Rational Choice in Games with Externalities and Contractions*

By James C. Cox, Vjollca Sadiraj, and Susan Tang

December 2019

* We thank the National Science Foundation (grant number SES-1658743) for research funding.

Rational Choice in Games with Externalities and Contractions

Abstract. Provision games are public good games with positive externalities. Appropriation games are public good games with negative externalities. Data from Andreoni (1995), and many later papers reporting experiments with these games, are inconsistent with standard theory. To model this behavior we offer an extension of Sen's Property α that includes moral reference points, an approach that is consistent with the discussion in Sen (1993). This new Property M is applied to individual choices in public good games with mixed externalities and contractions, and stress-tested with experimental treatments that induce changes in the observable moral reference points by contracting feasible sets or reallocating endowments.

JEL Classifications: C93, D03, D64, H41
Keywords: public goods, externalities, rational choice, moral reference points, experiment

1. Introduction

Andreoni's (1995) paper sparked an experimental literature which explores behavior in simultaneous-move provision and appropriation games. The distinction between the games is that the provision game involves contributions to a public account, with positive externalities among the players, while the appropriation game involves extractions from a public account, with negative externalities. Andreoni found that the positive-externality game produced significantly more cooperative outcomes than the negative-externality game even though the feasible sets of money payoffs were identical in the two games. This central result has been found to be robust in later studies (e.g., Park 2000; Dufwenberg, Gächter, and Hennig-Schmidt 2011; Cox and Stoddard 2015; Khadjavi and Lange 2015). We next explain why this finding has central implications for rational choice theory.

Because the feasible sets are money-payoff identical in the paired provision and appropriation games, for any given vector of others' choices Property α (Sen 1971, 1993), a central tenet of rational choice theory, implies that money payoffs from an individual's choices will be the same in the two games. Of course, the implication that choices be the same in the two games also applies to special cases of rational choice theory such as conventional preference theory

(Hicks 1946, Samuelson 1947, Debreu 1959), revealed preference theory (Afriat 1967, Varian 1982), and social preferences models (Fehr and Schmidt 1999, Bolton and Ockenfels 2000).[1]

The observed payoff non-equivalence of choices in the paired provision and appropriation games calls for extension of choice theory that is consistent with data from these games. In section 3 we offer such extension of rational choice theory that is based on further development of the implications of Property M that is applied in Cox, et al. (2018) to rationalize data from dictator games with giving and taking opportunities. This approach implements Sen's (1993, p. 495) vision that choice theory should not be characterized solely by internal consistency conditions, such as Property α or the Generalized Axiom of Revealed Preference, but should also incorporate external criteria such as objectives, values, or norms. The central challenge is how to extend the theory in this way while preserving the central feature that makes it empirically testable: quantitative restrictions on observable choices. We respond to this challenge by identifying moral reference points that are observable features of feasible sets. Property M is an extension of Property α that incorporates these observable moral reference points.

We derive the implications of Property M for best response choices from *endogenous* contractions of feasible sets not discussed in previous literature. These endogenous contractions provide within-subjects stress tests of null hypotheses based on Property α and alternative hypotheses that follow from Property M. The experimental design and protocol for testing these hypotheses is described in section 4. Section 5 reports on empirical validity of implications of statements of the two properties for individual choice *conditional* on others' choices, using data from the experiment reported herein. Section 6 reports hypothesis testing for equilibrium play with data from the experiment reported by Khadjavi and Lange (2015). Section 7 concludes the discussion.

[1] Contributing any positive amount in a provision game or extracting less than the maximum feasible amount in an appropriation game is, of course, *inconsistent* with the selfish preferences, special case interpretation of conventional preference theory but consistent with other-regarding preferences. But the non-equivalence of choices in provision and appropriation games (at a given vector of others' actions) is inconsistent with rational choice theory, and therefore inconsistent with conventional preference theory, *per se*, whether or not the preferences are selfish or other-regarding. Reciprocity can explain violations of consistency in *sequential* public good games but not in simultaneous public good games (Cox, Ostrom, Sadiraj, and Walker, 2013), which is the research question in this paper.

2. Related Literature

To our best knowledge, Andreoni (1995) is the first study to look at behavior in positively-framed and negatively-framed voluntary contributions public good games. His between-subjects experiment co-varied game form (provision or appropriation) with wording of subject instructions that made highly salient the positive externality from contributions in a provision game or the negative externality from extractions in an appropriation game. Subsequent literature explored both empirical effects of variations in evocative wording of subject instructions and effects of changing game form (from provision to appropriation) with neutral wording in the subject instructions. We here summarize findings on effects of game form and various framings on contributions, extractions, and beliefs.

2.1 Subjects' Characteristics

This literature looks at interaction between subjects' attributes (social-value orientation, gender, attitudes towards gains and losses) and game framing (positive or negative). The main findings include: (1) play of individualistic subjects but not social-value oriented subjects is sensitive to the framing of the game (Park 2000); (2) more cooperative choices by women than men in the negatively-framed game but not in the positively-framed public good game; (3) for both genders, positive framing elicits higher cooperation than negative framing (Fujimoto and Park 2010); and (4) lower cooperation in taking than in giving scenarios with gain framing but the effect appears to be driven entirely by behavior of male subjects (Cox 2015). With loss framing, no clear effect is detected (Cox 2015).[2] Cox and Stoddard (2015) explore effects of interaction of partners vs. strangers pairing with individual vs. aggregate feedback in payoff equivalent provision (give) and appropriation (take) games and find that the take frame together with individual feedback induces bimodal behavior by increasing both complete free riding and full cooperation.

2.2 Beliefs and Emotions

While give vs. take frames are found to affect contributions, this effect appears to be less strong than the effect on beliefs (Dufwenberg, Gächter, and Hennig-Schmidt 2011, Fosgaard, Hansen and Wengström 2014). A close look at triggered emotions in positively-framed and negatively-framed

[2] In the Loss-Giving setting, subjects *contribute* to prevent loss whereas in the Loss-Taking setting, subjects *take* to generate a loss (Cox 2015).

public good games is offered by Cubitt, Drouvelis, and Gächter (2011) who find no significant effects of punishments or reported emotions.[3] This is one of few studies that find no game form effect on contributions.

2.3 Environment

Studies in this category focus on effects of features of the environment (such as status quo, communication, power asymmetry) on play across take or give public good games. Messer, Zarghamee, Kaiser and Schulze (2007) report an experimental design that interacts status quo (giving or not giving) in a public good game with presence or absence of cheap talk or voting. They report that changing the status quo from "not giving" to "giving" increases average contributions in the last 10 rounds from 18% (no cheap talk, no voting) up to an astonishing 94% (with cheap talk and voting). Cox, et al. (2013) report an experiment involving three pairs of payoff-equivalent provision and appropriation games. Some game pairs are symmetric while others involve asymmetric power relationships. They find that play of symmetric provision and appropriation simultaneous games produces comparable efficiency whereas power asymmetry leads to significantly lower efficiency in sequential appropriation games than in sequential provision games. Cox, et al. (2013) conclude that reciprocity, but not unconditional other-regarding preferences, can explain their data. A framing effect on behavior is observed in public good games with provision points (Bougherara, Denant-Boemont, and Masclet 2011). Soest, Stoop and Vyrastekova (2016) compare outcomes in a provision (public good) game with outcomes in a claim game in which subjects can appropriate the contributions of others before the public good is produced. They report non-positive production of the public good in the claim game even in early rounds of the experiment.

The experiment in the literature that is most closely related to ours is reported by Khadjavi and Lange (2015). They report on play in a mixed game in a between-subjects design that allows for symmetric opportunities for both provision (give) and appropriation (take) with the initial (exogenously-specified) endowment halfway between those in give or take scenarios. They find that (1) the appropriation game induces less cooperative behavior than the provision game

[3] Cubitt et al. use two measures of emotional response including self-reports and punishment.

(replicating the central result in Andreoni, 1995) and that (2) their mixed frame data does not differ significantly from data for their provision game.

One notable difference of our approach from previous literature is inclusion of a within-subjects design for eliciting provision and appropriation responses in three different mixed games that span the design space between the pure provision and appropriation games. A more fundamental departure from previous literature is our inclusion of *endogenous* contractions of feasible sets, in a within-subjects design, that is motivated by Property M. While the Khadjavi and Lange design allows for *exogenous* contraction in the mixed game our design introduces endogenous contractions known to include previous choices in (provision or appropriation) games in addition to beliefs on other's choices. Such endogenous contractions are essential to ascertaining whether behavior in provision, appropriation, and mixed games conforms to Property M's predicted deviations from implications of the Property α in within-subjects experimental treatments.

3. Theory of Play in Games with Externalities and Contractions

We next report, in section 3.1, implications of conventional theory – based on Property α – for provision, appropriation and mixed games with contractions of feasible sets. Best response choice implications of Property M across games are reported in section 3.2.

3.1 Conventional Theory

The Contraction Consistency Axiom, also known as Property α (Sen 1993, p.500) states that for any feasible sets *S* and *T* and choice sets $\Omega(S)$ and $\Omega(T)$, one has

$$\text{PROPERTY } \alpha: [x \in \Omega(S) \ \&\ x \in T \subseteq S] \rightarrow x \in \Omega(T)$$

In words, any allocation $x \in \Omega(S)$ that is chosen from *S* is also chosen from any subset *T* of *S* that contains *x*. Property α is a necessary condition for existence of a transitive ordering of choices (Sen, 1971).[4] For any given vector of others' choices, in games with identical feasible sets of

[4] Property α is a more general characterization of rationality than is the Generalized Axiom of Revealed Preference (GARP), which is the necessary and sufficient condition for existence of a utility function that represents revealed preferences (Varian, 1982). But choices can be rational even though not representable by a utility function, for example choices for lexicographic preferences.

payoffs, as well as for certain types of contractions of feasible choice sets, Property α implies invariance of (best response) choice sets. This implication can be used to inform the design of experimental treatments.

A general description of the games with social dilemmas that are the subject of our study is as follows. Each player, i (=1,…,n) chooses an allocation (w_i, g_i) of an amount W of a scarce resource between two accounts: w_i to individual i's private account and g_i to the public account that is shared with n-1 other players. As in conventional linear public good games, let $\beta \in (1/n, 1)$ denote the marginal per capita rate of public account return. When the total amount of others' allocation to the public account is G_{-i}, individual i's money payoff is $\pi_i = w_i + \beta(g_i + G_{-i})$. By non-satiation, $w_i + g_i = W$ and therefore player i's optimal allocation of the total resource, W between the two accounts is uniquely determined by her allocation in the public account, g_i. The distinguishing characteristic of the provision, appropriation and mixed games is the endowed allocation of the resource W across the two accounts. The value of initial per capita endowment, g^e in the public account uniquely identifies the game with total endowment $ng^e \in [0, nW]$ to the public account and endowment $W - g^e$ to the private account of each of the n agents. $g^e = 0$ is a provision game; $g^e = W$ is an appropriation game; and $g^e \in (0, W)$ is a mixed game.

Let, $\boldsymbol{g}_{-i}$ be a vector of allocations to the public account by agents other than agent i.[5] Let π denote the vector of payoffs to all agents including agent i. In our g^e-games, for any given $\boldsymbol{g}_{-i}$ the feasible set of individual i (in the money payoff space) is

$$S(\boldsymbol{g}_{-i}) = \{\boldsymbol{\pi}(x, \boldsymbol{g}_{-i}) \mid x \in [0, W], \boldsymbol{g}_{-i} \in [0, W]^{n-1}\} .$$

If we let $g_i^b = br(\boldsymbol{g}_{-i})$ denote agent i's best-response allocation when others' allocations to the public account are $\boldsymbol{g}_{-i}$ then the vector of payoffs $\pi(g_i^b, \boldsymbol{g}_{-i})$ belongs to the choice set Ω for the feasible set $\mathrm{S}(\boldsymbol{g}_{-i})$:

$$\pi(g_i^b, \boldsymbol{g}_{-i}) \in \Omega(\mathrm{S}(\boldsymbol{g}_{-i})) \qquad (*)$$

[5] We use bold font to denote vectors.

3.1.a Endowed Resource Allocation and Choice

For any given marginal per capita return, β and total resource, W, the first observation is that Property α implies, for any given decisions of others, $\boldsymbol{g}_{-i}$, player *i*'s chosen allocation is not affected by the endowed per capita allocation, g^e in the public account (see appendix 1) because his feasible set in the payoff space remains $S(\boldsymbol{g}_{-i})$ for all g^e. A second observation (see appendix 1) is that Property α implies player *i*'s choice remains g_i^b if, instead of feasible allocation set $[0,W]$, individual i faces some contracted subset of allocations, $C=[c,W]\subseteq[0,W]$ that contains $\boldsymbol{g}_{-i}$ and g_i^b; we call these subsets, non-binding contractions.[6] Indeed, for any given c such that $c<\min(g_i^b,\min(\boldsymbol{g}_{-i}))$ the feasible set in the payoff space is $T(\boldsymbol{g}_{-i})=\{\boldsymbol{\pi}(x,\boldsymbol{g}_{-i})\,|\,(x,\boldsymbol{g}_{-i})\in[c,W]^n\}$. Property α requires that g_i^b be chosen in the contraction game because $T(\boldsymbol{g}_{-i})\subset S(\boldsymbol{g}_{-i})$ and $\boldsymbol{\pi}\left(g_i^b,\boldsymbol{g}_{-i}\right)\in T\left(\boldsymbol{g}_{-i}\right)$ by specification of the minimum compulsory allocation, $c<\min(g_i^b,\min(\boldsymbol{g}_{-i}))$.

Implications of the two observations are summarized in the following proposition (see appendix 1 for formal derivation).

Proposition 1. Assume that choices satisfy Property α. Let allocations of others, $\boldsymbol{g}_{-i}$ be given. If allocation g_i^b is optimal for individual *i* for some g^e-game then it remains optimal for:

a. All g^e-games, $g^e\in[0,W]$, and
b. All contractions $C=\left[c,W\right]$ such that $0\le c<\min(\mathrm{g}_i^b,\min(\boldsymbol{g}_{-i}))$.

The condition on the lower bound, c of allocations is to ensure that contractions C are non-binding (see statement (*) above) for any player *i*.[7] The supposition on contributions of others, $\boldsymbol{g}_{-i}$ being given reflects *i*'s belief − which in equilibrium is consistent with others' play − an issue we discuss in section 6. Part a of Proposition 1 says that a chosen allocation is the same in the provision, appropriation and mixed games. Part b says that individual *i*'s choice is invariant to contractions of the feasible set that require allocations to the public account to be no less than non-binding

[6] In the provision game, contraction sets of interest (such as, required minimum contributions, taxation) are of type $[c,W]$ for $c>0$.

[7] Note that if the lower bound, c is binding then by construction individual allocations are weakly increasing in c.

thresholds (that is, amounts c that are smaller than agent i's belief about the minimum allocations of others, $\min \boldsymbol{g}_{-i}$ as well as smaller than agent i's chosen allocation, g_i^b from the full set $[0,W]$).[8]

Proposition 1 and the above discussion of Property α make clear how central to empirical validity of rational choice theory (including conventional preference theory and social preferences) are the experimental results reported by Andreoni (1995) and numerous other studies cited in section 1 and section 2. Cox et al. (2018) propose an extension of Property α, that incorporates observable moral reference points, to model observed choices in dictator games with giving and taking opportunities. We here state the extended property as Property M and derive its implications for best response choices in provision, appropriation, and mixed games, and apply it to equilibrium play in section 6. One of the main ideas of Property M is positive monotonicity of final payoffs in endowed payoffs: the higher the payoff at the beginning of the game, the higher the payoff the player expects from playing the game. The other one is that "prosocial play" is a concept defined relative to the most selfish choices.

3.2 Morally Monotonic Choice

Sen (1993, p. 495) wrote: "Internal consistency of choice has been a central concept in demand theory, social choice theory, decision theory, behavioral economics, and related fields. It is argued here that this idea is essentially confused, and there is no way of determining whether a choice function is consistent or not without referring to something external to choice behavior (such as objectives, values, or norms)." Property M offers an extension of Property α that can accommodate the external considerations represented by moral reference points. As we shall see, the definition of "moral reference point" that we use is a suitable extension of choice theory because it is *observable*.

The definition of moral reference point incorporates two intuitions into theory of choice: that my moral constraints on interacting with you in "the game" we are playing may depend on (a) my endowed (or initial) payoff in the game and (b) the payoff each of us can receive when the other's payoff is maximized (a.k.a. our "minimal expectation payoffs"). Intuition (a) reflects the

---

[8] This is to ensure that options that are not included in the subset are revealed inferior with respect to both i's beliefs, $\boldsymbol{g}_{-i}$ about others' contributions and player i's choice, g_i^b.

idea that prosocial behavior grants that the larger my endowed payoff the larger the payoff I expect from playing the game. This initial position (or "property right") effect captures an important feature of everyday life when one is faced by decisions in a fairness game: at the beginning of our interaction, before either of us takes actions that affect both of our payoffs, what initially "belongs to me"? Intuition (b) reflects the idea that prosocial choices require that: (*i*) your final payoff increase in your minimal expectation payoff − "the least you can expect in the game"; but (*ii*) so does my final payoff compared to my minimal expectation payoff − "the least I can expect in the game". This captures a second important feature of everyday life when one is faced by decisions in a fairness games: within the environment of our interaction, what can you legitimately expect from me and what can I legitimately expect for myself by playing the game?

3.2.a Minimal Expectation Payoffs in our Two-Player g^e- Games

As an illustrative example consider two-player g^e-games (with no contraction). The endowment is $2g^e \in [0,2W]$ to the public account and $W - g^e$ to the private account of each of the two agents. First consider minimal expectations payoffs from the perspective of player 1 given player 2's choice to allocate amount g_2 to the public account. The least payoff player 2 can get is $W-(1-\beta)g_2$ in case player 1 defects and allocates 0 to the public account, in which case he gets his maximum payoff; we call this player 2's (g_2-conditional) minimal expectation payoff from the perspective of player 1. On the other hand, player 2's maximum payoff occurs when player 1 makes the most generous choice that results in allocating W to the public account, and therefore player 1 expects no less than $\beta(W+g_2)$; we call this player 1's (g_2-conditional) minimal expectation payoff from the perspective of player 1. These minimum expectations payoff amounts appear in the Player 1 Perspective column of Table 1. By symmetry, minimal expectations payoffs from the perspective of player 2, when player 1's allocation to the public account is g_1, are as shown in the right-most column of Table 1. Social norm considerations require that choice produces payoffs that are positively monotonic in the minimal expectation payoffs.

<Table 1: Minimal Expectations Payoffs for Two Players about here>

3.2.b Moral Reference Points for Two-Player g^e- Games

If there are no transfers between accounts then each agent gets payoff $W - g^e$ from her private account plus payoff $2\beta g^e$ from the public account; this is an agent's *endowed* payoff, $\omega^e = W + g^e(2\beta - 1)$. We propose the endowed payoffs to capture the status quo effect on choices. One feature incorporated into moral monotonicity is that a player expects her own final payoff should be increasing with respect to her endowed payoff in the game. To capture effects of both minimal expectations payoffs and endowed payoffs, Cox et al. (2018) propose as a moral reference point the ordered pair that agrees with the minimal expectation payoff of the other player but is the 0.5-convex combination of one's own minimal expectation payoff and one's own initial endowed payoff. Moral reference points for two players are shown in Table 2.

<Table 2: Moral Reference Points for Two Players about here>

3.2.c Moral Reference Points for N-Player g^e- Games

Generalizing the idea, prosocial play requires each individual i = 1,2,…,n to obtain a final payoff that is no less than the minimum payoff, i_* he gets from actions that give at least one other player the maximum possible payoff she can obtain given feasible (payoff) set $S \subseteq \times_i A_i$. From the perspective of player i, for the minimal expectations vector $(1_*, 2_*, ..., n_*)$[9] and endowed payoff e, the moral reference point of set S is $s_i = (1_*, 2_*, ..., 0.5(i_* + e), ..., n_*)$.

3.2.d Property M

Property M states that choices are monotonic on moral reference points. Let $\Omega(S)$ and $\Omega(T)$ denote choice sets for S and T. Let $\boldsymbol{r}$ denote the moral reference point of decision maker i and let r_j, $j = 1, 2, \cdots, n$, denote the coordinates of $\boldsymbol{r}$ with respect to individual players j. Let s^* and t^* denote the decision maker's choice in S and $T \subseteq S$. Property M is defined as follows.

[9] For example, let player 1's feasible choice set be S={x,y,z} with a monetary payoff mapping: {π(x)=(2,4,7), π(y) = (4,2,9), π(z) = (1,3,8)}. The minimal expectation payoff, 1_* for individual 1 is 1_* = 2 = min {2, 4}) for player 2 gets his maximum payoff (of 4) at x (where 1's payoff is 2) whereas player 3 gets his maximum payoff (of 9) at y (where player 1's payoff is 4). Similarly, minimal expectation payoff, 2_* for player 2 is 2_* = 2 whereas for player 3 it is 3_* = 7 = min{9,7}.

Property M : For all $T \subseteq S$, and $\boldsymbol{s}^* \in \Omega(S) \cap T$

a. if $r_j^T < r_j^S$ and $\boldsymbol{r}_{-j}^T \geq \boldsymbol{r}_{-j}^S$ then $t_j^* \leq s_j^*$ for all $\boldsymbol{t}^* \in \Omega(T)$

b. if $r_j^T > r_j^S$ and $\boldsymbol{r}_{-j}^T \leq \boldsymbol{r}_{-j}^S$ then $t_j^* \geq s_j^*$ for all $\boldsymbol{t}^* \in \Omega(T)$

In words, Property M says that if the moral reference point of decision maker i associated with subset T of S is less (line a) or more (line b) favorable to individual j than the moral reference point associated with S then decision maker i will allocate to individual j a payoff in T that is weakly smaller (line a) or weakly larger (line b) than in S. One case included in the statement of Property M is that in which (decision maker) i and (individual) j are *not* distinct. When the contraction preserves the moral reference point we postulate that choices satisfy Property α.

Without any loss of generality we focus on player 1 to derive implications of Property M for individual choices given others' play in our g^e-games. Let the vector of allocations by others result in the aggregate allocation G_{-1}. It can be verified (see appendix 2) that the ($\boldsymbol{g}_{-1}$-conditional) moral reference point from player 1's perspective in the g^e-game is

$$\begin{aligned} r_{-1}^e &= W - (1-\beta)G_{-1} \\ r_1^e &= 0.5\beta\left(W + G_{-1}\right) + 0.5\omega^e \end{aligned} \qquad (1)$$

where $\omega^e = W + (n\beta - 1)g^e$.

3.2.e Initial Endowment and Contraction Effects in Best Response Choices

To get *initial allocation* or g^e-effect on choices, first note (see (1)) that other's dimension of player 1's moral reference point, r_{-1}^e does not depend on g^e, thus it is constant across g^e-games. The own dimension, r_1^e, however, is increasing in g^e because initial endowed payoff, ω^e increases in g^e (as $\beta > 1/n$). Property M postulates that player 1 aims for a larger payoff for herself when r_1 increases and, therefore *ceteris paribus*, will choose an action that leaves her with a larger final payoff in the game with the larger g^e. Thus Property M reflects the intuition that the larger the endowment the more entitled the player feels to a larger payoff from play, which player 1 can achieve by decreasing her (best response) g_1 allocation to the public account. Similar statements hold for players $2, \cdots, n$.

The *contraction effects* are as follows. Let the g^e-game and $\boldsymbol{g}_{-1}$ be given and let $g_1^b(\boldsymbol{g}_{-1} \mid e, 0)$ be the amount player 1 allocates to the public account when the set is [0, *W*] and the endowment is determined by *W* and *e*. We now examine the implications of Property M for player 1's best response choice when she faces a non-binding contraction, $C = [c, W]$. The initial endowed payoff in the g^e-game is contraction invariant because $\omega^e(c) = W + (n\beta - 1)g^e$ does not depend on *c*. However, minimal expectations vary as allocations to the public account below *c* are not feasible (i.e., $g_1 \geq c$). The payoff of player 1 now takes its maximum when player 1 allocates *c* (as 0 is not feasible anymore) in the public account, therefore the (g_{-1}-conditional) other's dimension minimal expectation payoff increases to $i_*(c) = W - g_i + \beta(c + G_{-1}) > i_*(0)$. On the other hand, other's payoff still reaches its maximum (w.r.t. player 1's actions) when player 1 invests all *W* in the public account. Thus, the ($\boldsymbol{g}_{-1}$-conditional) moral reference point in the game with contraction is *c*-invariant for own dimension but increasing in *c* for other's dimension. Property M implies that player 1's choice will leave the other player with a larger payoff in the g^e-game with contraction, which player 1 can do by increasing his (best response) allocation to the public account. This implication of Property M reflects the intuition that a player's resolution of a social dilemma will depend on how much payoffs differ from those for the most selfish feasible action. Imposition of a positive minimum required contribution, *c* raises the reference point for calibrating the extent of free riding from 0 to *c*. Therefore, contrary to crowding out incentives for public contributions, Property M implies that non-binding lower bounds, *c* on individual allocations to the public account have a positive effect on resolution of social dilemmas. In this way, we get:

Proposition 2. Assume that choices satisfy Property M. Let allocations of others to the public account, $\boldsymbol{g}_{-i}$ be given and let $g_i^b(\boldsymbol{g}_{-i} \mid e, 0)$ be agent *i*'s best response in a g^e- game with feasible set $[0, W]$. Let $C = [c, W]$ be a contracted feasible set such that $c \in (0, \min(\boldsymbol{g}_{-i}, g_i^b(\boldsymbol{g}_{-i} \mid e, 0)]$. Then:

a. The best response choice decreases in the initial endowment, g^e to the public account;
b. The best response choice in g^e-game with contraction $C = [c, W]$ increases in *c*.

3.2.f Implications of Property M for Games with and without Contractions of Feasible Sets

A first observation is that the finding by Andreoni (1995) and many subsequent authors that allocations to the public account are lower in an appropriation game than in a provision game with the same feasible set are consistent with the Proposition 2.a implications of Property M. In contrast, their data are *not* consistent with the Proposition 1.a implications of Property α. If individual choices satisfy Property α then an implication of the axiom is that beliefs about others' allocations are the same across the two games, and therefore, so are individual choices.

A second observation is that parts b of the two propositions provide the theoretical foundation for a stress test of hypotheses using within-subjects data. Part b of Proposition 1, based on Property α, implies that choices are invariant to imposition of non-binding lower bounds on allocations to the public fund. In contrast, part b of Proposition 2, based on Property M, implies that imposition of such non-binding lower bounds will increase (best response) allocations to the public account because they favor others by increasing their minimal expectations points (that are *observable* features of feasible sets).

4. Experimental Design and Protocol

We here report a design of two-player experiments with provision, appropriation and mixed games. We chose a two-player design because it provides sharp tests of theoretical implications.[10] We observe play in a game and elicit subjects' beliefs about play by the other player. Observed play and elicited beliefs are used to inform non-binding contractions of feasible sets that exclude only alternatives that have not previously been chosen nor believed in being chosen by subjects matched in a subsequent play of a contracted game. This design provides sharp discrimination between implications for play of Property α vs. Property M.

We give every subject an initial allocation of 10 "tokens" between a public account (with g^e) and a private account (with 10- g^e). Each token has value $1 in the private account and value $1.50 in the public account (or $0.75 for each of two subjects). The classic (contribute only) provision game corresponds to $g^e = 0$ while the payoff equivalent (extract only) appropriation

[10] In section 6, we present tests of data reported by Khadjavi and Lange (2015) for mixed game experiments with more than two players but *exogenous* contraction of the feasible set that may be binding for some subjects.

game corresponds to g^e=10. Three payoff equivalent mixed games, with both contributions and extractions being feasible, correspond to g^e = 2 or 5 or 8.

Our design crosses set contractions with two types of externalities: positive only (for a provision game), negative only (for an appropriation game). In addition, we have treatments (for mixed games) that allow for actions with both positive and negative externalities. In all treatments, the game is between two players and the public account marginal per capita return, β is 0.75.[11] Table 3 shows parameter configurations, in terms of initial allocations between the two accounts, used in each treatment. The decision task consists of allocating $W = 10$ tokens between the private account and public account. Different subjects participated in the provision game (PG), mixed game (MG) and appropriation game (AG) treatments. Each subject made three decisions without feedback on others' choices and was paired with a different other subject in each of the three decision tasks. In addition, after making each decision every subject was asked to report own expectation ("guess") about the other's decision; correct guesses were paid $2 and incorrect guesses were not paid. One of the three decisions was randomly selected for payoff at the end of each experiment session. After all choices and guesses had been entered, subjects were asked to complete a questionnaire. In addition to demographic questions, it contained questions about a subject's altruistic activities and about their opinions of the altruism vs. selfishness of others.[12]

In the provision game (with g^e = 0), initially all 10 tokens of each player are in his or her private account. The endowed payoff of each subject is $10. The desired allocation between the two accounts can be implemented by transferring (up to 10) tokens from the private to the public account. In the appropriation game (with g^e = 10), initially there are a total of 20 tokens in the public account and 0 in each private account, and therefore the endowed payoff of each subject is $15 because each token has value $1.50 in the public account. The desired allocation between the two accounts can be implemented by transferring (up to 10) tokens from the public account to the private account. Similarly, in the mixed g^e = 5 game the desired allocation can be achieved by transferring up to 5 tokens between the two accounts; the endowed payoff here is $12.50 for each subject. Subjects who participated in the mixed games faced tasks in g^e =2,5,8 games in random order.

---

[11] The social dilemma follows from $0.75 < 1 < 2 \times 0.75$.

[12] The questionnaire is available upon request.

<Table 3. Experimental Design and Treatments about here>

Provision and appropriation games are implemented (within-subjects) with and without contractions. In a baseline (B) game, the set for tokens that can be invested in the public account includes integers in [0,10]. In a contraction (C) game, the set of tokens that can be invested in the public account includes integers in $[c,10]$ for some $c \geq 0$, chosen to be "non-binding," as explained below. To control for order effects, half of the subjects participated in BCB design and the other half in CBC design. For each pair of subjects who faced the contraction set $[c,10]$ in treatment C after the larger set [0,10] in treatment B, the contraction set contained the observed choices and beliefs of both players in the previous baseline treatment.[13] To control for "corner set" effect and/or one-sided error the minimum contribution, *c* was 1 less than the smallest contribution within a pair of subjects.[14] For example, if the contributions of a pair of subjects in the provision game (PG) were 3 and 5 and the reported beliefs were 4 and 3 then the set of allocations for the pair in the provision game with contraction (PG^c) was {2,…,10}.

The construction of contractions in the appropriation (AG) treatment was guided by the same logic. As an illustration, for a pair of subjects with appropriations 2 and 6 in the AG treatment and the reported beliefs 4 and 3, the contracted set in AG^c for transferring tokens from the public account to the private account would be {0,1,…,7}. This set, described in terms of the number of tokens allowed to be allocated to the public account (which is our variable of interest and the focus of the data analysis), is {3, 4,…,10}.

5. Empirical Play in Games with Externalities and Contractions

We first look at behavior across provision, appropriation and mixed games with no contractions. Then we analyze behavior in the provision and appropriation games with and without contractions.

---

[13] In a CBC session, the contraction sets used in the first C task are the same as in a preceding BCB session.

[14] Exceptions to the "$1 less" criterion are when choices in the preceding task are at a corner amount of 0 or close to 10. In a BCB session, if either subject guessed 0 or allocated 0 to the public account in the first B task then the set in treatment C would be [0,10]. If application of the "$1 less" criterion would have resulted in a set with fewer than three options (i.e., lower bound 8 or 9) the set of allocations for task C was [5,10].

5.1 *Effects of Endowed Allocations on Choices*

Seventy-two subjects participated in (a within-subjects design) mixed-game treatment with each subject making three decisions.[15] In addition we have data from eighty other subjects who participated in the provision game and another eighty subjects who participated in the appropriation game.

By conventional rational choice theory (Principle α) the final allocations to the public account (see Proposition 1, part a) are invariant to the endowed allocations, g^e; this is our null hypothesis. Application of moral monotonicity (Principle M) in our games, on the other hand, implies that final and endowed allocations in the public account are inversely related (see Proposition 2, part a); this is our alternative hypothesis. We begin with comparing decisions of subjects in the mixed games with decisions of subjects in the provision game (g^e =0, no contraction) and in the appropriation game (g^e =10, no contraction). After that we report and discuss estimates of g^e -effect and the guessed other's *g* allocation effect using a tobit regression with random effects.

5.1.a Types of Externalities and Choice.

When feasible allocations consist of integers from [0,10], average number of tokens allocated to the public account in the provision, mixed and appropriation games are, respectively, 4.01, 3.64 and 3.09,[16] suggesting adverse effect of initial per capita allocation in the public account on resolution of social dilemmas. For free-riding, measured as observed public account allocations of 0 or 1, the provision game elicits least free-riding (30.13%) whereas the appropriation game elicits the most free-riding (52.2%); the free-riding figure for the mixed games is between (42.59%).[17] For statistical inferences we use Kolmogorov-Smirnov test for distributions of *g* allocations and Pearson chi2 test for free riding behavior.[18] Choices of subjects in our experiment are characterized by:

[15] That is, one decision in each of the 2-game, 5- and 8-game; the order of the three decision tasks was randomized across subjects.

[16] The 95% Confidence Intervals are: [3.46, 4.57] in provision game, [3.13, 4.15] in mixed game and [2.55, 3.63] in appropriation game.

[17] Figures (in %) for full free-riding (i.e., *g*=0, allowing for no decision errors) are: 21 (provision), 39 (mixed) and 48 (appropriation).

[18] To ensure independence, when a subject made more than one decision per treatment (e.g. in a BCB session subjects are making two choices in appropriation game), tests are applied to the average of the subject's *g* allocations. Use of

(i) Larger public account allocations (p-value=0.022) and less free-riding (p-value=0.003) in provision than appropriation game data;

(ii) Similar public account allocations (p-value=0.497) and free-riding (p-value=0.247) in provision and mixed game data;

(iii) Similar public account allocations (p-values=0.384) but less free-riding (p-value=0.075) in mixed than appropriation game data.

Based on these findings we conclude:

Result 1. Provision game elicits higher average allocation to the public account and appropriation game elicits more free-riding (public account allocations of 0 or 1).

Result 1 rejects Property α in favor of Property M.

5.1.b Endowed per capita g^e Allocation Effects in Mixed Games (Within-Subjects Analysis)

There is some variation in the means (3.9, 4.2 and 5.1) of guessed other's g allocations with respect to initial g^e. Propositions 1 and 2 provide statements of implications of Property α and Property M conditional on the other's g allocation. To test the empirical validity of these statements we analyze the chosen g allocations of subjects whose guesses about others' chosen g allocations did not change with initial allocation g^e.[19] We constructed a new variable, Δg: the difference between the chosen g allocations observed for different initial g^e allocations (conditional on the guess not changing). For each subject, $\Delta g = g^i - g^j$, where superscripts $i<j$ denote the g^e values from {2,5,8}; that is Δg is the difference between the public account allocation in the i-game and the allocation in the j-game. The null hypothesis that follows from Property α is $\Delta g=0$ (Proposition 1, part a) whereas the alternative hypothesis that follows from Property M is $\Delta g>0$ (Proposition 2, part a). The mean of Δg is 0.782 (95% C.I.=[-0.05,1.61]) and the (Property α) null

all data (rather than average choices at the individual level) in our tests, produces similar results but p-values are smaller. For the distributions of g allocations in mixed and provision games the p-value is 0.007 (*KS* test) whereas for free-riders, p-value is 0.00 (Pearson chi2 test).

[19] There are 56 such choices from 32 (out of 72) subjects.

hypothesis is rejected by *t*-test (one-sided p-value=0.032) in favor of the (Property M) alternative hypothesis.[20]

5.1.c Initial per capita g^e *Allocation Effects in All Games (Between-Subjects Analysis)*

To understand effects of endowed allocations on chosen allocations we utilize a tobit regression (with random effects) reported in Table 4. In the simple model, the list of regressors include the subject's guess of the other's chosen allocation and our treatment variable, the known initial endowment of the public account. As a robustness check, in other models we expand the list of regressors to include demographics (gender, race), self-image (helping others with homework, donating to charity, giving money to strangers when asked, sharing secrets) and image of others (inwardly dislike helping, help with disabled car, self-interested). The estimate of the effect of

<Table 4: Tobit Regressions about here>

initial endowment, g^e in the public account is -0.1 (different from 0 at 5% level of significance) for all four specifications, rejecting the null hypothesis of no g^e effect (Proposition 1, part a), that follows from conventional choice theory, in favor of the alternative hypothesis of moral monotonicity (Proposition 2, part a). We conclude that:

> **Result 2**. Allocation to the public account decreases as the initial endowment of the public account increases.

Result 2 rejects Property α in favor of Property M.

5.2 Contraction Effects

For any given allocation by the other player, Property α requires that choices in the provision game or appropriation game are preserved in any contraction set that contains choices of both players (as well as other's expected contributions). Property M makes the same prediction for "contractions" that are not strict (that is, *C*={0,1,…,10}) but for *C*={ c_i,…,10}, with positive c_i,

[20] If we don't include *selfish* subjects (subjects who *always* allocated 0 in the public account), the mean of Δg is 1.229 (95% C.I. =[-0.08, 2.53])

Property M predicts g allocation increasing in (nonbinding) c_i. Tests of these predictions are reported in the following subsections.

5.2.a Within-subjects Data Analysis

We constructed a new variable, Δg_i^{ca} that takes its values according to the difference between the subject's observed allocations in the public account from the (non-binding) contracted set, $C=\{c,\ldots,10\}$ and the full set, $A=\{0,\ldots,10\}$. The null hypothesis from Property α is that Δg_i^{ca} values are drawn from a distribution with mean 0, provided that the guess of other's contribution did not change. For such cases (that is, subjects with unchanged guesses), the mean of Δg_i^{ca} is significantly larger than 0 in the provision game but not in the appropriation game.[21] We also looked at Δg_i^{aa}, the within-subjects difference in g allocations in tasks in which subjects faced the full set, $\{0,\ldots,10\}$ (that is, not proper contractions). Both Property α and Property M require the mean of the distribution of Δg_i^{aa} be 0. Data fail to reject this null hypothesis as the mean is -0.06 (95% C.I.= [-0.31,0.18], p-value=0.607 (*t*-test)).[22]

5.2.b Best Responses and Contractions

Figure 1 shows (own) g allocations, averaged across subjects, at each level of guesses of other's contribution.[23] Consistent with Property M, we observe best response allocations in games with proper contractions, C above the ones from the full set, A.[24] It should be noted that this is *not* an artifact of the design as the contraction each subject faced contained his own choice observed in the full set, A (as well as the guessed contribution of the other).[25] For statistical inference, we use tobit regression (with random effects) reported in Table 5. In the simple model the list of

[21] The 95% C.I. is [0.13, 1.71] (p-value = 0.02; *t*-test) in the provision game and [-0.60, 1.78] (p-value = 0.32, *t*-test) in the appropriation game.

[22] Provision game: 0.2 (mean), p-value = 0.44 (*t*-test); Appropriation game: -0.14 (mean), p-value=0.34 (*t*-test).

[23] 480 decisions from 160 subjects across the two games (provision and appropriation) were aggregated as follows. Let D be an indicator variable for proper contraction (i.e., $c_i>0$). Let a vector $\boldsymbol{v}$ = (game, D, g^e), be given. For each feasible guess of other's g allocation, we constructed the mean of (observed) g allocations for each combination (game, D). Thus, we have one value of g allocation for each level of guessed other's g allocation given scenario $\boldsymbol{v}$. This gives us a mapping (at an aggregate level) of a guessed other's g to one's own g allocation for the case $\boldsymbol{v}$ = (game, c, g^e). We do this for each possible vector $\boldsymbol{v}$.

[24] See Figure 2a in appendix 4 for nonlinear best responses.

[25] For example, a subject who contributes 3 (and guessed, say 4) in full public good game, A can still make a lower contribution, 2 in the contraction game, C which is a feasible choice as for this subject, C={2,…,10}.

regressors includes the subject's guess of the other's g_{-i} allocation and the value of lower bound, c_i. The predicted estimate for the c_i parameter is 0 for conventional rational choice theory

<Table 5: Tobit Regressions about here>

(Proposition 1, part b) but positive for moral monotonicity theory (Proposition 2, part b). For robustness check we also add demographics to the list of regressors. Tobit estimates of non-binding lower bounds, c_i (for contractions) are positive for both specifications and in both games, provision and appropriation. Our third result that favors Principle M over Principle α is:

> **Result 3**. *Non-binding* lower bounds on public account allocations induce higher average allocations to the public account, controlling for the belief about other's allocation.

5.2.c Pooled Data

Last, but not least, 696 decisions from 232 subjects across all games were used in a tobit regression (with random effects) reported in Table 6. Recall that a negative estimate for g^e and a positive estimate for *c* is predicted by Property M. Tobit estimates are consistent with the Property M prediction: the g^e estimate is -0.1 (p-value < 0.1) whereas the *c* estimate is 0.6 (p-value < 0.01).

<Table 6. Tobit Regressions about here>

6. Implications of Property M for Equilibrium Play

Our data provide support for Property M predictions of a negative effect of the size of the endowed allocation in the public account and a positive effect of non-binding lower bounds on *g*-allocations on individual best response *g*-allocations. In this section we turn our attention to efficiency of play (in equilibrium) across these games in the absence or presence of concerns for moral costs associated with individual choices.

Tobit estimates (reported above) of other's contribution on *g* allocations reveal that best response functions, $br(g_{-i})$ are increasing but not that fast, i.e. the marginal response $br'(g_{-i}) \in (0,1)$. A generalization of this result to *n* players is an increasing best response *g* allocation in the total contributions of others, G_{-i} (= g_{-i} if *n*=2) with the marginal response between 0 and 1/(n-1). The question we ask in this section is what are the implications of Property M for equilibrium play in (g^e, c)-games. Do the shifts of best responses triggered by changing moral reference points translate to equilibrium efficiencies increasing with c and decreasing with g^e? The answer to this question is positive; a formal proof is provided in appendix 3 but we here provide an intuitive explanation. We use the provision game without contraction as the baseline. For tractability, the best response as well as the moral reference points are defined with respect to the average of the total allocation of others. Suppose that $\boldsymbol{g}^p$ is a Nash equilibrium in the baseline (provision without contraction) game. Let $c < \min\{g_i^p \mid i = 1,\ldots,n\}$ and consider provision game with contraction, $[c, W]$. Allocation, g_i^p can be seen to be more prosocial when the minimal feasible allocation is 0 than when it is c. If so, individual i incurs a higher moral cost (social pressure) of allocating g_i^p in the provision game with contraction, $[c, W]$. To lessen the increased moral cost he may allocate more than g_i^p in the game with contraction. This together with best responses increasing in other's average allocations (as revealed by tobit estimates reported in the previous section) suggest equilibrium play in the provision game with contraction will be more efficient than in the baseline provision game.

On the other hand, in a mixed g^e-game with no contraction, individual i starts the game with a higher endowed payoff $(W + (\beta n - 1)g^e > W)$ than in the baseline provision game. Higher endowed payoff in the mixed game makes the individual feel entitled to a larger own monetary payoff in a mixed game than in the provision game, which can be realized by allocating less than g_i^p to the public account in the mixed game. Again, this together with positive monotonicity of best responses suggest the equilibrium in the mixed game will be less efficient than in the provision game.

Let $\boldsymbol{g}^*$ be a Nash equilibrium in a (g^e, c)-game and let $G^* = \sum_i g_i^*$ denote the total allocations to the public account. If g allocations are (**) C^1 functions of total contributions of others and $br_i'(G_{-i}) \in (-1, 1/(n-1))$ for all i then the following statements are shown to be true in appendix 3.

Proposition 3. For all $0 < c < \min\{g_i^* \mid i = 1,\dots,n\}$ and for all $g^e \in [0,W]$, if choices satisfy:

1. Property α then $G^*(g^e,c)$ is invariant to g^e and c
2. Property M then $G^*(g^e,c)$ is decreasing in g^e and increasing in c

The maximum difference in public account endowment is between the provision game, in which $g^e = 0$, and the appropriation game in which $g^e = W$, the entire resource endowment. As stated in part 1 of Proposition 3, Property α predicts invariance of equilibrium play to endowment to the public account, g^e or non-binding lower bounds, c to public account allocations. In contrast, as stated in part 2 of Proposition 3, Property M predicts a negative effect of larger initial endowment, g^e but positive effect for larger (non-binding) lower bounds, c on allocations to the public account.

We here report analysis of data from the multiple-round and multiple-player experiment reported by Khadjavi and Lange (2015) to ascertain the empirical validity of predictions in part 1 and part 2 of Proposition 3.[26] The experimental design of Khadjavi and Lange (2015) shares some similarities with our design. They include a provision game (PG), appropriation game (AG), and mixed game (MG). Each token in the private account has value 1 in experimental currency and value 1.6 in the public account. Games include four players, hence the public account marginal per capita rate of return is 0.4. The per capita endowments of tokens in the provision game, appropriation game and mixed game are, respectively, the ordered pairs (20, 0), (0, 20) and (12, 8) in which the first integer is the endowment to the private account and the second integer is the per capita endowment to the public account. For these games, the feasible set of tokens to be allocated to the public account includes discrete values contained in [0, 20]. For the game with contraction, the per capita endowment of tokens is (12, 8) and the feasible set of allocations to the public account includes discrete values contained in [8, 20]. There are ten periods in each game. We pool the Khadjavi and Lange (2015) data from their treatments to analyze the effects of endowments of tokens and the lower bound c (which is 8 in their design). Since Khadjavi and Lange (2015) do not elicit subjects' beliefs about others' g allocations, we generate proxies for the beliefs using total allocations, G_{-i} from the immediately preceding period for other players in the same group.

[26] We thank Khadjavi and Lange for sharing their data.

In order to allow time for behavior of subjects to stabilize, we use data from the second half of the sessions (rounds 6-10). Figure 3 displays (average) g allocations for each level of others' average contribution, G_{-i} in the immediately preceding round. Consistent with Property M predictions, we see larger best responses in the mixed game with contraction than in the full mixed game. The observed pattern in the aggregated data is supported by tobit estimates, reported in Table 7 for models without (column (1)) dummy variables for rounds 7,8,9, and 10 as well as with the dummies (column (2)). Reported parameter estimates are robust across the two models except

<Table 7. Tobit Regression of Equilibrium Play about here>

for marginal change in the constant. The marginally significant negative estimated coefficient (-0.2) for the g^e parameter is inconsistent with implications of Property α (part 1 of Proposition 3) but consistent with implications following from Property M (part 2 of the proposition). The significantly positive estimated coefficient (0.7 or 0.8 depending on the specification) for the Contraction lower bound (b) rejects Property α in favor of Property M (which predicts a positive estimate).[27] The estimate for the total contributions of others, G_{-i} is positive, suggesting increasing best response, and is also less than 1/3 (=1/(n-1)), which is consistent with supposition (**) of Proposition 3.

> **Result 4.** Estimated best response function is decreasing in endowment of the public account and increasing in lower bound constraint on allocations to the public account.

The endowment effect in Result 4 is inconsistent with Property α but predicted by Property M. The lower bound constraint effect in Result 4 is predicted by Property M but not known to be inconsistent with Property α because the exogenous constraint can be binding for some subjects.

7. Conclusion

The topic of our paper falls within a literature sparked by Andreoni's (1995) experiment with positively-framed (provision) and negatively-framed (appropriation) public good games. Because

[27] This last conclusion must be stated with caution because the contraction of the feasible set was imposed exogenously and, hence, could have been a binding constraint for some subjects. See section 4 above for description of the *endogenous* contractions, used in our own experiment, designed to be non-binding.

Andreoni's games are payoff equivalent, conventional choice theory requires choice outcomes across the two games be similar. This was not observed; subjects' choices in Andreoni's experiment were more cooperative in the provision game than in the appropriation game. Andreoni used emotive subject instructions that made highly salient the positive externalities in the provision game and the negative externalities in the appropriation game, but the pattern has been replicated in several subsequent studies that used neutral wording. The data from these experiments challenge conventional choice theory.

We derive implications for allocations in provision and appropriation games from the conventional Property α and the alternative Property M. In previous applications (Cox, et al. 2018), Property M has been used to rationalize behavior in dictator games with give and take opportunities and play in strategic games with contractions of feasible sets including investment, moonlighting, carrot, stick and carrot/stick games. We explain that Property M can rationalize the robust result that is inconsistent with Property α (and its GARP, conventional preferences, and social preferences special cases): provision games elicit more cooperation than payoff-equivalent appropriation games.

We report an experiment with payoff-equivalent provision, appropriation, and mixed games that discriminates between null hypotheses implied by Property α and one-sided alternatives provided by Property M. A novel feature of our experiment is *endogenous* (*non-binding*) contractions of feasible sets that contain other's choices as well as beliefs on other's choices as interior points. Observed play and elicited beliefs are used to inform contractions of the sets of allocations that exclude only alternatives that have not been chosen nor believed in being chosen by both subjects that are matched in a subsequent play of a contracted game. Conventional choice theory predicts that such exclusion of "irrelevant alternatives" will have no effect on chosen allocations. In contrast, moral monotonicity principle predicts that the non-binding constraints on choices embodied in the contractions will affect choices because they change players' moral reference points. Data are largely *in*consistent with the implications of Property α but consistent with implications of Property M. Similar conclusions follow from our analysis of data from the experiment reported by Khadjavi and Lange (2015).

References

Afriat, S.N., 1967. The Construction of Utility Functions from Expenditure Data. Int. Econ. Rev. 8, 66–77. https://doi.org/10.2307/2525382

Andreoni, J., 1995. Warm-Glow versus Cold-Prickle: The Effects of Positive and Negative Framing on Cooperation in Experiments. Q. J. Econ. 110, 1–21. https://doi.org/10.2307/2118508

Bolton, G.E., Ockenfels, A., 2000. ERC: A Theory of Equity, Reciprocity, and Competition. Am. Econ. Rev. 90, 166–193. https://doi.org/10.1257/aer.90.1.166

Bougherara, D., Denant-Boemont, L., Masclet, D., 2011. Cooperation and Framing Effects in Provision Point Mechanisms: Experimental Evidence. Ecol. Econ. 70, 1200–1210. https://doi.org/10.1016/J.ECOLECON.2011.01.023

Cox, C.A., 2015. Decomposing the Effects of Negative Framing in Linear Public Goods Games. Econ. Lett. 126, 63–65. https://doi.org/10.1016/J.ECONLET.2014.11.015

Cox, C.A., Stoddard, B., 2015. Framing and Feedback in Social Dilemmas with Partners and Strangers. Games 6, 394–412. https://doi.org/10.3390/g6040394

Cox, J.C., List, J.A., Price, M., Sadiraj, V., Samek, A., 2018. Moral Costs and Rational Choice: Theory and Experimental Evidence. Exp. Econ. Cent. Work. Pap. Ser.

Cox, J.C., Ostrom, E., Sadiraj, V., Walker, J.M., 2013. Provision versus Appropriation in Symmetric and Asymmetric Social Dilemmas. South. Econ. J. 79, 496–512. https://doi.org/10.4284/0038-4038-2012.186

Cubitt, R.P., Drouvelis, M., Gächter, S., 2011. Framing and Free Riding: Emotional Responses and Punishment in Social Dilemma Games. Exp. Econ. 14, 254–272. https://doi.org/10.1007/s10683-010-9266-0

Debreu, G., 1959. Theory of Value; An Axiomatic Analysis of Economic Equilibrium. Yale University Press.

Dufwenberg, M., Gächter, S., Hennig-Schmidt, H., 2011. The Framing of Games and the Psychology of Play. Games Econ. Behav. 73, 459–478. https://doi.org/10.1016/J.GEB.2011.02.003

Fehr, E., Schmidt, K.M., 1999. A Theory of Fairness, Competition, and Cooperation. Q. J. Econ. 114, 817–868. https://doi.org/10.1162/003355399556151

Fosgaard, T.R., Hansen, L.G., Wengström, E., 2014. Understanding the Nature of Cooperation Variability. J. Public Econ. 120, 134–143. https://doi.org/10.1016/J.JPUBECO.2014.09.004

Fujimoto, H., Park, E.-S., 2010. Framing Effects and Gender Differences in Voluntary Public Goods Provision Experiments. J. Socio. Econ. 39, 455–457. https://doi.org/10.1016/J.SOCEC.2010.03.002

Hicks, J., 1946. Value and Capital; An Inquiry into Some Fundamental Principles of Economic Theory. Clarendon Press.

Khadjavi, M., Lange, A., 2015. Doing Good or Doing Harm: Experimental Evidence on Giving and Taking in Public Good Games. Exp. Econ. 18, 432–441. https://doi.org/10.1007/s10683-014-9411-2

Messer, K.D., Zarghamee, H., Kaiser, H.M., Schulze, W.D., 2007. New Hope for the Voluntary Contributions Mechanism: The Effects of Context. J. Public Econ. 91, 1783–1799. https://doi.org/10.1016/J.JPUBECO.2007.08.001

Park, E.-S., 2000. Warm-Glow versus Cold-Prickle: A Further Experimental Study of Framing Effects on Free-Riding. J. Eon. Behav. Organ. 43, 405–421. https://doi.org/10.1016/S0167-2681(00)00128-1

Samuelson, P.A., 1947. Foundations of Economic Analysis. Harvard University Press.

Sen, A.K., 1971. Choice Functions and Revealed Preference. Rev. Econ. Stud. 38, 307–317. https://doi.org/10.2307/2296384

Sen, A.K., 1993. Internal Consistency of Choice. Econometrica 61, 495–521. https://doi.org/10.2307/2951715

van Soest, D., Stoop, J., Vyrastekova, J., 2016. Toward a Delineation of the Circumstances in Which Cooperation can be Sustained in Environmental and Resource Problems. J. Environ. Econ. Manage. 77, 1–13. https://doi.org/10.1016/J.JEEM.2015.12.004

Varian, H.R., 1982. The Nonparametric Approach to Demand Analysis. Econometrica 50, 945–973. https://doi.org/10.2307/1912771

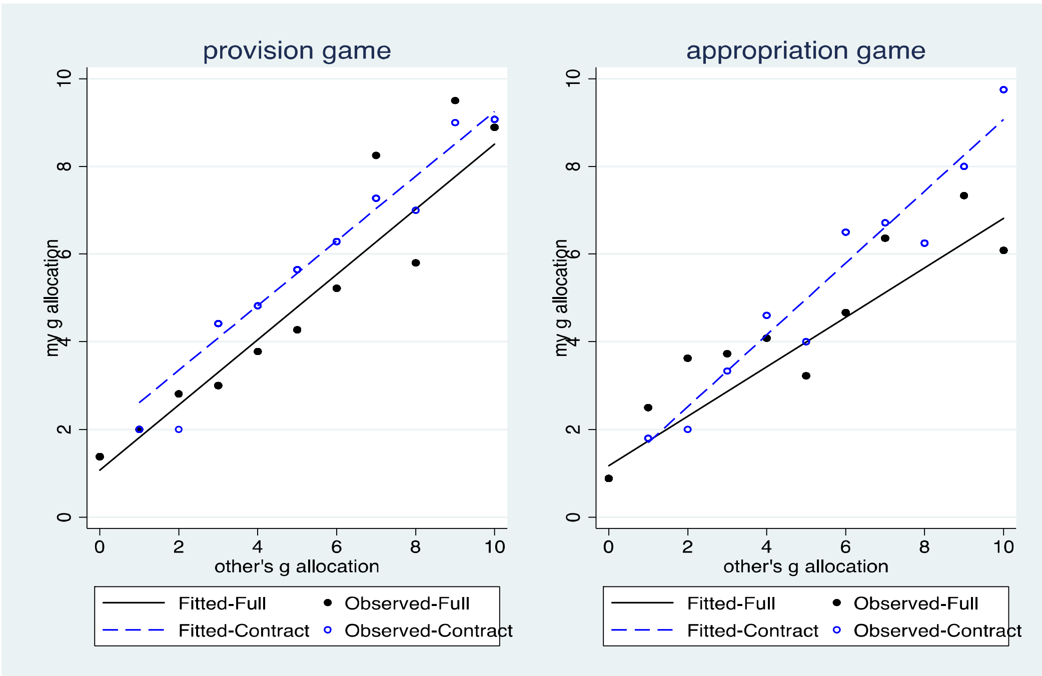

Figure 1. Best Response (average) g allocations

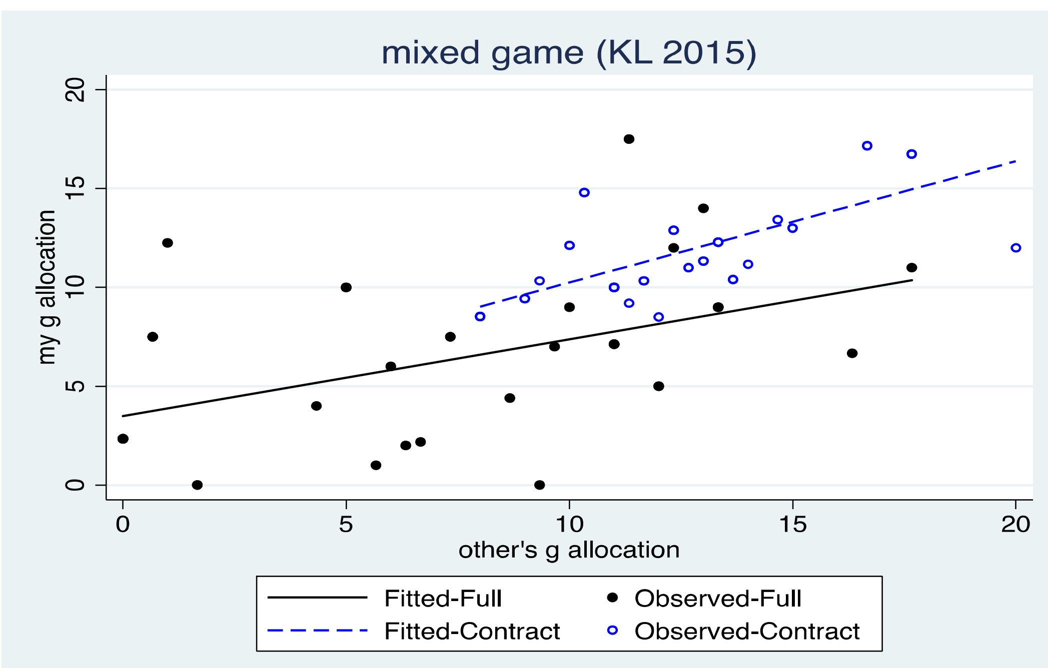

Figure 2. Best Response (average) g allocations (Khadjavi and Lange 2015, period 6-10 data)

Table 1. Minimal Expectations Payoffs of S(g) in Two-Player g^e - Games

	Player 1 Perspective	Player 2 Perspective
Player 1 Payoffs	$\beta(W+g_2)$	$W-(1-\beta)g_1$
Player 2 Payoffs	$W-(1-\beta)g_2$	$\beta(W+g_1)$

Notation: W is total amount of resource, β is the marginal per capita return from the public good, $g_i = g^e - x_i^e$ where x_i^e is *i*'s decision in the g^e-game and g_i is the corresponding contribution in the provision game.

Table 2. Moral Reference Points of S(g) in Two-Player g^e - Games

	Player 1 Perspective	Player 2 Perspective
Player 1 Payoffs	$0.5\omega^e + 0.5\beta(W+g_2)$	$W-(1-\beta)g_1$
Player 2 Payoffs	$W-(1-\beta)g_2$	$0.5\omega^e + 0.5\beta(W+g_1)$

Notation: ω^e is the endowment, W is total amount of resource, β is the marginal per capita return from the public good, $g_i = g^e - x_i^e$ where x_i^e is i's decision in the g^e -game and g_i is the corresponding contribution in the provision game.

Table 3. Experimental Design and Treatments

	Contracted Provision	Provision	Mixed Games			Approp.	Contracted Approp.
Dollars							
Endowment	\$10	\$10	\$11	\$12.5	\$14	\$15	\$15
Tokens							
Initial Private	10	10	8	5	2	0	0
Action Set	[c,10][a]	[0,10]	[-2,8]	[-5,5]	[-8,2]	[-10,0]	[-t,0][b]
Feasible Allocations in Public Account	[c,10]	[0,10]	[0,10]	[0,10]	[0,10]	[0,10]	[10-t,10]
Design Nr. of Subj.: Order	Within Subjects 40: ACA 40: CAC		Within Subjects 72: random order of 8,5,2			Within Subjects 40: ACA 40: CAC	
Decision Tasks per Subject	3		3			3	
Nr. of Subjects	80		72			80	
Nr. of Obs.	240		216			240	

[a] $c = \min(g_i^* - 1, guess(g_{-i}) : i = 1,2)$, [b] $t = \max(t_i^* + 1, guess(t_{-i}) : i = 1,2)$.

Table 4. Best Response *g* Contributions when initial allocations vary (no contraction)
(Tobit regression with Random Effects)

Dependent Variable: g Allocation	(1)	(2)	(3)	(4)
Guessed Other's allocation	1.005***	1.014***	1.022***	1.024***
	(0.079)	(0.079)	(0.079)	(0.079)
Initial Allocation in the Public	-0.131**	-0.141**	-0.132**	-0.146**
Account, g^e	(0.065)	(0.066)	(0.065)	(0.065)
Demographics	no	yes	yes	yes
Self Image	no	no	yes	yes
Image of Others	no	no	no	yes
Constant	-0.662	-0.989	-1.203	-0.831
	(0.550)	(0.763)	(0.787)	(0.798)
Observations	554	554	554	554
Log. Likelihood	-1019	-1018	-1014	-1012

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

Table 5. Best Response *g* Allocations in Games with and without Contractions
(Tobit Regression with Random Effects)

Dependent Variable:	Provision Game		Appropriation Game	
g Allocation	(1)	(2)	(1)	(2)
Guessed Other's	0.694***	0.711***	0.661***	0.656***
allocation	(0.093)	(0.093)	(0.130)	(0.128)
Contraction	0.769***	0.784***	0.767***	0.774***
lower bound, *c*	(0.168)	(0.161)	(0.232)	(0.226)
Demographics	no	yes	no	Yes
Constant	-0.626	-1.309*	-2.371***	-3.927***
	(0.571)	(0.765)	(0.903)	(1.502)
Observations	240	240	240	240
Nr of Subjects	80		80	
(left-, un-,right-) censored	(70,129,41)		(87, 123,30)	

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

Table 6. Tobit Regressions (Random Effects) of *g* Allocations across All Games

Dep.Variable: *g* Allocation	(1)	(2)	(3)	(4)
Initial Endowment, g^e	-0.098*	-0.108*	-0.099*	-0.106*
	(0.056)	(0.057)	(0.055)	(0.055)
Contraction Lower Bound, *c*	0.555***	0.562***	0.588***	0.587***
	(0.124)	(0.124)	(0.120)	(0.119)
Guessed Other's allocation	0.867***	0.874***	0.873***	0.869***
	(0.067)	(0.067)	(0.067)	(0.066)
Demographics	no	yes	yes	yes
Self Image	no	no	yes	yes
Image of Others	no	no	no	yes
Constant	-1.097**	-1.450**	-1.699**	-1.388**
	(0.507)	(0.678)	(0.687)	(0.697)
Observations	696	696	696	696
Log. Likelihood	-1209	-1207	-1194	-1190
Number of Subjects (232); Number of (left-, un-, right-) censored observations (277, 317, 102)				

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

Table 7. Tobit Regression (random effects) of "Equilibrium" Play

(Khadjavi and Lange (2015) data, periods 6-10)

Dependent Variable: g Allocation	(1)	(2)
Initial Endowment, g^e	-0.190*	-0.211*
	(0.113)	(0.115)
Contraction Lower Bound, b	0.672***	0.789***
	(0.246)	(0.251)
Total Allocations of Others One Round Earlier, G_{-i}	0.255***	0.213***
	(0.039)	(0.039)
Dummy for Period (6-10)	no	yes
Constant	-3.152*	-0.318
	(1.654)	(1.806)
Observations	800	800
Log. Likelihood	-1464	-1450
Number of (left-, un, right-) censored observations (410, 328, 62).		

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

Appendix 1: Payoff Equivalence of Games

Without any loss of generality, we focus on player 1. Let Γ be the set of social dilemma games that differ from each other only with respect to the initial distribution of a resource, W between the public and private account. If the initial amount in the public account is ng^e then we call the game, g^e-game. By this notation, the provision game is the g^0 -game as there is nothing in the public account at the beginning of the game whereas the appropriation game is the g^W -game as initially there is nW in the public account. We show that the social dilemma, g^e -games in Γ are payoff equivalent with the provision game.

Provision game. Let player 1 contribute, $g_1 \in [0, W]$ in the public account and let the total amount in the public account be some G_{-1} that includes contributions of others but not 1's contribution. Then *i*'s payoff in the provision game (i.e., g^0-game) is

$$\pi_1^0(g_1 \mid G_{-1}) = W - g_1 + \beta(g_1 + G_{-1})$$

g^e*-game from* Γ. Initially, $W - g^e$ units of the resource, W is in the private account and ng^e units are in the public account. Transfers (x) can be made between accounts. Let E_{-1} be the total amount of resource in the public account that include others' transfers and "initial resources", $(n-1)g^e$ (in addition to g^e). Write $E_{-1} = g^e + G_{-1}$ and note that player 1's decision in the g^e-game that leaves player 1 with the same payoff as in the provision game is transfer $x_1 = (W - g^e) - (W - g_1) = g_1 - g^e$. Indeed, player 1's payoff is

$$\pi_1^e(x_1 \mid E_{-1}) = W - g^e - x_1 + \beta(x_1 + E_{-1})$$

Substitute $x_1 = g_1 - g^e$ and $E_{-1}(= g^e + G_{-1})$ in the last equation to get

$$\begin{aligned}\pi_1^e(x_1 \mid E_{-1}) &= (W - g^e) - (g_1 - g^e) + \beta((g_1 - g^e) + (g^e + G_{-1})) \\ &= W - g_1 + \beta(g_1 + G_{-1}) \\ &= \pi_1^0(g_1 \mid G_{-1})\end{aligned}$$

Note that when $W - g^e < W - g_1$, player 1's initial allocation in the private account is too little (compared to the level, $W - g_1$ in the provision game) and therefore player 1's *negative* transfer (x_1) in g^e -game is from the public account to her private account. On the other hand, when $W - g^e > W - g_1$, player 1's *positive* transfer is from the private account to the public account.

Appropriation game. In the g^W –game when others leave $A(= W + G_{-1})$ in the public account, player 1's transfer, $x_1 = W - g_1$ from the public account to the private account leaves player 1 with the same payoff as the provision game; the effect of appropriating $W - g_1$ is

$$\begin{aligned}\pi_1^W(x_1 \mid A) &= x_1 + \beta(-x_1 + A) \\ &= W - g_1 + \beta(-(W - g_1) + W + G_{-1}) \\ &= \pi_1^W(g_1 \mid G_{-1})\end{aligned}$$

Appendix 2. Moral Reference Points across Games

Again, without any loss of generality we focus on player 1 in a g^e -game. Let the others' transfers vector, $\boldsymbol{x}_{-1}$ be given. By payoff equivalence (see above), $x_i = g_i - g^e$ where $g_i,_{i>1}$ is *i*'s corresponding contribution in the provision game. The amount in the public account then is $E_{-1} = ng^e + \sum_{i>1} x_i = g^e + G_{-1}$ in the public account. The maximum feasible payoff of player 1 is when all resource *W* is in 1's private account, in which case others' average payoff is

$$\begin{aligned} 2_* &= (W - g^e) - \frac{1}{n-1}\sum_{i>1} x_{-i} + \beta(E_{-1} - g^e) \\ &= (W - g^e) - \frac{1}{n-1}\sum_{i>1} (g_{-i} - g^e) + \beta G_{-1} \\ &= W - (1-\beta)G_{-1} \end{aligned}$$

The maximum feasible others' average payoff, (as a consequence of player 1's choice) is when all 1's resource *W* is in the public account and therefore

$$1_* = \beta\left(W - g^e + E_{-1}\right) = \beta\left(W + G_{-1}\right)$$

It follows from 1's endowed payoff, $\omega^e = W - g^e + \beta n g^e$ that player 1's moral reference point is

$$\begin{aligned} r_1^e &= 0.5(1_* + \omega^e) = \frac{1}{2}(1+\beta)W + \frac{1}{2}\left(\beta - \frac{1}{n}\right)ng^e + \frac{1}{2}\beta G_{-1} \\ r_2^e &= W - (1-\beta)G_{-1} \end{aligned}$$

Note the larger g^e the more favorable the game to player 1, and by MMA, the larger the payoff player 1 expects form playing the game.

Appendix 3: Proof of Proposition 3

Let a profile of contributions, $\boldsymbol{x}^*$ be a Nash equilibrium in the (g^e , *c*)-game with initial per capita allocation, g^e in the public account and lower bound, *c* on allocations in the public account. We use notation $g_i = x_i - g^e$ to convert decisions in terms of corresponding contribution in the public fund in the provision game (see Appendix 2 above). Let $G = ng^e + \sum_i x_i$ denote the total resource in the public account in the equilibrium $\boldsymbol{x}^*$. To simplify writing we abuse notation and drop index

i in individual i's decision. So, let $f(G_{-i}) = br_i(G_{-i} \mid e, c)$ where $G_{-i} = (n-1)g^e + \sum_{j \neq i} x_j = \sum_{j \neq i} g_i$ denote (well-behaved) individuals' best response $g_i = x_i - g^e$ allocations. We look at the effect (if any) of initial g^e and constraint, c on best response, $f(G_{-i} \mid e, c)$.

***g^e** Effect*. Consider a game with a larger initial per capita allocation, $g^{e_+}(> g^e)$ in the common fund but the same bound c. Let $f_+(.) = br(. \mid e_+, c)$ denote individual's best response allocations in the g^{e_+}-game.

For conventional rational choice theory, $f_+(G^*_{-i} \mid e_+, c) = f(G^*_{-i} \mid e, c)$ (see Proposition 1.a). Therefore, $\boldsymbol{x}^*$ is a Nash equilibrium if and only if $\mathbf{x}^\wedge$, where $x_i^\wedge = x_i^* + (g^{e_+} - g^e)$ is a Nash equilibrium in the g^{e_+}-game because the two decision vectors result in the same contributions, $g_i^*(= x_i^* - g^e = x_i^\wedge - g^{e_+})$ for all i.

For choices that satisfy Property M (by Proposition 2.a), $f(G^*_{-i}) > f_+(G^*_{-i})$ and therefore $\boldsymbol{x}^\wedge$ is not an equilibrium in the g^{e_+}-game. Let $\mathbf{x}^+$ be a Nash equilibrium in the g^{e_+}-game and $G^+ = ng^{e_+} + \sum_i x_i^+$. We show that the amounts in the public account in $\mathbf{x}^*$ and $\mathbf{x}^+$ satisfy, $G^+ < G^*$.

Write $\boldsymbol{f}_+(.) = \boldsymbol{f}(.) - \boldsymbol{\varepsilon}(.)$ for some positive $\varepsilon(.)$ functions (by Proposition 2.a) and verify that for i, there exist $z_i \in [G^+_{-i}, G^*_{-i}]$ such that

$$g_i^+ - g_i^* = f_+(G^+_{-i}) - f(G^*_{-i}) = f(G^+_{-i}) - \varepsilon_i(G^+_{-i}) - f(G^*_{-i}) = (G^+_{-i} - G^*_{-i}) f'(z_i) - \varepsilon_i(G^+_{-i})$$

where the third equality follows from the mean value theorem. To simplify writing let a_i and δ_i denote $f_i'(z_i)$ and $\varepsilon_i(G_{-i}^+)$. Add $a_i\left(g_i^+ - g_i^*\right)$ to both sides of the last expression and divide by $1+a_i$ both sides to get

$$g_i^+ - g_i^* = \frac{a_i}{1+a_i}(G^+ - G^*) - \frac{1}{1+a_i}\delta_i, \quad i = 1\ldots n$$

Summation with respect to i gives

$$(1 - \sum_{i=1\ldots n}\frac{a_i}{1+a_i})(G^+ - G^*) = -\sum_{i=1\ldots n}\frac{\delta_i}{1+a_i}$$

It follows from $-1 < a_i < 1/(n-1)$ (see (**) in the text above Proposition 3) that the first term in left-hand-side of the last expression is positive and the term in the right-hand-side is negative. Therefore, the second term in the left-hand-side must be negative. Thus, $G^+ < G^*$ which concludes the proof.

b Effect. Let $\boldsymbol{h}_+(.) = br(.|e, c_+)$ denote the best response *g* allocations in the (g^e, c_+) -game with a larger (non-binding) constraint *c+*; i.e., $c < c_+ < \min(g_i^*, i = 1,\ldots,n)$.

For conventional rational choice theory (Proposition 1.a) $h_+(G_{-i}^*) = f(G_{-i}^*)$ and therefore $\mathbf{g}^*$ remains a Nash equilibrium in the (g^e, c_+)-game.

For choices that satisfy Property M (Proposition 2.a) $f(G_{-i}^*) < h_+(G_{-i}^*)$ and therefore $\mathbf{g}^*$ is not an equilibrium anymore. Let $\mathbf{g}^+$ be the Nash equilibrium in the (g^e, c_+)-game. To show that $G^+ > G^*$ let $\Delta g_i = g_i^+ - g_i^*$ and verify that

$$\Delta g_i = h_+(G_{-i}^+) - f(G_{-i}^*) = f(G_{-i}^+) + \varepsilon_i(G_{-i}^+) - f(G_{-i}^*) = (G_{-i}^+ - G_{-i}^*)f'(z_i) + \gamma_i$$

for some $\gamma_i > 0, y_i \in [G^+_{-i}, G^*_{-i}]$. As in the proof for g^e effect, let d_i denote $f_i^{'}(y_i)$ and follow similar steps to verify that

$$(1 - \sum_{i=1\dots n} \frac{d_i}{1+d_i})(G^+ - G^*) = \sum_{i=1\dots n} \frac{\gamma_i}{1+d_i} > 0$$

To conclude the proof note that by property (**) the first term in the left-hand-side expression is positive and therefore $G^+ > G^*$.

Appendix 4: Nonlinear Best Responses

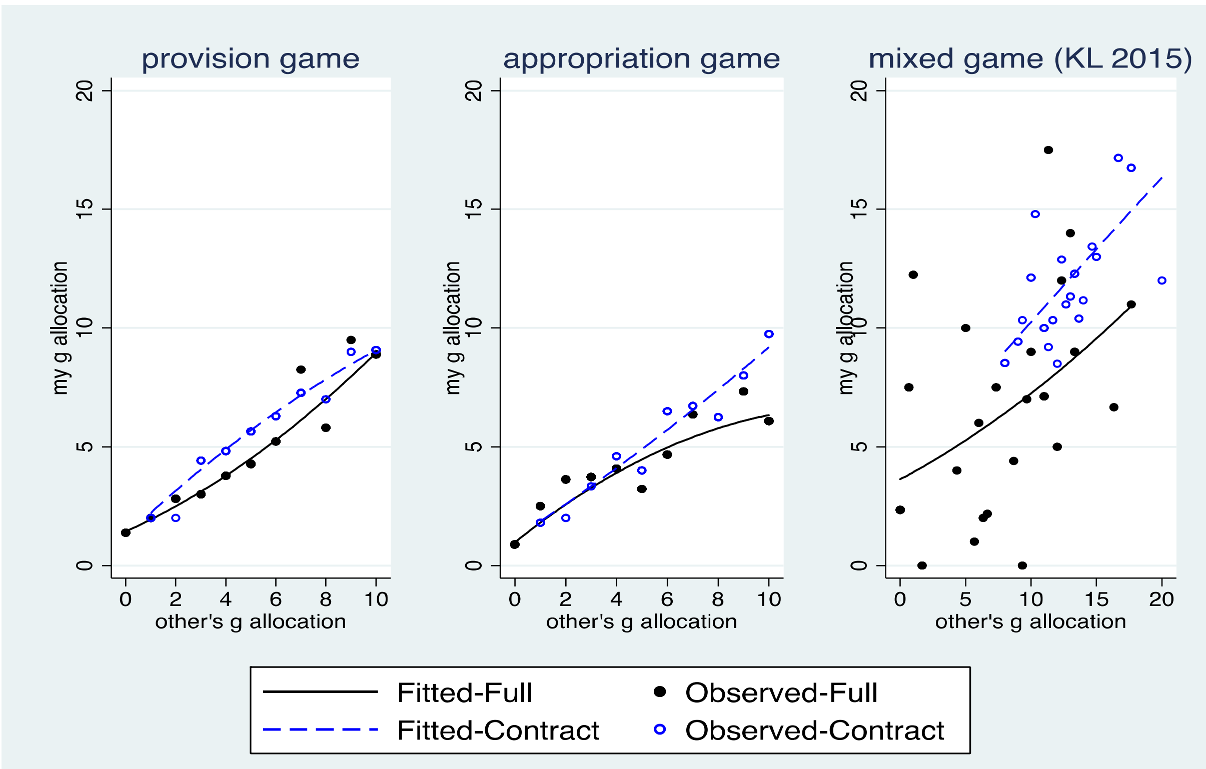

Figure 2a. Best Response (average) *g* allocations