Supplementary Materials to "Preferences and constraints: The value of economic games for studying human sociality"

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Contents

1 Study site

This study was conducted in a coastal site ($n = 115$) in Colombia. The population is composed of a majority of Afrcolombians, along with minorities of Mestizos and indigenous Emberá. Like many other communities in the region, this community has been heavily affected by Colombia's internal conflicts. A large proportion of residents in the site are considered internally displaced persons within Colombia, having resettled after being forced from their natal communities. This is important because it provides a social context in which the establishment and maintenance of social relationships is critical in buffering the severe resource shocks associated with high levels of poverty and forced displacement. In terms of subsistence, the community currently relies on a mixture of fishing and local wage labor. However, hunting, horticulture, and animal husbandry are also practiced.

For all demographic and survey response data, individuals were interviewed in the winter of 2016. Economic games were played in the winter of 2017.

CTR obtained a TP-7 visa, required to conduct research in Colombia, prior to data collection. Informed consent was obtained from each respondent and the community leader (when appropriate) prior to data collection. Because of limited literacy rates at the study site, informed consent was obtained verbally. All field protocols were approved by the Max Planck Institute for Evolutionary Anthropology, Department of Human Behavior, Ecology and Culture, and declared exempt from additional IRB oversight.

2 Data

Economic games and transfers To measure cooperation, we used three network-structured economic games[1]: an allocation game, a taking/leaving game, and costly punishment game. For each of these games, we presented individuals with a photo array containing 7x10 cm photographs of all male and female adults residing in the field-site during the winter of 2016. In total there were 115 targets or alters to whom

focal players could allocate coins or tokens. These photos were organized onto four 35x50 cm boards. The positions of the boards were randomized between respondents, and the order of the photographs on the boards was randomized on four separate occasions over the course of data collection. In total, 93 respondents completed the economic games. All three games were played in sequence—in the same order—during the same interview. After all interviews were complete, all game participants were given the currency allocated to them by themselves and other community members during the games. Total stakes per person amounted to 82,500 Colombian pesos ($\sim$27 USD) at the time of data collection.

In the giving game, the stakes were set at 15,000 Colombian pesos. Individuals could allocate any number of 1,000 peso coins to any cell in the photo array, including their own. Individuals varied widely in how much was kept and how much was given, with a mean giving rate of 11,760 (78.4%), a median of 13,000 (86.6%), a standard deviation of 3,500, a minimum of 0, and a maximum of 15,000 pesos. In the taking game, an initial allocation of one 500 peso coin to each photo was provided by the researcher for a total stakes of 57,500 pesos; participants could leave the 500 peso coin placed by the researcher on each photo or take it for themselves. Again, individuals varied widely in how much was taken and how much was left, with a mean leaving rate of 39,800 (69.2%) pesos, a median of 47,000 (81.7%), a standard deviation of 17,600, a minimum of 0, and a maximum of 57,500 pesos. In the costly punishment game, the stakes were set at 10,000 Colombian pesos, which were allocated directly to the recipient. Individuals could keep the coins or use them purchase red tokens to punish/reduce other community members. Each token cost 1,000 pesos, and led to a reduction of the target's income by 4,000 pesos—the same multiplier used elsewhere[1]. Punishment was fairly infrequent, with a mean payment rate for punishing of 1,600 (16%), a median of 0, a standard deviation of 2,800, a minimum of 0, and a maximum of 10,000 pesos.

Food or money transfer ties between each pair of individuals were assessed by asking each individual to name all individuals to whom they have given food or money in the last 30 days, and all individuals who have given them food or money over the same time period. This question was asked as part of the social network battery conducted in the winter of 2017.

Covariates We consider eighteen variables that might play a role in explaining variation in economic game play and resource transfers in our statistical models. In order to normalize the effects of our shrinkage priors, we divide each of these variables by their respective maximums before model fitting. Missing data were imputed a single time prior to model fitting using the mean or median of the distribution for the relevant variable.

1) *Community co-residence*

A binary indicator if individuals i and j reside in the same local cluster of homes. There are three such clusters in the study site.

2) *Friendship*

Friendship ties between each pair of individuals were assessed by asking each individual to name all individuals with whom they have spent time socializing in the last 30 days. This question was asked as part of the social network battery conducted in the winter of 2017.

3) *Marriage*

Marriage ties between each pair of individuals were assessed by asking each individual to

name all individuals with whom they are currently married. This question was asked as part of the marriage history survey conducted in the winter of 2017.

4) *Relatedness*

Relatedness ties between each pair of individuals were created by first asking each individual in the community to name all parents and children. A community-wide pedigree was then constructed and used to create a pairwise matrix of relatedness values.

5) *Age*

Age is typically based on self-reported date of birth. In the majority of cases, individuals know their date of birth from their national ID, or presented their ID card to the research team. In a small set of cases, especially among the elderly and indigenous sub-samples, age is only a self-reported estimate.

6) *Education*

Education is given as the self-reported number of years that the respondent spent receiving formal education.

7) *Ethnicity as indigenous*

A binary indicator for identity as Emberá Chamí or a related group.

8) *Sex*

A binary indicator for identity as male.

9) *Out-migration*

A binary indicator for individuals who were present in the community in winter 2017, but who were not present in the community in winter 2018 during the economic games. Many of these individuals were reported to have been involved in activities damaging to the local community by the residents who remained.

10) *Physical attractiveness*

In winter of 2018, a photo array of all adult community members from the census in winter 2017 was presented to each respondent. Physical attractiveness was measured by asking all adults in the community to place up to eight tokens on the eight most attractive members of the opposite sex, and eight more on the eight most attractive members of the same sex. Our physical attractiveness rating is then the total number of tokens placed on a focal person's photo by all alters in the the community.

11) *Depression*

A survey tool similar in design to the Kessler Psychological Distress Scale[2] (K6) was presented to each respondent in the study site in winter 2017. An individual was classified as depressed if they responded that they were *often* or *always* depressed over the last 30 days.

12) *Same ethnicity*

A binary indicator if individuals i and j are either both indigenous or both non-indigenous. If both respondents were of the same ethnicity, this value is 1; if one respondent was non-indigenous and the other indigenous, this value is 0.

13) *Same sex*

A binary indicator if individuals i and j are either both male or both female. If both respondents were of the same sex, this value is 1; if one respondent was male and the other female, this value is 0.

14) *Material wealth*

As our primary measure of economic stability, we use data on the household wealth. This variable is composed of the sum total of the local monetary value of all: cars, trucks, motorcy-

cles, mototaxis, motorboat, canoes, computers, TVs, washing machines, refrigerator, stoves, microwaves, cell phones, cows, pigs, and chickens present in the household of the focal respondent.

15) *Unable to work*

Some individuals are unable to work to provide for themselves and their families. Ability to work is a binary measure based on a qualitative assessment by CTR, based on interviews with respondents. Those individuals with limited ability to work include some, but not all, elderly residents, as well as those individuals who have suffered injuries that prevent them from working.

16) *Food insecurity*

Food insecurity was assessed during interviews with the question: how many days in the last month did you have so little food that you or someone in your family had go to bed hungry? Respondents indicating that someone in their household went to bed hungry for one or more days were coded as food insecure. This is a binary variable.

17) *Grip strength*

Grip strength was assessed using a Camry Digital Hand Dynamometer. Two readings were taken on each hand, and the average of all four ratings was used as our measure of grip strength.

18) *Reciprocation*

In each model, we include the transpose of the outcome matrix as a dyadic predictor. This captures reciprocity of giving in the self-reported transfers and RICH allocation game, reciprocity of leaving in the RICH taking game, and reciprocity of punishment in the RICH costly reduction game.

3 Modeling outcomes

Let $A_{[i,1:J]} \in \mathbb{N}^J$ be a vector of coin allocations or transfer ties by individual i across J alters. We can model these outcomes using a multinomial regression model:

$$A_{[i,1:J]} \sim \text{Multinomial}(\text{Softmax}(\theta_{[i,1:J]})) \quad (1)$$

where the Softmax function maps $\theta_{[i,1:J]} \in \mathbb{R}^J$ to a unit simplex, which give the probability of an allocation to each alter. To parameterize the model, we first define intermediate variables. The effects of covariates linked to a focal individual are defined as:

$$\psi_{[i]} = \alpha_{[0]} + \alpha_{[1]} X_{[i]} + \alpha_{[2]} Y_{[i]} + \dots \quad (2)$$

The effects of covariates linked to alters are defined as:

$$\phi_{[i,1:J]} = \beta_{[1]} X_{[1:J]} + \beta_{[2]} Y_{[1:J]} + \dots \quad (3)$$

And, the effects of covariates linked to dyads are defined as:

$$\kappa_{[i,1:J]} = \gamma_{[1]} Z_{[i,1:J]} + \dots \quad (4)$$

We can then define $\theta_{[i,1:J]}$ as:

$$\theta_{[i,1:J]} = \left(\psi_{[i]} + \left(\phi_{[i,1:J]} + \kappa_{[i,1:J]}\right)\right) \circ Q_{[i,1:J]} \quad (5)$$

Here X and Y are covariate vectors, while Z is a matrix. This implies that $\psi_{[i]}$ is a scalar, and that $\phi_{[i]}$ and $\kappa_{[i]}$ are J-vectors. Finally, Q is a $J \times J$ matrix with ones on the off-diagonals and zeros on the diagonal, and serves as an indicator for *focal* and *alter* cases; in other words, Q indicates which individual is focal and which individuals are alters in each row. The symbol $\circ$ denotes the Hadamard product, which leads to the i^{th} cell in $\theta_{[i]}$ being set to zero. As such, the predictor variables represent the change in log-odds of an allocation to an alter, relative to an allocation to self.

In the giving model, $A_{[i,1:J]}$ represents the number of coins placed by focal individual i on the photographs of alters $1, \ldots, J$, where the photograph of individual i is included in the set of J photographs (individuals can allocate to themselves by placing coins on their own photos). In the taking (i.e., leaving) model, $A_{[i,1:J]}$ represents the number of coins left by individual i on the photographs of alters $1, \ldots, J$—this is limited by the study design to be either a single coin or nothing, with the exception of the photograph of the focal individual, who will have the sum total of coins taken from alters. In the costly punishment model, $A_{[i,1:J]}$ represents the number of tokens placed by focal individual i on the photographs of alters $1, \ldots, J$—with the exception that $A_{[i,i]}$ represents the number of coins kept by individual i and not allocated to punishment. Finally, in the food and money transfer model, $A_{[i,1:J]}$ represents the directed ties between individual i and alters $1, \ldots, J$—with the note that $A_{[i,i]}$ is set to one, since all individuals can be assumed to transfer food to themselves.

Because this model is heavily parameterized relative to the number of individuals in the sample, we use regularizing double exponential priors on all top-level parameters:

$$\alpha \sim \text{Double Exponential}(0, 2.5) \quad (6)$$

$$\beta \sim \text{Double Exponential}(0, 2.5) \quad (7)$$

$$\gamma \sim \text{Double Exponential}(0, 2.5) \quad (8)$$

These priors incorporate variable selection into the parameter estimation process by shrinking small effects towards zero, reducing effective parameter complexity.

Software Data analysis was handled entirely in R (version 3.4.2)[3]. Statistical models were coded in Stan and fit using the RStan package (Version 2.16.2)[4]. We diagnosed model fits and Markov Chain Monte Carlo performance using trace plots, $\hat{R}$, and reported effective samples[5]. Code and data for diagnostics and analysis replication are provided in the Supplementary Materials and will be maintained on GitHub at `www.github.com/ctross/preferencesandconstraints`.

4 Results

Here we present the results of an analysis of the three RICH games alongside the results of a similar analysis of self-reported resource transfers (Figs 1 and 2 show the standardized and raw estimates, respectively). There are two key points to note. First, classic dyadic factors, such as kinship, friendship, reciprocation, and village co-residence are associated positively with both self-reported resource transfers and experimental allocations—demonstrating that behavior in this specific experimental game parallels behavior in a corresponding "real world" context. Second, note also that experimental transfers in the allocation game are influenced more by focal and alter characteristics than self-reported allocations in the resource transfer network—possibly demonstrating that this specific experimental game allows respondents more freedom to act on preferences than they have in "real world" contexts. Jointly, these results both support the ecological validity of RICH games and demonstrate that experimental games can measure preferences in a way that self-report and observational studies sometimes cannot.

Fig 1 presents the standardized regression coefficients, scaled such that the posterior confidence regions are of equal width. Fig 2 presents the raw parameters as estimated in the statistical

models. In either figure, each column represents a single outcome variable/statistical model, and each row represents a predictor variable of that outcome. Rows are broken into blocks illustrating the effects of decider/focal characteristics, alter characteristics, and dyadic characteristics. Below, we detail some of the important patterns uncovered using these economic games.

[Figure 1 about here.]

[Figure 2 about here.]

Each column in Figs 1 and 2 illustrates the results of a multivariate model predicting allocations from focal players to a set of alters as a function of 10 focal characteristics, 11 alter characteristics, and 7 dyadic characteristics.

In the first column, top block, we see that food insecure and depressed individuals are significantly less likely to report transferring food or money to other community members, whereas the materially wealthy are more likely to make such transfers (though the 90% confidence interval includes zero). In the next block, we see that indigenous and educated alters are more are likely to be given small amounts of food or money, whereas those alters who out-migrated from the community between 2017 and 2018 were less likely to be given such allocations. Note also, that this social network question was asked in 2017, prior to any out-migrations, so the negative effect estimated here likely reflects the dissolving of social bonds that preceded excommunication or out-migration. Finally, we see in the third block that a resource transfer is more likely between individuals of the same sex and same community, as well as between friends or kin. There is also a strong signal of reciprocation. A transfer tie between i and j is more likely if there is also a tie between j and i. Note that the absence of a positive effect of marriage on a transfer is due to the question being framed specifically in terms of inter-household transfers.

In the second column, top block, we see that the materially wealthy, indigenous and educated, as well as those individuals who can no longer work, were more likely to give coins to others in the allocation game. In contrast, those who were older and those who reported symptoms of depression were less likely to give coins to others. In the next block, we see that males, those rated as physically attractive, and those who cannot work were more likely to be allocated coins. In contrast, those who out-migrated, the materially wealthy, those with high grip strength, and those with symptoms of depression were less likely to be allocated coins. Finally, we see in the third block that a coin allocation is more likely between individuals of the same sex, same community, and same ethnicity, as well as between friends, spouses, or kin. There is also a strong signal of reciprocation. A giving tie between i and j is more likely if there is also a tie between j and i.

In the third column, top block, we see that those rated as physically attractive, the materially wealthy, those with high grip strength, and those with higher education, as well as those individuals who reported food insecurity, were more likely to leave coins for others in the taking/leaving game. In contrast, males, indigenous, and those who reported symptoms of depression were less likely to leave coins for others. In the next block, we see that the food insecure and those with symptoms of depression were more likely to be left coins. In contrast, those who out-migrated, the materially wealthy, and those with high grip strength were less likely to be left with coins. Finally, we see

in the third block that a coin is more likely to be left for an alter, if that alter is of the same ethnicity as the focal, and if the pair is related or married. There is also a signal of reciprocation. A leaving tie between i and j is more likely if there is also a tie between j and i.

Finally, in the fourth column, top block, we see that males, those who cannot work, and those who reported symptoms of depression were more likely to punish others. In contrast, the wealthy, indigenous, food insecure, and elderly were less likely to punish others. Those rated as physically attractive, the materially wealthy, those who out-migrated, and those with high grip strength were more likely to be punished. In contrast, the food insecure were less likely to be punished by others. Finally, we see in the third block that punishment is more likely to occur between same-sex dyads living in the same community, and less likely to occur between kin.

5 Discussion

The results of this analysis—both those based on self-reported giving and those based on experimental RICH games—are in line with a range of anthropological studies demonstrating that kinship[6–9], reciprocity[10–16], and need-based heuristics[17–20] are predictive of cooperation and costly resource transfers.

Importantly for our purposes, the use of both self-reported resources transfers and networked structured economic games among the same sample of individuals allows us to compare and contrast the methods, and comment on the utility of each in explaining human behavior.

On the one hand, RICH economic games can be a tool for anthropologists, economists, and psychologists, as such games have comparably high external validity, relative to other economic games. Note, for example, that individuals with symptoms of depression were less likely to give coins to others or leave coins for others, and more likely to spitefully punish others—paralleling the negative effect of depression on self-reported transfers to other community members. Similarly, wealthy individuals were more likely to give coins to and leave coins for others, and less likely to spitefully punish others—paralleling the positive effect of wealth on self-reported transfers to other community members. Similar parallels between self-reports and RICH games can be noted for dyadic predictors, like kinship, friendship, community coresidence, and reciprocation.

On the other hand, there are many more statistically reliable predictors of experimental allocations than self-reported resource transfers. This potentially indicates that respondents in the economic games are acting on preferences that they are not able to express in daily life, due to at least one of a variety of constraints. If we were to rely strictly on analysis of empirical resource transfers, we would miss many of the preferences underlying inter-personal relationship formation and maintenance.

More broadly, there are even cases where the direction of the effect flips between the analysis of self-reported resource transfers and the analysis of experimental allocations. Take, for instance, the effect of food insecurity on a focal individual's probability of making a resource transfer to another household. In the self-reported transfers model, this effect is reliably negative, but in the allocation game it is null, and in the leaving game it is reliably positive. Given the constraints of food availability for food insecure households, even if a focal person wanted to share with others, they simply may not have the resources available to do so. In the allocation game, the constraints of resource availabil-

ity are somewhat relaxed, and the focal respondents have enough coins to allocate to several community members. In the leaving game, constraints are fully relaxed, and the focal respondents can allocate something to every member of the community should they desire. When constraints on resource availability were relaxed by the game contexts, food insecure respondents were more free to express their preferences, and in general, were more generous than the average game player precisely because they were interested in reciprocating relationships that they have been unable to reciprocate previously.

Rather than attending to the highly constrained products of individuals interacting in social systems, economic games are designed to measure the comparatively unconstrained preferences of individuals. As such, experiments like these are not replacements for observational studies of behavior. However, by measuring both the unconstrained preferences of individuals (game behavior) and the socio-ecologically constrained realizations of these preferences (self-report or observational studies), researchers can learn more about how socio-cultural institutions shape social dynamics and better appreciate the contours of social life.

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List of Figures

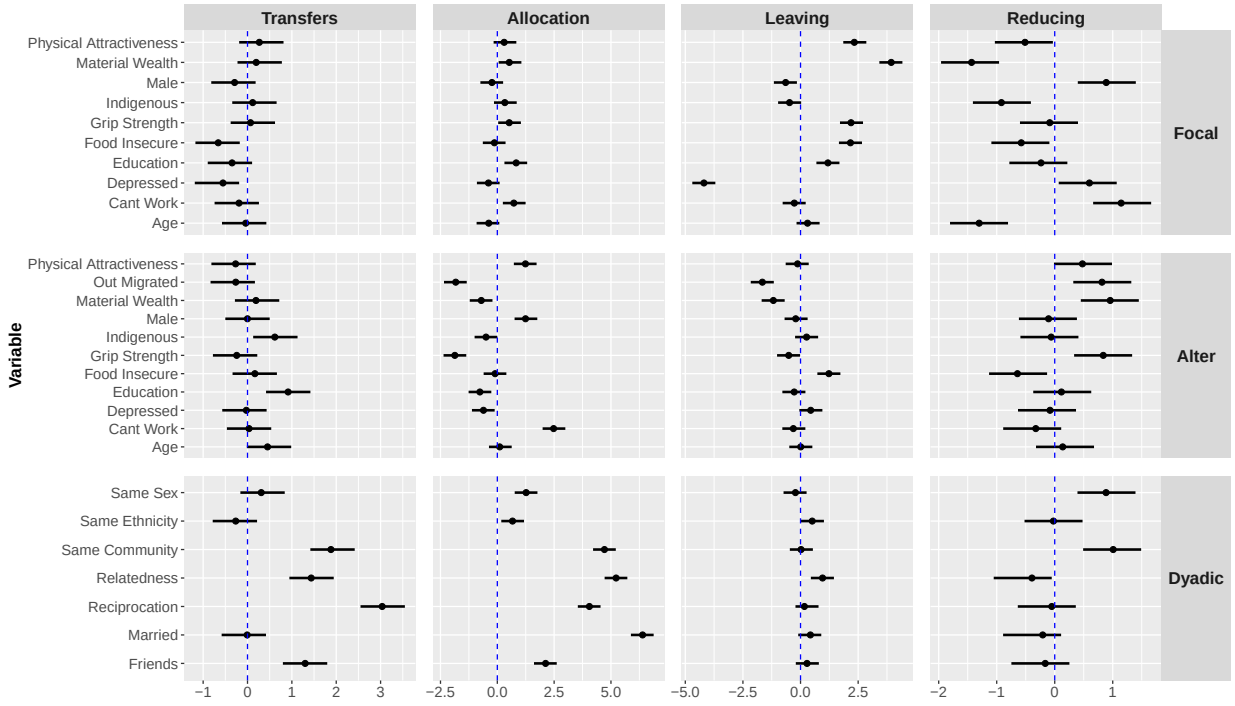

Figure 1: Multivariate model estimates (medians and 90% credible regions) of predictors of allocations to alters. Each column indicates an outcome variable: from left to right, i) resource transfers over the 30 days prior to the survey, ii) coin allocations in the allocation game, iii) coin allocations in the taking/leaving game, and iv) token allocations in the reducing game. The top block of estimates in each model gives the effects of focal characteristics on the probability of allocating to alters. The second block of estimates gives the effects of alter characteristics on the probability of allocating to alters. The bottom block of estimates gives the effects of dyadic characteristics on the probability of allocating to alters. Each estimate gives the effect of a single predictor controlling for all other predictors of that outcome. These estimates are standardized such that each estimate in a given model has a equal width 90% credible region.

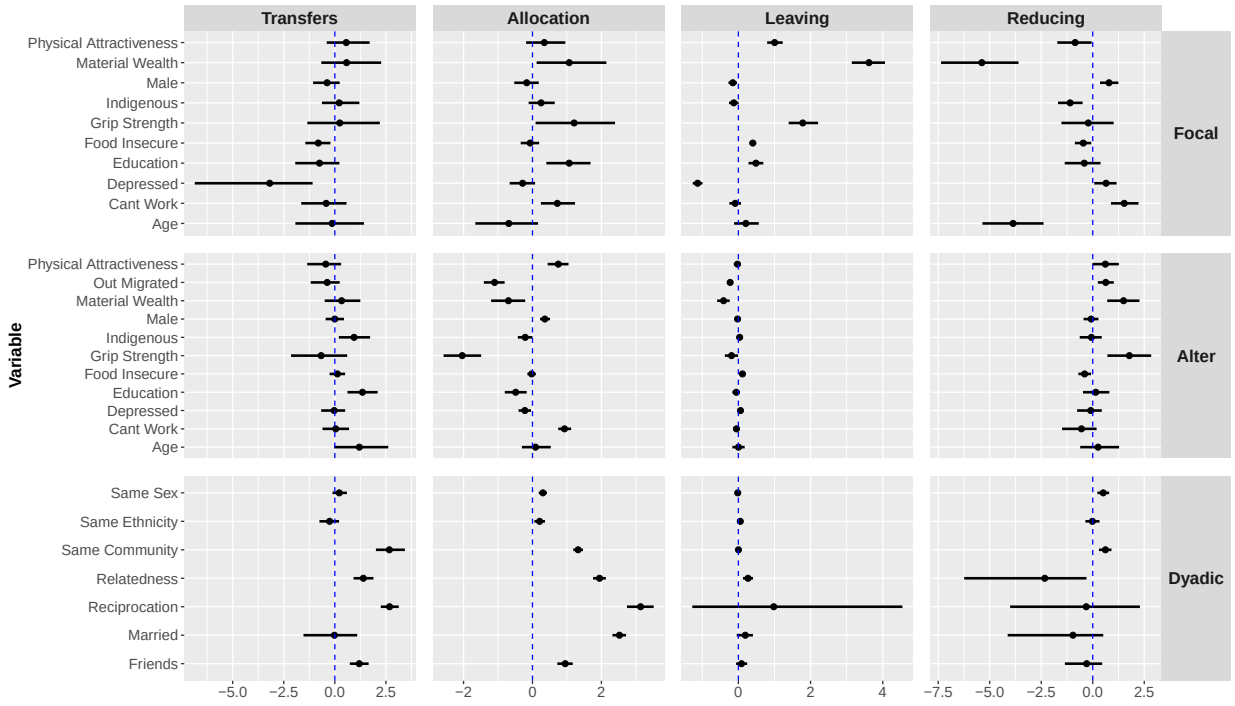

Figure 2: Multivariate model estimates (medians and 90% credible regions) of predictors of allocations to alters. Each column indicates an outcome variable: from left to right, i) resource transfers over the 30 days prior to the survey, ii) coin allocations in the allocation game, iii) coin allocations in the taking/leaving game, and iv) token allocations in the reducing game. The top block of estimates in each model gives the effects of focal characteristics on the probability of allocating to alters. The second block of estimates gives the effects of alter characteristics on the probability of allocating to alters. The bottom block of estimates gives the effects of dyadic characteristics on the probability of allocating to alters. Each estimate gives the effect of a single predictor controlling for all other predictors of that outcome. These estimates are not standardized.