Power Asymmetry in Repeated Play of Provision and Appropriation Games

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Abstract. This paper studies the effect of power asymmetry on resolution of social dilemmas in repeated play of linear public good games. The experiment uses a 2X2 design that crosses power symmetry or asymmetry in games with positive (provision) or negative (appropriation) externalities. Our data suggest that power asymmetry has a detrimental effect on voluntary allocations to a public good, with the effect being more pronounced in the asymmetric-power appropriation game. Allocations to a public good increase with "social" income, which is inconsistent with allocations by different individuals being strategic substitutes. With power asymmetry, second movers earn more than first movers in the appropriation game but not in the provision game.

1. Introduction

Serious harm to collective welfare – for example, from global warming – can be exacerbated by social dilemmas in which self-interests conflict with collective interest. Large scale social dilemmas can play out with repeated interactions in environments with power asymmetries between decision makers. Using a laboratory experiment with repeated play, we ask whether social dilemmas are more or less of a problem with asymmetric or symmetric power among agents in provision and appropriation games.

Symmetric power public good games are well studied. In the previous literature, Andreoni (1995) and Khadjavi and Lange (2015) report repeated-play experiments with pairs of payoff-equivalent provision and appropriation games with symmetric power. Cox, Sadiraj and Tang (2022) report one-shot experiments with pairs of payoff-equivalent, symmetric-power games with endogenous contractions of feasible sets. To the best of our knowledge, Cox, Ostrom, Sadiraj and Walker (2013) is the first paper to report one-shot experiments with pairs of payoff-equivalent games with symmetric and asymmetric power. One could reasonably argue, however, that much of the private allocation to public goods is a repeated activity of well-defined communities. The present paper examines how power asymmetry affects repeated play (of partners) in provision and appropriation games to determine the efficiency of allocations.

The endowments in a provision game are in Individual Funds, from which surplus-creating contributions to a Group Fund can be made by participants. The endowment in an appropriation game is in a Group Fund from which surplus-destroying extractions can be made by participants. In the appropriation game, the value of the endowment of the Group Fund is: (a) strictly greater than the sum of the values of the endowments of the Individual Funds in the provision game; and (b) equal to the maximum attainable total payoff in the provision game.

We examine two types of power in two pairs of games. In the baseline games, all n agents move simultaneously. In contrast, in the king game n-1 "peasants" simultaneously move first. The "king" subsequently moves after observing the (simultaneous) first moves of the peasants. In provision games the king can contribute to the Group Fund or appropriate some or all of the contributions by first movers. In appropriation games the "king" can appropriate any of the Group Fund endowment remaining following appropriation decisions by first movers.

Our paper makes several contributions to the literature. We study the effect of power asymmetry on resolution of social dilemmas and the prevalence of full cooperation in repeated play of linear public good games. Compared to the power symmetry in simultaneous-move linear public good games, power asymmetry is introduced along two dimensions: (i) second movers have an extended opportunity set; and (ii) they know the first movers' choices before making their decisions.[1] Second, we explore whether effects of power asymmetry depend on the type of externality: positive, in a provision game, or negative in an appropriation game. Third, data from our experimental design allows us to contribute to an ongoing discussion on whether different individual's voluntary allocations to a public good are strategic substitutes, as commonly assumed in the literature (and also predicted by unconditional altruism) or complements that can be consistent with reciprocity (*i.e.*, conditional altruism). Note that, in case of strategic substitutes, the sequential implementation provides more incentives for the first movers to lower their contributions to the Group Fund (or increase their appropriations from the Group Fund) and free ride on the second mover's contribution or appropriation decision. Fourth, our data on earnings are informative on whether there is a behavioral strategic advantage to moving first, and whether the party that has an advantage would prefer sequential implementation with asymmetric power over symmetric-power, simultaneous implementation.

We find that asymmetric power elicits more free riding and lower contributions to the Group Fund in the provision game and greater appropriations from the Group Fund in the appropriation game. These effects are more pronounced with the negative externalities in a

[1] Early studies testing Varian's (1994) model of simultaneous vs. sequential choice in public good games include Andreoni, Brown, and Vesterlund (2002) and Gächter, et al. (2010) who report experiments on simultaneous and sequential play in two-player nonlinear public good games with induced, decreasing, selfish best-response functions.

sequential appropriation game than with the positive externalities in a sequential provision game. In the provision game, second movers' contributions increase in total contributions of others and first movers' contributions increase with an increase in the previous round total contributions of others. Similarly, in the appropriation game, second movers' appropriations decrease with a decrease in appropriation by others and first movers' appropriations decrease with a decrease in the previous round total appropriation by others. Both results suggest that different individual's voluntary allocations to a public good are strategic complements. First movers' payoffs are smaller with power asymmetry than with power symmetry. With power asymmetry, empirically there is a strategic advantage in moving second in the sequential appropriation game but not in the sequential provision game. In our experiment, however, both first movers and second movers receive higher payoffs in symmetric power games, in particular when there are negative externalities.

2. Power Symmetry and Asymmetry in Public Good Games

To control for (unconditional) other-regarding preferences, we focus on payoff equivalent pairs of public good games that consist of a provision game and an appropriation game.

2.1 Symmetric Power Simultaneous-Move Provision Game

The simultaneous-move provision game (PG) is a contributions game in which n agents (simultaneously) choose amounts they will contribute from their endowed Individual Funds to a Group Fund that yields a surplus to be shared equally among all group members. Each agent is endowed with e "tokens" in an Individual Fund, that each have value 1, and can choose an amount g_j from the feasible set $\{0,1,2,\cdots,e\}$ to contribute to the Group Fund. Contributions to the Group Fund create surplus: each "token" added to the Group Fund decreases the value of the Individual Fund of the contributor by 1 and increases the value of the Group Fund by m, where $n > m > 1$. The monetary payoff to agent i equals the amount of her endowment that is retained in her Individual Fund (i.e. *not* contributed to the Group Fund) plus an equal ($1/n$) share of m times the total amount contributed to the Group Fund by all agents. There is a social dilemma because $n > m > 1$. Using notation, $\gamma = m/n$, the money payoff to player i is:

(1) $$\pi_i^p = e - g_i + \gamma \sum_{j=1..n} g_j$$

2.2 Asymmetric Power (king) Sequential-Move Provision Game

In the king-provision game (KPG), n-1 agents ("peasants") simultaneously move first. Subsequently, the "king" (agent $j = n$) observes their choices and then decides how much to contribute or how much to take from the other agents' contributions. Each of the first movers chooses the number of tokens to contribute g_j, $j = 1, 2, \cdots, n-1$, from the same feasible set as in the PG game. The king can choose to contribute any number of tokens, up to his endowment e, to the Group Fund. Alternatively, the king can choose to take (in integer amounts) any part of the tokens contributed by the n-1 first movers. If we define $G_{-n} = \sum_{j=1}^{n-1} g_j$, then the king can choose an amount x_N (to take or contribute) from the feasible set $K_{PG} = \{-G_{-n}, -G_{-n}+1, \cdots, 0, 1, 2, \cdots, e\}$.

2.3 Appropriation Games

In the simultaneous-move appropriation game (AG), n agents decide how much to extract from a Group Fund. The n agents are jointly endowed with $E = ne$ tokens in a Group Fund that has value mE. Each agent can choose an amount z_j from the set $\{0, 1, 2, \cdots, e\}$ to extract from the Group Fund. Extractions from the Group Fund destroy surplus: each token removed from the Group Fund increases the Individual Fund of the extractor by 1, but reduces the value of the Group Fund by m where, as above, $n > m > 1$. Agents share equally in the remaining value of the Group Fund after all extractions. The monetary payoff to player i equals the end value of his Individual Fund plus an equal (1/n) share of the remaining value of the Group Fund after the extractions by all agents. As above, there is a social dilemma because $n > m > 1$. The payoff to player i is:

(2) $$\pi_i^a = z_i + \gamma(E - \sum_{j=1..n} z_j)$$

Payoff equivalence of the provision and appropriation games follows from the one-to-one mapping, $g_i = e - z_i$ and specifications (1) and (2):[2]

[2] In the data analysis, we use $g_i = e - z_i$ the amount left in the Group Fund, as a player's choice in the appropriation game.

$$\pi_i^p = e - g_i + \gamma \sum_{j=1..n} g_j = e - (e - z_i) + \gamma \sum_{j=1..n} (e - z_j) = \pi_i^a$$

One observes that any n-vector of agents' payoffs that is attainable in the provision game is also attainable in the paired appropriation game.

In the king-appropriation game (KAG), n-1 agents simultaneously move first. Subsequently, the king observes their choices and then decides how many of the remaining tokens (if any) to extract. Each of the n-1 first movers chooses an amount to extract z_j, $j = 1, 2, \cdots, n-1$, from the same feasible set as in the appropriation game. The king chooses an amount to extract from the feasible set of integers $\mathrm{K}_{AG} = \{0, 1, 2, \cdots, E - \sum_{j=1}^{n-1} z_j\}$.

3. Benchmark Predictions

A stylized fact from the previous literature is that positive levels of public good provision are observed in studies of simultaneous linear public good games where full free riding (contributing nothing) is the dominant strategy for players with self-regarding (*homo economicus*) preferences. One of the explanations put forward in the literature is altruism.[3] Altruistic players may have a positive demand for the public good but, in the sequential game, they may still free-ride and leave it to second movers to provide the public good. Varian (1994) shows that there will be less public good in a Stackelberg (sequential) equilibrium than in a Nash (simultaneous) equilibrium of the public good game. We illustrate this for the case when individual demand for the public good does not vary with income (e.g., quasi-linear preferences).

3.1 Implications of Altruism for Play in the Stage Game

Assume quasi-linear preferences, and let G_j denote player j's demand for the public good when the amount of endowment in an Individual Fund is e. Without any loss of generality, index (altruistic) players according to their demand for the public good when others contribute nothing: $0 < G_i \leq G_{i+1} \leq \cdots$ e. The interesting scenario is when at least one player has a positive demand for the public good (that is, $i \,\square\, 1$), otherwise every player contributes 0 and there is no public good, which is inconsistent with the stylized fact stated above.

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[3] See Appendix A.1 for an example of (altruistic) preferences defined over money payoffs.

Simultaneous game. In the simultaneous game, the equilibrium level of public good provision is G_n. If there is only one player with demand G_n then in the Nash equilibrium she is the only contributor, and all other players free ride. Otherwise, there are many Nash equilibria, where all players with demand G_n coordinate in contributing the total amount G_n.

(King) Sequential game. In this game, there can be only two cases with respect to the second mover (king) type.

Case 1. Player n (with the highest demand for the public good) is the second mover. In the subgame perfect equilibrium (SPE), all first movers free ride and let player n contribute G_n. So, compared to the simultaneous game, the number of free riders increases unless player n is the only player with the high demand, in which case it remains the same. In any equilibrium in the simultaneous game, player n's contribution is at most G_n, so it follows that in this case: (i) all first movers free ride, but (ii) the level of public good provision remains the same.

Case 2. Player n is not the second mover. Let some player j (whose demand is not G_n) be the second mover. We distinguish between two subcases, depending on whether player j's demand for the public good, G_j , is positive.

2.a. G_j is positive. In the SPE, the total public good provision is G_j and all first movers free ride. So, we find less public good than in the simultaneous game.

2.b. G_j is not positive. Player j will appropriate all there is in the Group Fund, so in the SPE, all first movers contribute 0, so does the king, and there is no public good provision. Compared to the simultaneous game we have: (i) less public good (in fact, none) and (ii) all first movers contribute less (actually 0).

Our first set of hypotheses about the power asymmetry effect on behavior is:

H1: Prevalence for free riding by first movers is higher in the king sequential game than in the simultaneous public good game.

H2: Contributors in the simultaneous public good game decrease their contributions when they move first in the king sequential game.

H3: Public good provision is larger in the simultaneous game than in the king sequential public good game.

3.2 Implications of Altruism for Play in the Repeated Game

If full cooperation can be sustained by selfish players, then it will be sustained by altruistic players.

So, we look at whether full cooperation can be an equilibrium outcome with selfish players. In infinitely repeated games,[4] allocating the full endowment e to the Group Fund in every round can be supported in an equilibrium with trigger strategies if the discount factors, δ_i of all players are sufficiently large: (*) $\delta_i > \frac{1-\gamma}{\gamma(n-1)}$, where γ is the marginal per capita rate of return.

In the sequential game, the condition for defection to be non-profitable for the king is (**) $\delta > n\left(\frac{1-\gamma}{n-1}\right)$.[5] Note that, the latter condition requires a higher level of patience than the former, as $\gamma > 1/n$. So, if the king's discount factor does not satisfy (**) but all players discount factors satisfy (*) then, with repetition, full cooperation can emerge in the simultaneous game but not in the sequential king game. However, while a higher patience threshold has a negative effect on sustaining full cooperation, in the sequential game one needs only one player (the king) to be sufficiently patient. We have the following hypothesis for infinitely repeated games:

> H4: Full cooperation can be sustained with sufficiently patient players, but the effect of power asymmetry on its prevalence is ambiguous.

3.3 Implications of Reciprocity

The allocations to the Group Fund by first movers select the feasible set of the second mover. If first movers allocate nothing to the Group Fund, this selects the feasible set that is least generous to the second mover.[6] If first movers allocate all of their tokens to the Group Fund, this selects the feasible set that is most generous to the second mover. Other first mover allocations that are between zero and all tokens are in between in generosity, and are acts of commission in both provision and appropriation games. All positive allocations to the Group Fund (i.e. transfers *from* Individual Funds) by first movers in a provision game are acts of commission that make the feasible set *more* generous to the second mover than is the feasible set corresponding to endowments. All allocations to the Group Fund by first movers in an appropriation game that correspond to transfers (out of the Group Fund and) *into* first movers' Individual Funds are acts of

[4] For details see Appendix A.2.
[5] No FM would deviate from contributing all of the endowment, e because that triggers SM to switch to "take all," so there are no immediate gains.
[6] See Cox, Friedman, and Sadiraj (2008, pg. 36) for the partial ordering of feasible sets, "More Generous Than."

commission that make the feasible set *less* generous to the second mover than is the feasible set corresponding to the endowment. Hence, Axioms R and S (Cox, Friedman, and Sadiraj 2008, pgs. 40-41) imply that (*i*) for any given allocation G_{-n} to the Group Fund by first movers, the second mover's preferences will be more altruistic in the provision game than in the appropriation game, and (ii) the acquired preferences become more altruistic the higher the total allocations of others in the Group Fund. Our final hypothesis is:

H5: The second mover's best response allocation in a provision game is higher than in a payoff-equivalent appropriation game.

4. Experimental Design and Protocol

Experiment sessions were conducted at both Georgia State University and Indiana University, Bloomington. In each session, subjects were recruited from subject databases that included undergraduates from a wide range of disciplines. Via the computer, the subjects were privately and anonymously assigned to four-person groups. Subjects were not informed which of the others in the room were assigned to their group. Since no information passed across groups, each session involved numerous independent groups. At the beginning of each session, subjects privately read a set of instructions that explained the decision setting.[7] In addition, an experimenter reviewed the instructions publicly. The stage game was repeated for 15 decision rounds, with fixed matching of subjects within groups across decision rounds.

4.1 (Stage) Game Parameters

In the provision game, in each round each individual is endowed with 10 tokens worth 1 experimental currency unit (ECU) each in what is referred to in the experiment as an Individual Fund. The decision task of each individual is whether to move tokens to a Group Fund. Any tokens moved to the Group Fund are tripled in value. Individual earnings equal the end value of the Individual Fund plus one-fourth of the end value of the Group Fund. Second movers in the king-provision game are allowed choices as described above (Section 2.2).

[7] Complete subject instructions for the experiment are available at http://excen.gsu.edu/jccox/subjects.html. In the instructions for the asymmetric power treatments, first movers were referred to as Type X players and second movers were referred to as Type Y players.

In the appropriation game, each group is endowed with 40 tokens worth 3 ECUs each in their Group Fund. The decision task of each individual is whether to move tokens to their own Individual Fund. Any tokens moved from the Group Fund reduce the value of the Group Fund by 3 ECUs and increase the value of the Individual Fund of the decision maker by 1 ECU. Individual earnings equal the end value of the Individual Fund plus one-fourth of the end value of the Group Fund. Second movers in the king-appropriation game are allowed choices as described above (Section 2.3).[8]

4.2 Repeated Game

In the repeated provision game and repeated appropriation game treatments in the experiment, subjects were informed that there would be multiple decision rounds, but not the specific number of rounds. Following decision round 10, a public announcement was made that the experiment would end after 5 more decision rounds. This procedure was followed to support analysis of behavior based on the first 10 rounds that would not include the end-game effect often found in social dilemma studies. Between rounds, subjects had access to a history table that displayed the decisions by each group member for all prior rounds, with each subject's decision identified by an ID letter that remained the same across rounds. In the repeated king-provision game and repeated king-appropriation game treatments, a second mover (king) was informed of choices by the first movers in a round before making their own choice in that round. The experiments were conducted using a double anonymous (or double blind) payoff protocol.[9]

5. Experiment Results

5.1 Total Group Fund Allocations

In all four treatment conditions, the Pareto optimal allocation is for the group to allocate all tokens to the Group Fund, resulting in a payment of 120 to the group. Table 1 presents summary results for the four treatment conditions. Figure 1 complements Table 1, displaying average Group Fund allocations at each decision round, pooling observations within treatments. Average group fund values in implementations with asymmetric power are well below the ones observed in symmetric

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[8] All values reported below are in ECUs. The exchange used to pay subjects was 1 = 10 ECUs.

[9] Each subject used a mailbox key to collect their payoff envelope in private. Mailbox key numbers, that were subjects' private information, were the only way subjects' responses were identified.

power implementations: 78.65 (provision) and down to 66.68 (king-provision); similarly, down from 76.68 (appropriation) to 38.80 (king-appropriation).

[Insert Table 1 about here]

These patterns, visible in Figure 1, are persistent across the first 10 rounds, and robust across type of externality (provision or appropriation games). Figure 1 suggests some learning taking place (in early rounds) and negative end-game effects on cooperation. Ignoring early rounds and the last two rounds, with symmetric power (top lines), public good value levels seem to stabilize around 82 (provision) and 77 (appropriation). With asymmetric power (bottom lines), these levels decrease to 70 (king-provision) and 40 (king-appropriation).

[Insert Figure 1 about here]

A more formal statistical analysis supports these visual patterns. Table 2 presents the results from an OLS regression analysis that incorporates dummy variables for power asymmetry and game form, with the simultaneous provision game serving as the baseline treatment condition. The average Group Fund Values in all treatments are statistically greater than 0 but below full cooperation (120). Consistent with hypothesis H2, the estimated effects of asymmetric power on the amount of the public good are negative: -11.97 (p-value<0.001) in the king-provision treatment and even lower, at -39.85 (p-value<0.001) in the king-appropriation treatment.[10] Consistent with previous studies, the data exhibit a clear end-game effect (-6.88, *p*-value=0.015).

[Insert Table 2 about here]

Our first result is consistent with findings in previous literature whereas the second result provides support for Hypothesis 3.

<u>*Result 1:*</u> Across decision rounds, average Group Fund allocations are well above the minimum allocation of 0, but also well below the maximum allocation of 120.

[10] -39.85 is statistically smaller than -11.97 (Wald test, *p*-value < 0.01).

Result 2: Average Group Fund allocations in games with asymmetric power are smaller than in the symmetric power games. Furthermore, the king-appropriation game yields less public good than the king-provision game.

The results presented above represent average public good levels across rounds, which in the case of asymmetric power games is a function of decisions by both first movers and second movers within groups.

5.2 First and Second Mover Decisions

The analysis presented in this section explores the decisions of first and second movers. Figure 2 presents across rounds (group average) data for first movers in all 4 treatment conditions.

[Insert Figure 2 about here]

First Mover Choices. There are three first mover subjects in games with asymmetric power and four subjects in symmetric-power (simultaneous) games, so we work with first mover group *average* allocations in the Group Fund. Recall, a fully cooperative decision by first movers would imply a Group Fund allocation of 30 per person. Average allocations in the king implementations appear below the ones in the symmetric power games, in particular in the appropriation game. Given the low level of Group Fund allocations in the king-appropriation treatment, it is important to note that this behavior occurred even though Group Fund allocations by first movers in this treatment begin in period 1 (15.8 tokens) at higher levels than in provision (13.6 tokens) and king-provision (11.3 tokens) treatments. Furthermore, in king-provision, first movers allocated 0 tokens to the Group Fund in only 6 of 255 decision rounds. In contrast, in king-appropriation first movers appropriation left 0 tokens in the Group Fund in 45 of 240 decision rounds.[11]

To estimate treatment effects on free riding behavior we adopt a probit regression (Table 3, first three columns) whereas for treatment effects on positive allocations we use generalized least-squares estimators (Table 3, last three columns).

[11] For king games, the estimated odds ratio of free riding in the appropriation game is 4.14 (p-value=0.001; standard errors clustered at group level); regressors include dummies for appropriation game, last five periods, and location (GSU).

[Insert Table 3 about here]

In all specifications we have dummies for each treatment, for each round and a dummy for location (GSU). In model specifications (2) and (3), in the list of regressors we add the rate of free riders or total allocations of others in the previous round, respectively. Examining first the probit regressions, in the appropriation games we observe an increase in free riding with the power asymmetry in king-appropriation.[12] In the provision game, however, free riding is similar (0.143, p-value=0.594) in simultaneous and king games. Consistent with Hypothesis 1, we conclude that:

Result 3: Power asymmetry elicits more free riding by the first movers, but the effect is significant only in the king-appropriation game.

Turning to the GLS specifications, in terms of first movers' positive allocations, our data suggest a clear negative effect of power asymmetry, which is robust to game form: -0.811 (p-value= 0.065, king-provision), and the null hypothesis that the estimated coefficients of king-appropriation (-0.768) and appropriation (0.188) are equal is rejected at 10% significance level (chi2=3.51, p-value= 0.061). We have the following result that is consistent with Hypothesis 2

Result 4: Power asymmetry induces lower allocations to the public good by first movers.

As expected, the greater the free riding in the previous round, the lower are public good allocations in the current round and the greater the public good allocation by others in the previous round, the higher are allocations in the current round, suggesting increasing best response functions if previous allocations by others serve as a proxy for others' current allocations. It should be noted that increasing best response functions are consistent with reciprocity but not with conventional unconditional altruism (see Appendix A.1) or the conventional assumption in the literature that treats different individual's public good allocations as strategic substitutes (Bergstrom, Blume, and Varian 1986). Second movers' choices are more informative on this issue as kings do observe others' total allocations to the Group Fund in the same round.

[12] 1.333 (resp. 0.818) is statistically larger than 0.466 (resp. 0.462) at 1% (resp. 10%) significance level.

Second Mover Choices. Of course, the choices by second movers in king-provision and king-appropriation may depend on the choices of first movers. Figure 3 presents across round data for second movers in power asymmetry conditions.

[Insert Figure 3 about here]

Recall, a fully cooperative decision by second movers would imply a Group Fund allocation of 30 tokens and negative values correspond to taking from the Group Fund created (or left) by first movers. Absent reciprocity, contributions are strategic substitutes, so if others (FMs here) decrease their allocations to the Group Fund then our (altruistic) SMs should increase theirs. The implication for reciprocal behavior is the opposite, as explained in section 3.3. Table 4 reports results of a data analysis similar to Table 3, but for SM behavior. Positive Group Fund allocations by SMs in the provision game increase with the FMs' total Group Fund allocations, 0.264 (p-value<0.01) and, consistent with hypothesis H5, are lower in the appropriation game, -1.12 (p-value=0.098).

[Insert Table 4 about here]

We have the following result that is consistent with hypothesis H5:

Result 5: Group Fund allocations of second movers in the king-appropriation game are below those in the king-provision game.

Further analysis of second mover choices within the king-appropriation game and king-provision game yields additional insight into how behavior varied across the two game forms. Figure 4 displays the percentage of second movers, within each game form and across decision rounds, who made positive allocations to the Group Fund.

[Insert Figure 4 about here]

Rather than having a dummy for positive allocations, for comparison to FM data analysis in Table 4 we report probit estimates for "free riding" denoted by a dummy variable equal to 1 if SMs did not add to the Group Fund. As with first movers, the appropriation game elicits more free riding behavior by second movers, 0.75 (p-value =0.027) than in the provision game. Stating this in terms of non-free riding behavior, we have the following.

Result 6: Across decision rounds, the percentage of positive Group Fund allocations of second movers in the king-appropriation game is well below that in the king-provision game.

Second Mover Take Behavior. The opportunity for a specific second mover to remove tokens allocated by first movers in a given decision round depends on the decisions of the first movers with whom that second mover is matched. Further investigation of second movers' behavior in games with asymmetric power is revealing. In the king-provision treatment there were 249 decisions (out of 255) in which first movers made positive allocations to the Group Fund. In these 249 cases, second movers chose to remove tokens from the Group Fund in 31 instances (12%). When they removed tokens, they removed on average 74% of the tokens. In contrast, in the king-appropriation treatment there were 194 decisions (out of 240) in which first movers left tokens in the Group Fund. In these 194 cases, second movers chose to remove tokens from the Group Fund in 71 instances (37%). When they removed tokens, they extracted on average 79.6% of the tokens. Interestingly, 4 of 17 second movers in the king-provision design never removed Group Fund allocations of first movers while only 1 of 16 second movers in the king-appropriation condition displayed similar behavior. While it is awkward to classify "taking less" as an altruistic behavior, it is nevertheless an indicator of decreased selfishness. If so, then there is another piece of evidence consistent with the implications of revealed altruism in Cox, Friedman and Sadiraj (2008).

Result 7: Limiting the analysis to rounds in which second movers removed Group Fund token allocations of first movers, there is little difference in the average level of removal between the king- appropriation game and the king-provision game. However, second movers removed tokens at a much higher frequency in the king-appropriation game than in the king-provision game.

5.3 Further Analysis across Periods

Recall that our experimental environment called for initially informing the subjects that there would be multiple decision rounds but not telling them how many rounds. After decisions were entered by the subjects in round 10, a public announcement was made that there would be five more decision rounds, after which the experiment would end. In this section, we focus on decision making in rounds 1, 10, and 15. In round 1, subjects had no prior history of decisions by other group members. Round 10 is the final round in which there was uncertainty over the number of future rounds. Round 15 was the known final round.

The top panel of Figure 5 displays the average Group Fund allocations for first movers in each of the four treatment conditions for rounds 1, 10, and 15, while the bottom panel displays the average Group Fund allocations for second movers in the two king treatment conditions.

[Insert Figure 5 about here]

In round 1, the (king) second movers, on average, allocated much more to the Group Fund in the king-provision game (18.4) than in the king-appropriation game (2.1).[13] The first movers behaved quite differently; on average they allocated less to the Group Fund in king-provision (11.4) than in king-appropriation (15.8).[14] By round 10, the first movers and second movers were more coordinated. In round 10, first movers allocated on average about five dollars more to the Group Fund in king-provision (17.3) than in king-appropriation (12.4). Similarly, in round 10 second movers' average allocation to the Group Fund was about five dollars higher in king-provision (16.9) than in king-appropriation (12.00).[15] In the (announced) last round 15, first movers allocated on average almost twice as much to the Group Fund in king-provision (12.1) than in king-appropriation (6.4). The last round effect on second movers is even more pronounced: they contributed on average only 2.3 in king-provision and *took* 7.9 of the first movers' allocation to the Group Fund in king-appropriation.

[13] z = -2.082 (p-value=0.037, Mann-Whitney test). The difference between distributions is significant at 5% according to Kolmogorov-Smirnov test (D=0.50, two-sided p-value=0.032, N=33). P-value reported by Epps-Singleton is 0.137.
[14] The difference between distributions is significant at 5% according to Kolmogorov-Smirnov test (D= - 0.504, two-sided p-value=0.031, N=33, i.e., one observation per group). P-value reported by Epps-Singleton is 0.05.
[15] z = -1.77 (p-value=0.078 for SM) but distributions are not different according to Kolmogorov-Smirnov test: p-values are 0.197 and 0.302, resp., for average group contributions of FMs and SMs. Epps-Singleton test: p-values are 0.298 and 0.228.

5.4 Full Contributions across Treatments

Hypothesis H4, states that the effect of power asymmetry on the likelihood of full cooperation is ambiguous. We look at data from our experiment to inform on this issue. In treatments with kings, 22.5% and 51% of SMs' Group Fund allocations were almost full (9 or 10 tokens), respectively, in the king-appropriation and king-provision games.[16] These figures for FMs were 28% and 42% in king-appropriation and king-provision treatments. In simultaneous games, on the other hand, percentages of almost full Group Fund allocations are double in the appropriation game (53%) but not in the provision game (49%). Compared to the king-appropriation game (KAG), the odds of almost full cooperation are about 3.5 times higher (3.73, p-value=0.012) in king-provision game (KPG), 6.5 higher (6.53, p-value<0.001) in the simultaneous provision game (PG), and 8.7 times higher (8.66, p-value<0.001) in the simultaneous appropriation game (AG).[17]

Result 8. Across treatments, the odds of almost-full cooperation are ordered: AG > PG > KPG > KAG.

5.5 Treatment Effects on Earnings

There is extensive research that focuses on the effects of simultaneous and sequential games on payoffs of players. We ask whether players who moved first in the sequential game earned more than in the simultaneous game, and how their earnings compare to the second movers' earnings. We report earnings in ECUs to maintain consistency with the unit of account used elsewhere in the paper; the earnings figures in U.S. dollars are 1/10 these amounts. Average individual earnings (in ECUs) of all subjects in simultaneous games is 344 (s.d. 73.7) whereas in games with power asymmetry, average earnings of both types are lower: 276 (s.d. 97.7) for first movers (FM) and 303 (s.d. 94.9) for second movers (SM).[18] For statistical inference, we use OLS regression with total earnings of subjects as the dependent variable (Table 5). Comparing earnings in simultaneous games with earnings in power asymmetry games (left panel), first movers on average earn about

[16] Refer to Table 1 for figures on full contributions, that is g=10.

[17] Random effects logistic regression with standard errors clustered at subject level.

[18] The median figures are: 350 (simultaneous games), 264 (FM in king games) and 273 (SM in king games).

32.06 less in the king-provision game and 106.2 less in the king-appropriation game. Considering only games with power asymmetry (right panel), average earnings of SMs and FMs are similar in the king-provision game but SMs earn about 46 more in the king-appropriation game.

[Insert Table 5 about here]

6. Concluding Comments

We report experiments with power symmetry and asymmetry in repeated payoff-equivalent provision and appropriation games. Subjects made fifteen decisions with fixed matching with others within groups. All rounds were paid using a double anonymous (or double blind) protocol.

In the asymmetric-power, king-provision and king-appropriation games, three first movers make their decisions first, and with knowledge of their decisions, the second mover (king) decides how much to contribute or take when given the capability of taking everything. In the symmetric-power provision and appropriation games, all players make choices at the same time without knowing what others contribute or extract in that decision round.

Data from our experiment support several conclusions about repeated play of the games. Consistent with previous literature, across decision rounds, public good allocations are well above the minimum allocation of zero but also well below the efficient allocation of all endowments. Average public good allocations in games with asymmetric power are smaller than in the symmetric power games. The asymmetric-power, king-appropriation game yields lower public good than the asymmetric-power, king-provision game, and less cooperative behavior from both first movers and second movers.

Second movers' behavior is inconsistent with the implications of unconditional altruistic preferences. Second mover data is also inconsistent with a common assumption in the literature that different individual's public good allocations are strategic substitutes; instead, we find that first mover's allocations are increasing in others' total allocations in the previous round. Second movers' public good allocations are also increasing in total allocation of others. In terms of average earnings per subject, playing the simultaneous games is preferred to being a first mover in an asymmetric-power game. In the latter, empirically there is an earnings advantage in moving second in the asymmetric-power appropriation game but not in the asymmetric-power provision game.

Negative externalities from appropriation decisions interact with power symmetry or asymmetry to elicit mirror-image patterns of extreme behavior. Seventy-three percent of decisions are either full Group Fund allocation (51%) or full free riding (22%) in the symmetric-power, appropriation game. However, in the king-appropriation game we observe the mirror image, with second movers choosing full Group Fund allocation (21%) or full free riding (53%). No such mirror-image is observed with positive externalities from provision decisions. In the provision games, the rates are very similar: (a) full free riding at 16% in the provision game and 20% of kings' choices in the king provision game; and (b) full Group Fund allocation at 43% in the provision game and 49% of kings' choices in the king-provision game. The sharply higher rate of full free riding with negative externalities when there is power asymmetry may be suggestive of the extreme difficulty of eliciting voluntary reductions of free riding on efforts to reduce global warming from countries with great asymmetry in power.

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Table 1. Summary Results for Repeated Game Settings*

game	**provision**		**appropriation**	
Power	**Symmetry PG**	**Asymmetry KPG**	**Symmetry AG**	**Asymmetry KAG**
Group Level				
Average Group Fund Value	78.65	66.68	76.68	38.80
Median Group Fund Value	84	63	78	16.5
Individual Level				
Full Allocations (g=10)	43%		51%	
First Movers (g=10)		40%		26%
Second Movers (g=10)		49%		21%
Free ride (g = 0)	16%		22%	
First Movers (g = 0)		15%		40%
Second Movers (g<=0)		20%		53%
Nr of Groups (Individuals)	15 (60)	17 (68)	16 (64)	16 (64)

* Maximum possible Group Fund Value = 120; g is individual contribution (provision game) or tokens left (the appropriation game) in the Group Fund.

Table 2. OLS Regression Analysis of Aggregate Data

Dep.Var: Average Group Fund Values within each period	(1)	(2)
(D) king-provision	-11.97***	-11.97***
	(3.308)	(3.152)
(D) appropriation	-1.978	-1.978
	(3.308)	(3.152)
(D) king-appropriation	-39.85***	-39.85***
	(3.308)	(3.152)
(D) Periods 1 to 5		-0.745
		(2.730)
(D) Periods 11 to 15		-6.882**
		(2.730)
Constant	78.65***	81.20***
	(2.339)	(2.730)
Observations	60	60
R-squared	0.768	0.796

The unit of observation is the average Group Fund Value of all groups who participated in each treatment taken at every period. Y_{it}=average(G(j,t): of all group j in Treatment i at period t}. Baseline is the provision game. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3. Treatments Effects at Intensive and Extensive Margins: First Movers' Choices

	Random Effects Probit Regression **Dep. Var:** Full Free Riding (all FM data: 1 if g= 0; 0 if g > 0)			**Random-Effects GLS Regression** **Dep. Var:** Positive Allocations (g = 0 not included)		
	(1)	(2)	(3)	(1)	(2)	(3)
king-provision	0.143	0.172	-0.029	-1.028**	-1.047**	-0.811*
	(0.269)	(0.217)	(0.254)	(0.504)	(0.503)	(0.440)
king-appropriation	1.333***	0.841***	0.818***	-1.058**	-1.151**	-0.768
	(0.290)	(0.234)	(0.286)	(0.522)	(0.540)	(0.490)
appropriation	0.466*	0.316	0.462*	0.291	0.268	0.188
	(0.267)	(0.221)	(0.258)	(0.433)	(0.434)	(0.405)
Free Rider Rate (t-1)		2.015***			-1.986***	
		(0.221)			(0.362)	
Others G (t-1)			-0.046***			0.083***
			(0.006)			(0.010)
GSU	0.534***	0.352**	0.498***	0.0518	0.202	0.156
	(0.187)	(0.151)	(0.178)	(0.360)	(0.370)	(0.332)
					yes	
Observations	3,345	3,122	3,122	2,589	2,407	2,407
Number of ID	223	223	223	214	214	214

Notes. Omitted Category is provision game. Model Specification in each column includes Indicators for each Period and an indicator for experiments in GSU. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4. Treatments Effects at Intensive and Extensive Margins: Second Movers' Choices

	Random Effects Probit Regression **Dep. Var:** Full Free Riding (all data: 1 if g<=0, 0 if g > 0)			**Random-Effects GLS Regression** **Dep. Var:** SM's Allocations (g=0 not included)		
	(1)	(2)	(3)	(1)	(2)	(3)
king-appropriation	0.667**	1.080**	0.751**	-2.706**	-0.663	-1.124*
	(0.288)	(0.435)	(0.340)	(1.092)	(0.899)	(0.679)
(FM) Free Rider Rate		-1.504***			-6.277***	
		(0.437)			(0.902)	
(FM) Others G			0.0149			0.264***
			(0.015)			(0.025)
GSU	0.043	0.143	0.050	0.503	1.087	0.797
	(0.295)	(0.370)	(0.318)	(1.105)	(0.829)	(0.625)
Observations	495	495	495	393	393	393
Number of ID	33	33	33	33	33	33

Notes. Omitted Category is king-provision game. Model Specification in each column includes Indicators for each Period. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 5. Total Earnings Random-Effects GLS Regression

Dep. Var:	Total Earnings (SM earnings not included)		Total Earnings in Games with Power Asymmetry	
	provision	appropriation	provision	appropriation
Power Asymmetry	-32.06**	-106.2***		
	(15.14)	(14.49)		
Type SM			9.020	46.00*
			(23.57)	(26.21)
GSU	30.71**	-63.74***	50.56**	-55.38**
	(15.12)	(14.34)	(20.45)	(22.70)
Constant	330.3***	373.6***	287.7***	263.2***
	(13.05)	(11.89)	(16.00)	(17.34)
Observations	111	112	68	64
R-squared	0.074	0.403	0.088	0.129

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Figure 1. Group Fund Values across Decision Rounds: Group Level

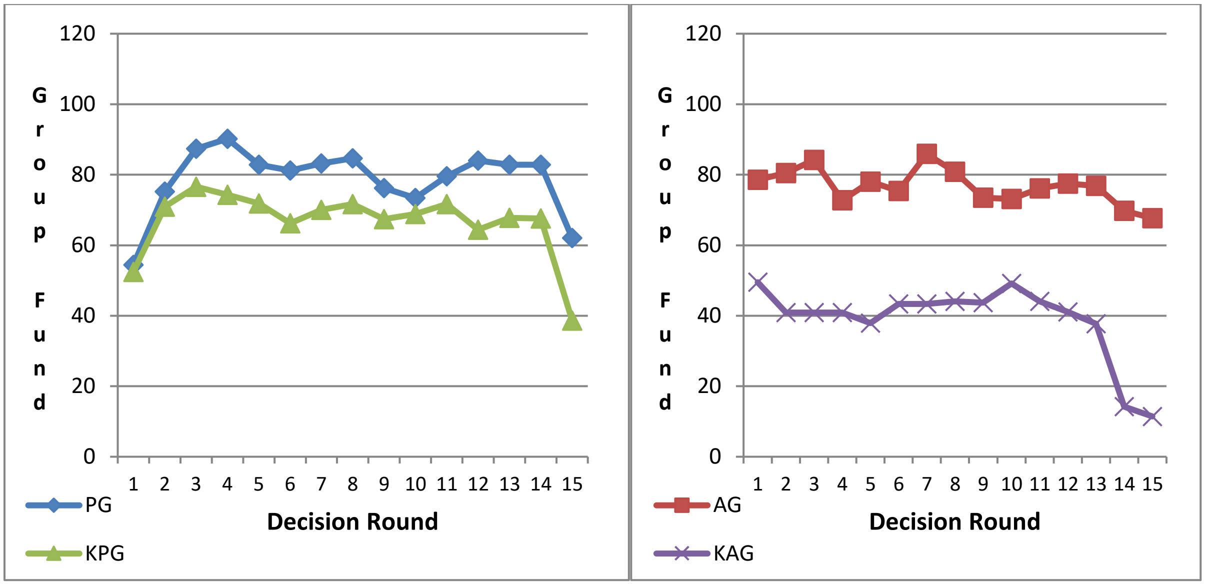


Figure 2: Average First Mover Allocation Values

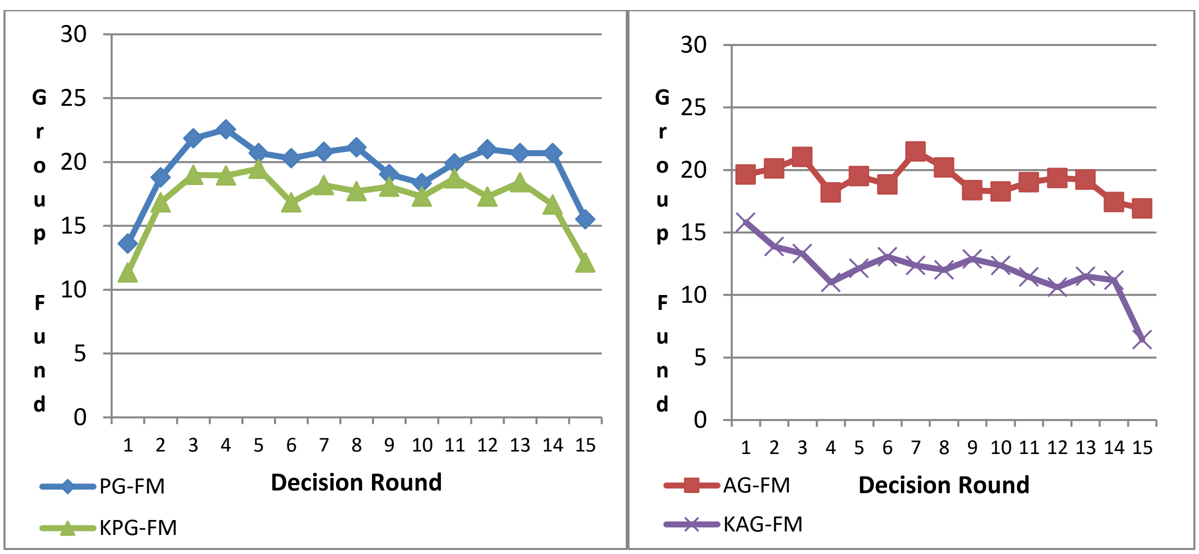


Figure 3: Average Second Mover Allocation Values

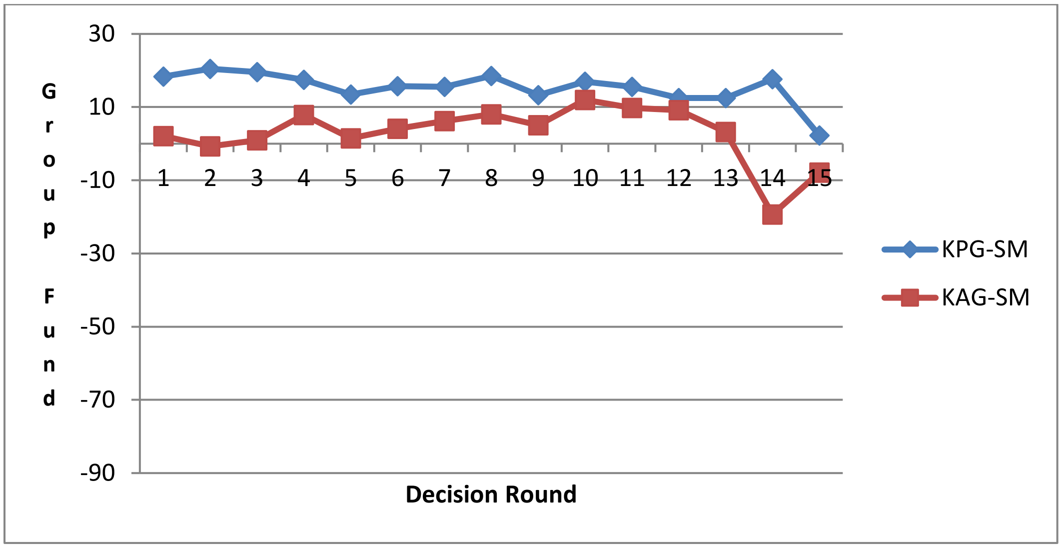


Figure 4: Percentage of Positive Second Mover Group Fund Allocations

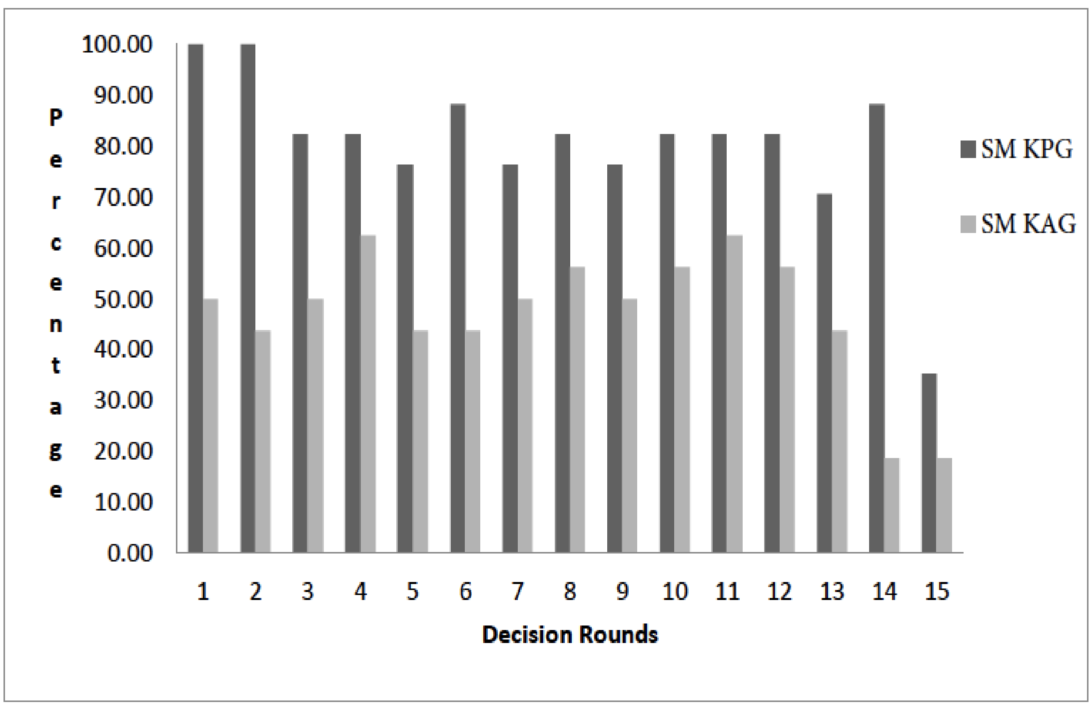
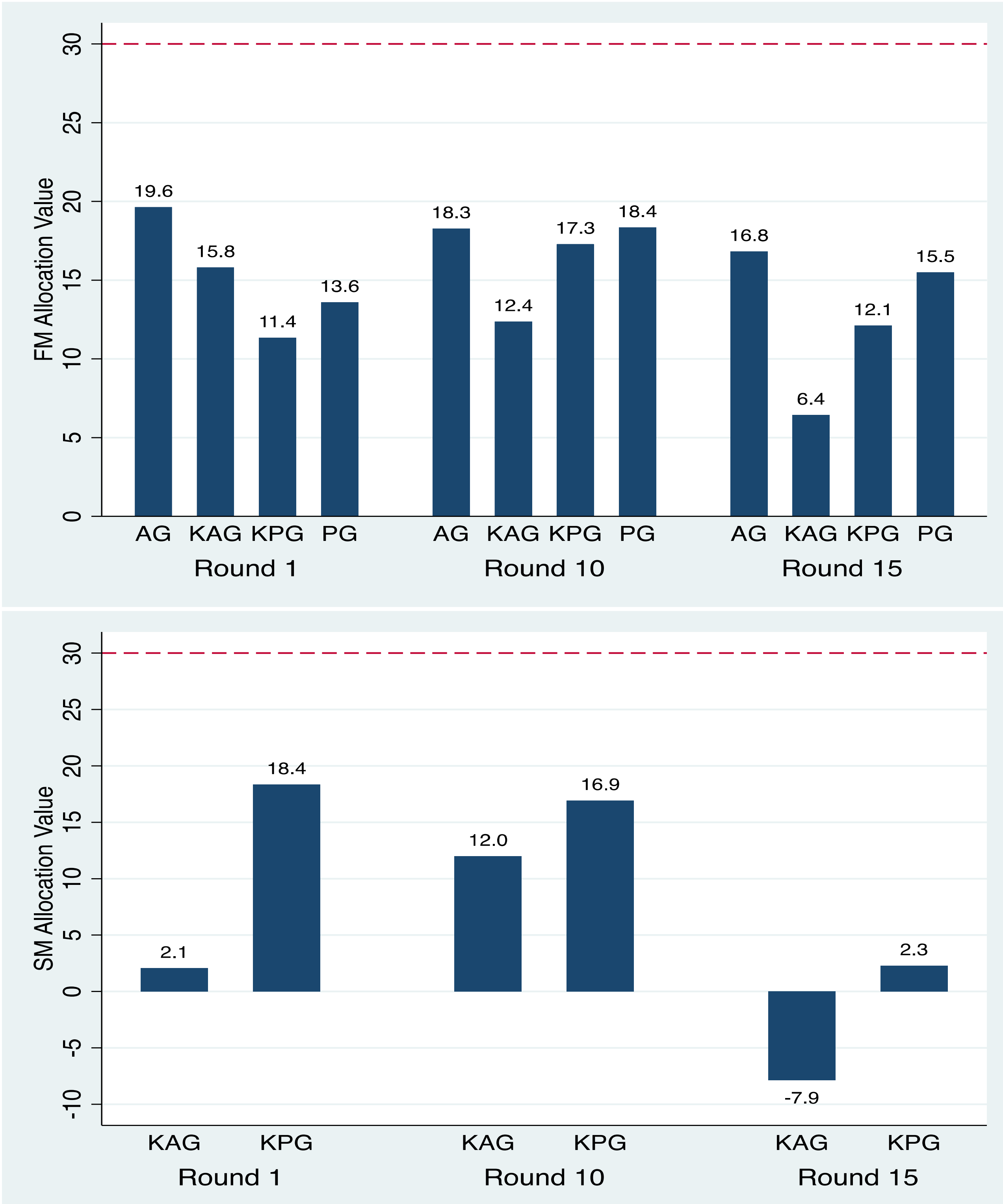


Figure 5: Average First and Second Mover Group Fund Allocations



Appendix

A.1. A Simple Model of Altruism

Altruism is one of the explanations of why people do not free ride. Let g_i denote player i's contribution and, $G=\sum_{i=1..n} g_i$ total contributions to the public fund. Following previous literature, let preferences be defined over payoffs, and for simplicity, suppose that player n's utility is given by

$$u(\pi)=\pi_n+\theta(G_{-n})v(\sum_{i\neq n}\pi_i)$$

where $\pi_j=e-g_j+\gamma G,$ for all $j\in\{1,\cdots$, $v(.)$ is a concave increasing function, and the weight on the total payoffs of others, $\theta(G_{-n})$ may vary with G_{-n} as in conditional altruism (reciprocity) models, or as in unconditional social preferences, it may be a constant. Given contributions of others, write $G=G_{-n}+g_n$, and note that player n's decision problem is

$$\max_G(e+G_{-n}-G+\gamma G)+\theta(G_{-n})v\left((n-1)(e+\gamma G)-G_{-n}\right)$$

In king-sequential, the constraint is $G\geq 0$, whereas in the simultaneous game the constraint is $G\geq G_{-n}$. At an interior solution, G^o

$$F(G_{-n})=(\gamma-1)+\theta(G_{-n})\gamma(n-1)v'\left((n-1)(e+\gamma G^o)-G_{-n}\right)=0$$

So, player n's demand for public good in the simultaneous game is $G^*=\max\{G_{-n},\min\{G^o,e\}\}$ whereas in the (king) sequential game is[19] $G^{**}=\max\{0,\min\{G^o,e\}\}$. The effect of others' total contributions, G_{-n} on interior solution is

$$\begin{aligned}\partial G^o/\partial G_{-n}&=-\frac{-\theta(G_{-n})\gamma(n-1)v''(.)+\theta'(G_{-n})\gamma(n-1)v'(.)}{\theta(G_{-n})\gamma^2(n-1)^2v''(.)}\\&=\frac{1}{\gamma(n-1)}\left(1-\frac{\theta'(G_{-n})v'(.)}{\theta(G_{-n})v''(.)}\right)\\&=\frac{1}{\gamma(n-1)}\left(1-\frac{d\ln\theta(G_{-n})}{d\ln v'(.)}\right)\end{aligned}$$

[19] $G^{**}=\left\{e\quad if\ G^o>e;\quad G^o\ if\ G^o\in(0,e);\quad 0\ otherwise\right\}$

Hence, player n's demand for public good increases in total contributions of others, and more so for conditional altruism as the second term within the bracket is negative. For unconditional altruism, $\partial G^o / \partial G_{-n}$ is less than 1 as in the social dilemma game, $\frac{1}{n-1} < \gamma$, but for conditional altruism it can be larger than 1.

Warm glow. For this model, the specification above modifies to $u(\pi) = \pi_n + v(g_{-n})$, and $\partial G^o / \partial G_{-n}$=1.

Note that, an implication of $\partial G^o / \partial G_{-n}$ weakly less than 1 is decreasing best response individual allocation, g_n as by $g_n = G - G_{-n}$ one has

$$dg_{-n} / dG_{-n} = dG / G_{-n} - 1 < 0$$

A.2. Cooperation in Repeated games

Consider the conventional strategy: start contributing *e*, and continue to do so as long as the total *G* is *ne*, otherwise switch to contributing 0 forever the first time the total *G* is not *ne*. In king games, this remains the FMs' strategy; the SM's strategy is: "contribute *e* if total FMs' contribution is (n-*1*)*e, otherwise* take all of FM's contributions."

In simultaneous games, at time t, no defection is worth $\pi^c / (1-\delta) = \gamma ne / (1-\delta)$ whereas the present value of defection is, $\pi^d + \delta e / (1-\delta) = (e + \gamma(n-1)e) + \delta e / (1-\delta)$. It follows that, defection is not profitable if $\delta > \frac{\pi^d - \pi^c}{\pi^d - \pi^n} = \frac{(e+\gamma(n-1)e) - \gamma ne}{(e+\gamma(n-1)e) - e} = \frac{1}{\gamma}\left(\frac{1-\gamma}{n-1}\right)$ (*)

In king games, SM's payoff from complying is $\gamma ne / (1-\delta)$, whereas defection is worth $Ne + \delta e / (1-\delta)$. The condition for defection to be non-profitable is $\delta > n\left(\frac{1-\gamma}{n-1}\right)$. A FM would never deviate (no matter the value of δ), as SM switches right away to "take all," so there is no immediate gain. An implication is that with sufficiently patient players, full cooperation can be sustained in equilibrium in all our payoff-equivalent repeated games. If the king's discount factor is $\delta \in (\frac{1}{\gamma}, n)\frac{1-\gamma}{n-1}$ and the first movers' discount factor satisfies, $\delta > \frac{1}{\gamma}\left(\frac{1-\gamma}{n-1}\right)$ then, with repetition, full cooperation can emerge in the simultaneous game but not in the sequential king game.