitted, the earnings of the round will be calculated and shown to you.

Rules

- The game consists of **10 rounds**.
- You will be **given 25 efforts** in every round and submit how much to allocate in Activity G.
- The return on Activity G is decided by the group's total allocation in Activity G.

$$\mathbf{20 - 0.1171 * (group's\ total\ effort\ allocated\ to\ Activity\ G)\ E\$\ per\ effort}$$

- The return on Activity A is **E$ 5** per effort.
- You must **share 60% of your returns from Activity G with group members**.
- The shared return will be **distributed equally to group members**.
- Your earnings for the round is:
  - Earnings from **Activity F**
  - **40%** of the Earnings from **Activity G**
  - Earnings from the **group's sharing**
- After everyone submitted, you will see your earnings.

Part 2: S_{30}-30% Partial-Output Sharing

Settings
You will be playing an **effort allocation game** in a group of 8 people. In each round, you will decide how to allocate efforts between two different activities.

But the following is new in this game:

Sharing Rule
Now you are **sharing 30% of returns from Activity G** with the group members. You will only keep 70% of returns from Activity G. This means that you will also **receive an equal amount from the group's share**. You will **not be sharing the returns from Activity F**.

Each round, you are endowed with **25 efforts** and must decide how many to allocate to **Activity F** and **Activity G**.

- **Activity F**: For each effort allocated to Activity F, you will receive a **fixed return of E$ 5**. You will **not be sharing the returns from Activity F** with anyone.
- **Activity G**: The return on efforts allocated to Activity G is **variable** and depends on the **total efforts allocated by the entire group, including yours**. In this game, you are **sharing 30% of the returns from Activity G** with the group members.

  The return for each effort allocated to Activity G is 70% of the following:

  $$\mathbf{20 - 0.1171 * (\text{group's total effort allocated to Activity G}) \text{ E\$ per effort}}$$

Note that the return from Activity G **decreases** as the total efforts allocated to Activity G by the group **increases**.

Your earnings for each round will depend on both **your own decisions** and the decisions of **others in your group**, as well as **the sharing rule for Activity G**.

Multiple Rounds
The Part 2 consists of **10 decision rounds**. In each round, you will face the same decision task, where you will allocate efforts between Activity F and Activity G.

Earnings
After everyone has submitted, the earnings of the round will be calculated and shown to you. For each round, your earnings are:

- Earnings from **Activity F**
- **70%** of the Earnings from **Activity G**
- Earnings from the **group's sharing**

Your final earnings will be the sum of every round's earnings.

Example Calculations

Situation 1:
In round 1, assume the group's total allocation to Activity G is **80 efforts**. The return for

each effort allocated to Activity G will be:

$$20 - 0.1171 \times 80 = 10.632 \textbf{ E\$ per effort}$$

If you allocate **10 efforts** to Activity G, your earnings from Activity G will be:

$$10 \times 10.632 = \text{E\$ } 106.32$$

Since you only keep **70%** of your returns, your personal earnings from Activity G will be:

$$106.32 \times 0.7 = \text{E\$ } 74.42$$

For your remaining **15 efforts** allocated to Activity F, your earnings from Activity F will be:

$$15 \times 5 = \text{E\$ } 75$$

You will also receive **1/8 of the group's 60% share** of Activity G returns, which is:

$$(10.632 \times 80) \times 0.3 \div 8 = 31.89 \approx \text{E\$ } 31.9$$

Thus, your total earnings for this round will be:

$$74.42 + 75 + 31.9 = \text{E\$ } 181.32$$

Situation 2:
In round 2, assume the group's total allocation to Activity G is **150 efforts**. The return for each effort allocated to Activity G will be:

$$20 - 0.1171 \times 150 = 2.435 \textbf{ E\$ per effort}$$

If you allocate **10 efforts** to Activity G, your earnings from Activity G will be:

$$10 \times 2.435 = \text{E\$ } 24.35$$

Since you only keep **70%** of your returns, your personal earnings from Activity G will be:

$$24.35 \times 0.7 = 17.045 \approx \text{E\$ } 17.05$$

For your remaining **15 efforts** allocated to Activity F, your earnings from Activity F will be:

$$15 \times 5 = \text{E\$ } 75$$

You will also receive **1/8 of the group's 60% share** of Activity G returns, which is:

$$(2.435 \times 150) \times 0.3 \div 8 = 13.696 \approx \text{E\$ } 13.70$$

Thus, your total earnings for this round will be:

$$17.05 + 75 + 13.70 = \text{E\$ } 105.75$$

After everyone has submitted, the earnings of the round will be calculated and shown to you.

Rules

- The game consists of **10 rounds**.
- You will be **given 25 efforts** in every round and submit how much to allocate in Activity G.
- The return on Activity G is decided by the group's total allocation in Activity G.

$$\mathbf{20 - 0.1171 * (group's\ total\ effort\ allocated\ to\ Activity\ G)\ E\$\ per\ effort}$$

- The return on Activity F is **E$ 5** per effort.
- You must **share 30% of your returns from Activity G with group members**.
- The shared return will be **distributed equally to group members**.
- Your earnings for the round is:
  - Earnings from **Activity F**
  - **70%** of the Earnings from **Activity G**
  - Earnings from the **group's sharing**
- After everyone submitted, you will see your earnings.

Appendix B. Decision Screens

S_0-Baseline

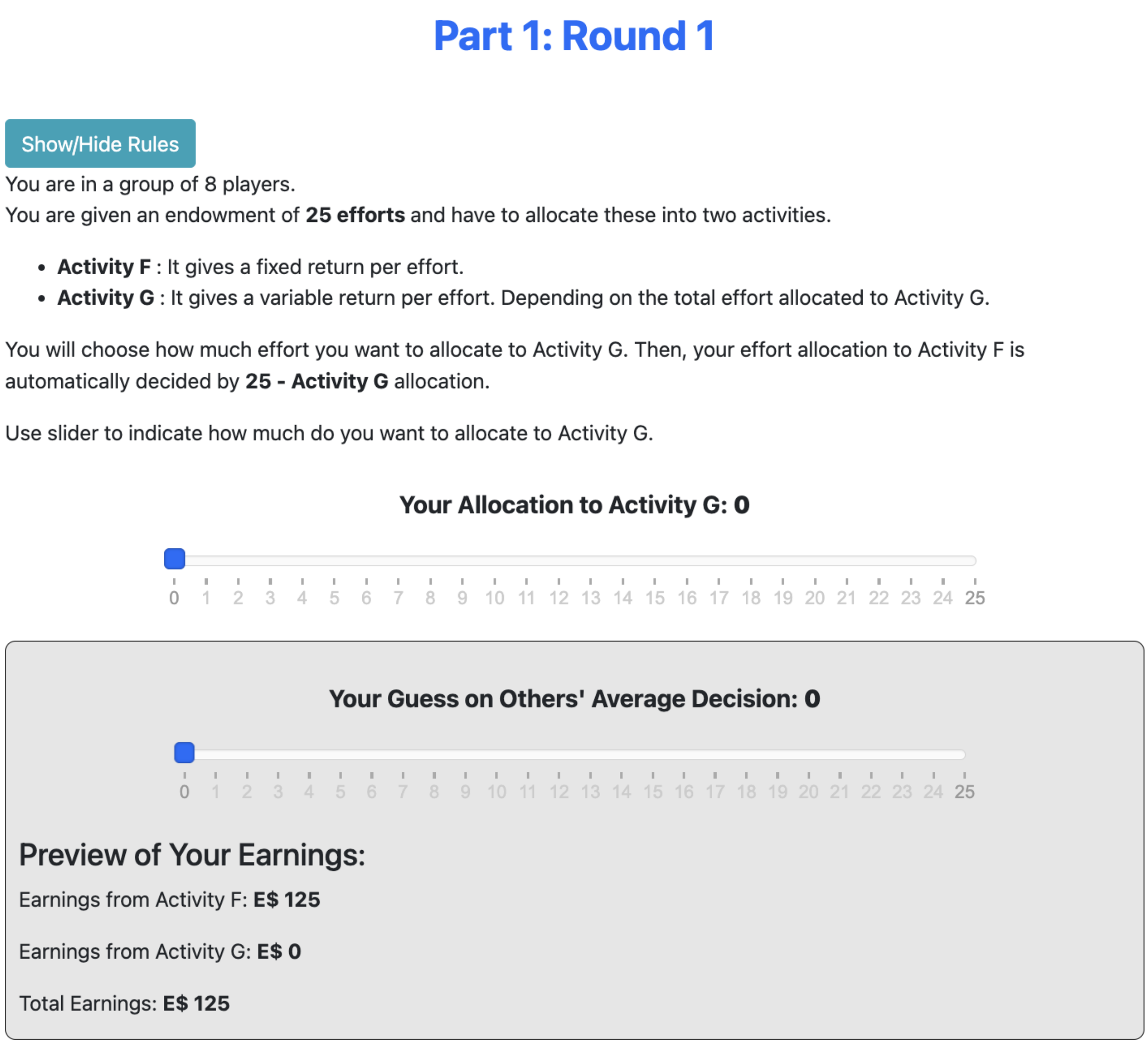


Figure 10: Decision page for S_0-Baseline

S_{60}-60% Partial Sharing

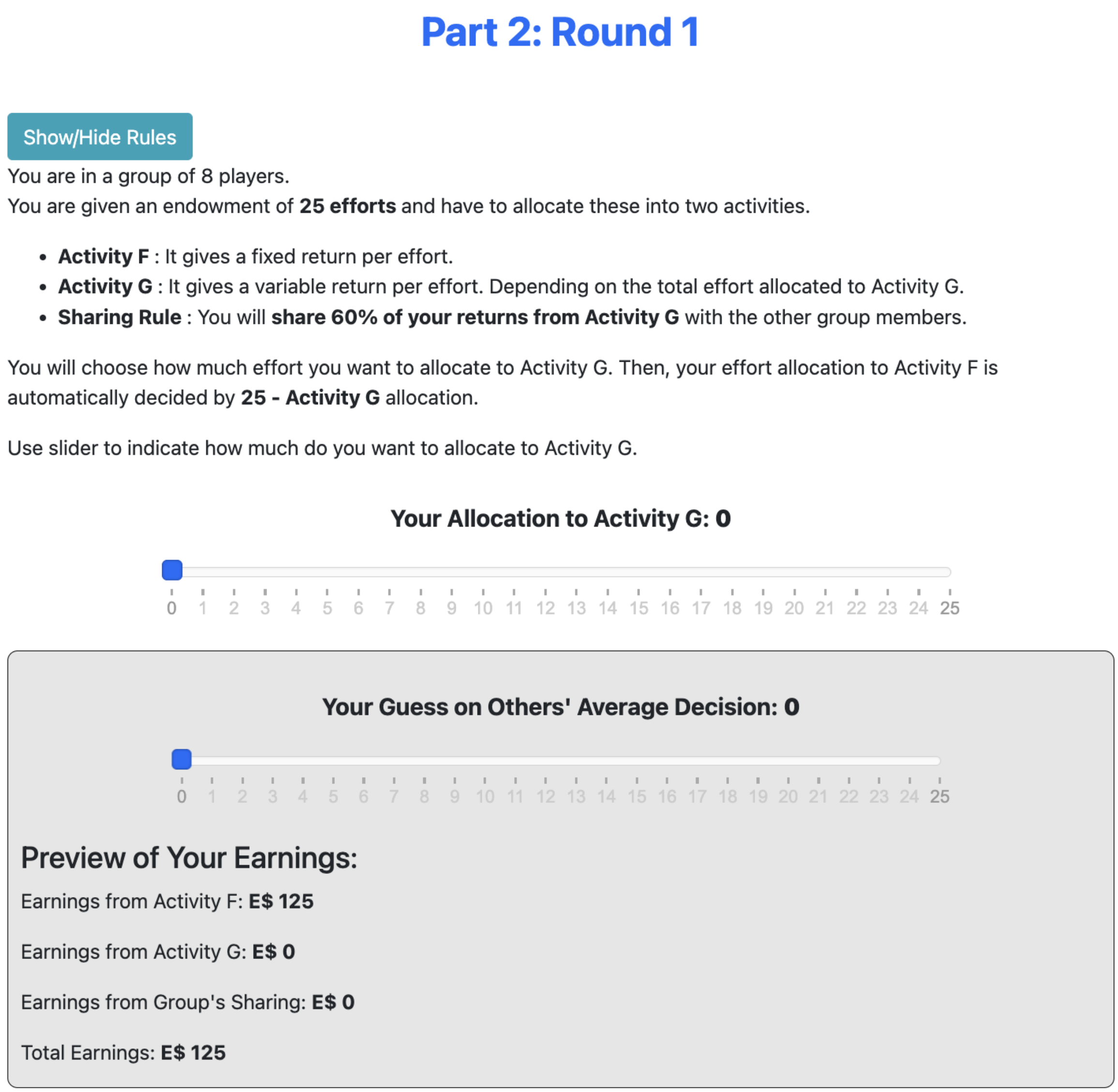


Figure 11: Decision page for S_{60}-60% Partial Sharing

S_{30}-30% Partial Sharing

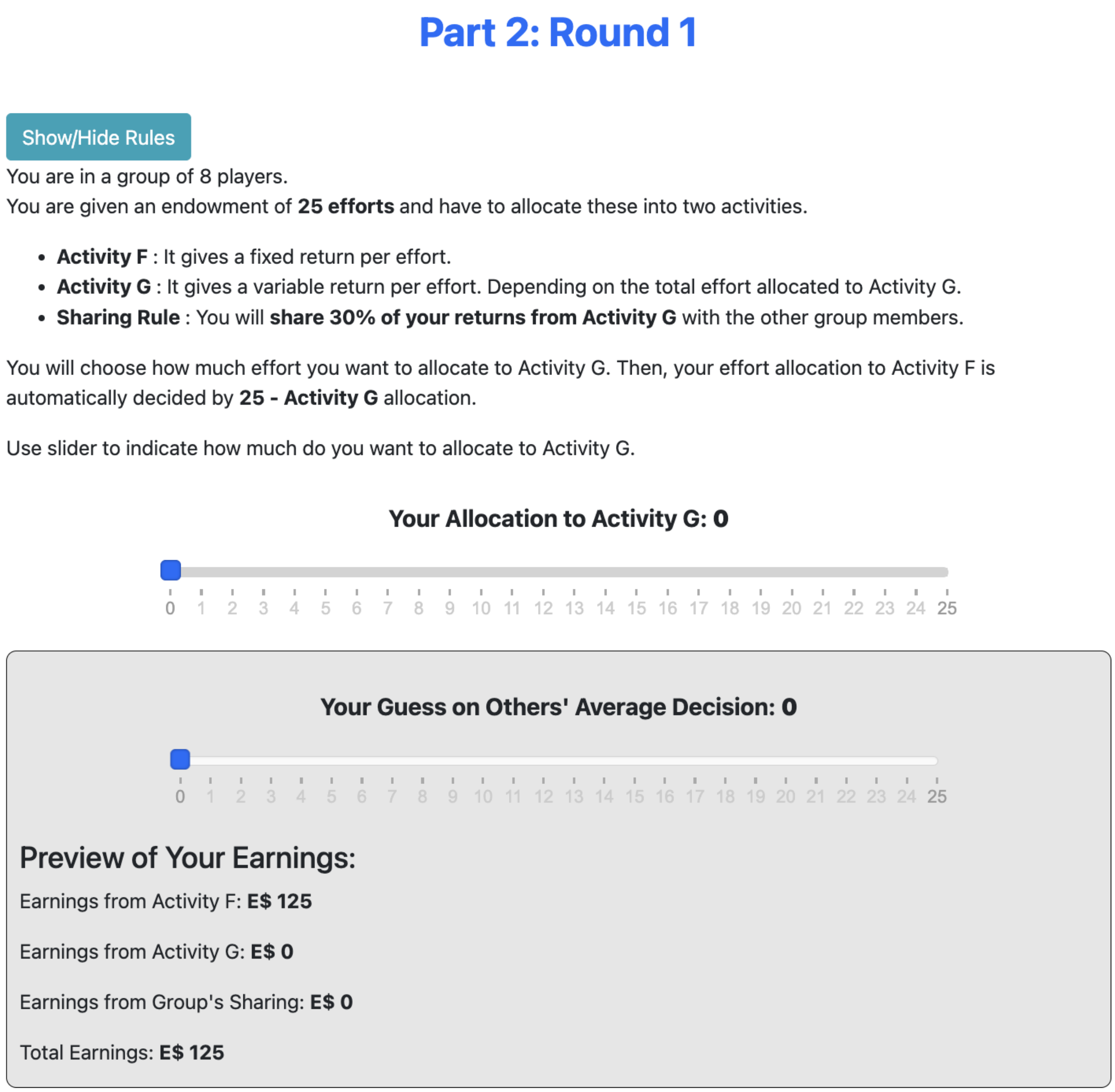


Figure 12: Decision page for S_{30}-30% Partial Sharing