

Altruism or Diminishing Marginal Utility?*

Romain Gauriot,[†]

New York University, Abu Dhabi

Stephanie A. Heger,[‡]

School of Economics, University of East Anglia

Robert Slonim,[§]

School of Economics, University of Sydney

September 30, 2020

ABSTRACT: We challenge a commonly used assumption in the literature on social preferences and show that this assumption leads to significantly biased estimates of the social preference parameter. Using Monte Carlo simulations, we demonstrate that the literature’s common restrictions on the curvature of the decision-makers utility function can dramatically bias the altruism parameter. We show that this is particularly problematic when comparing altruism between groups with well-documented differences in risk aversion or diminishing marginal utility, i.e., men versus women, giving motivated by pure versus warm glow motives, and wealthy versus poor. We conclude by proposing two approaches to address this bias.

KEYWORDS: Altruism, Marginal Utility, Biased Inferences

JEL CLASSIFICATION: C91, D64

*This paper has received valuable feedback from Christine L. Exley, Glenn W. Harrison, Andrew Lilley, Nikos Nikiforakis, Nathaniel T. Wilcox and from participants at presentations at the Sydney Experimental Brownbag, the Australia New-Zealand Workshop in Experimental Economics (Melbourne), the Behavioural Economics: Foundations and Applied Research Conference (Sydney), the Asia Pacific Economic Science Association Conference (Brisbane), The Lebanese Econometric Study Group (Beirut) and New York University, Abu Dhabi. The Sydney Informatics Hub and the University of Sydney’s high-performance computing cluster Artemis provided the high-performance computing resources that have contributed to the results reported within this paper. We are grateful for financial support from the Australian Research Council’s Discovery Projects funding scheme (project number DP150101307).

[†]Email: romain.gauriot@gmail

[‡]Email: saheger@gmail.com

[§]Email: robert.slonim@sydney.edu.au

1 Introduction

The standard model of other-regarding preferences includes a decision-maker who receives utility from his own payoff or private consumption and utility from an *other's* (e.g., another person's or a charitable organization's) payoff, where a preference parameter governs the relative intensity between these two utility components. Previous literature has taken an interest in (1) the magnitude of the social preference parameter (see Table A1 for a limited set of examples) and (2) the differences in the shape of utility functions over payoffs to self versus payoffs to other that may result in different risk preferences and response to incentives for self versus other (see Table A2).

However, a measurement problem, similar to the problem identified in Andersen et al. (2008) with regards to estimating discount rates, arises when estimating the social preference parameter in models if we ignore or make simplifying assumptions about the shape of the utility function. Our paper stresses the importance of controlling for the curvature of the utility function when estimating social preferences. The necessity to control for the curvature of the utility function when estimating a parameter of interest has been shown to matter in a wide range of applications (Harrison, 2018), such as the estimation of subjective probabilities (Andersen et al., 2014), the estimation of correlation aversion that arises when intertemporal utility is non-separable and there is an interaction between risk and time preference (Andersen et al., 2018), and the estimation of bid functions in first-price sealed-bid auctions (Harrison and Rutström, 2008).

In this paper, we show that estimates of social preference parameters are significantly biased by incorrect or overly strict assumptions about the curvature of the decision-maker's utility that are ubiquitous throughout this literature. And while the majority of the paper focuses on the simplifying assumptions made about curvature, we also show that common and strict assumptions about the social preference parameter lead to biased estimates of the curvatures of the decision-maker's utility function.

We begin with a simple illustrative model. Consider a decision-maker with separable utility over self payoffs given by $u(s)$ and utility over other's payoffs given by $v(o)$, which represents the utility the decision-maker gets from providing money to the other individual or organization.¹ The decision-maker is tasked with dividing income Y between himself, s , and an other, o ; that is, he is playing a dictator game. In laboratory dictator games, other is almost always another subject or a charitable organization. Outside the lab, an individual who is deciding whether to give to a charitable organization is playing a dictator game with the organization. To choose the amount

¹In this paper, we are agnostic about the source of $v(o)$ as it is outside the scope of this paper. However, following Harrison (2018), we acknowledge that it could represent the decision-maker's belief about the other's utility function, the other's true utility function or the decision-maker's paternalistic utility for the other. Alternatively, it may be entirely divorced from the utility the other actual receives and simply represents the utility the decision-maker gets from giving. Hofmeier et al. (2019) notion of imperfect empathy suggests that even if v represents the decision-maker's beliefs about the other's utility, it will be "imperfectly" incorporated and will still differ significantly from u .

he wishes to give to the other, the dictator maximizes

$$U(s, o) = (1 - \alpha)u(s) + \alpha v(o), \quad \text{subject to } Y = s + p \times o \quad (1)$$

where α represents the weight the decision-maker puts on the utility from other's payoffs relative to the utility he gets from self payoffs, Y represents the total income the decision-maker must split between himself and the other, and p is the price of giving. The first order condition for the decision-maker's maximization problem is given by

$$\frac{\alpha}{1 - \alpha} = p \frac{u'(s)}{v'(o)} \quad (2)$$

The first order condition clearly shows that the curvature of $u(\cdot)$, $v(\cdot)$ and the social preference parameter, α , all affect the choice of how much to keep for oneself and to give to the other. However, one of two simplifying assumptions is often made: (1) the curvatures of $u(\cdot)$ and $v(\cdot)$ are equal and inferences are made about α or (2) the decision-maker puts equal weight on the utility to self and other and inferences are made about the curvature of $u(\cdot)$ and $v(\cdot)$. While we found one exception to (1), DellaVigna et al. (2013) assume $u(\cdot)$ is linear and the curvature of $v(\cdot)$ takes on a specific value, Table A1, while not providing an exhaustive list, demonstrates the ubiquity of this simplifying assumption in the literature. On page 34 DellaVigna et al. (2013) discuss conceptually why u and v might differ, but do not discuss the bias induced on the altruism parameter when the researcher makes (overly) strict assumptions on the curvature of utilities.

Similarly, while we found a single exception to (2), Exley (2015) conducts a "normalization" task to avoid confounding altruism with her measures of risk aversion, Table A2 demonstrates the ubiquity of the second simplifying assumption in the literature. Again, Exley (2015) normalization task addresses the problems that occur by making assumptions about α , but because it was outside the scope of her paper, she does not discuss or quantify the bias that is induced by this strict assumption.

Most importantly, we found no paper that estimates the curvature of $u(\cdot)$, $v(\cdot)$ and α . Throughout the majority of our paper, we focus on the first case: the problem of making simplifying assumptions about the curvature and estimating α , but we return to the second case in an example in Section 4.4. In several papers listed in Table Appendix A, the authors do not explicitly model the preferences of the decision-maker. However, this does not mean the problem we identify does not exist in these cases. In fact, when preferences are not explicitly modelled and altruism is identified or measured, there is an *implicit* assumption that the curvatures of $u(\cdot)$ and $v(\cdot)$ are equal.

In this paper, we use Monte Carlo simulations to generate data allowing dictators to have different curvatures of utility over self and other's payoffs, and then estimate the dictators' pref-

ferences using the most common assumption in the literature, namely that the curvatures of $u(\cdot)$ and $v(\cdot)$ are equal. We show that this common assumption leads to significantly biased estimates of α .

Consistent with the simple illustrative model above, the Monte Carlo simulations show that the estimated bias in the degree of altruism, α , depends critically on $u(\cdot)$ and $v(\cdot)$. This result has important implications that go well beyond simply recognizing that the literature’s estimates of altruism are biased. Most importantly, this result has direct implications when comparing altruism between groups, particularly when the two groups may significantly differ in the shape of their utility functions due to differences in risk aversion or differences in giving motives. For example, if two groups differ in their degree of diminishing marginal utility over their own payoffs, then, *ceteris paribus*, we would incorrectly estimate different degrees of altruism for the two groups. Similarly, if two groups of subjects differ over the curvature of the utility for the other (e.g., with one group having more pure motives while another has more warm glow motives), *ceteris paribus*, we would again incorrectly estimate different degrees of altruism.

The most salient example is the literature that examines differences in altruism between men and women (Eckel and Grossman, 1998; Andreoni and Vesterlund, 2001; Cox and Deck, 2006).² In Section 4, we show that the standard assumption about the curvature of the utility functions, i.e., the curvatures of $u(\cdot)$ and $v(\cdot)$ are equal, is likely to lead to the over-estimation of altruism of women relative to men. Similarly, we examine how ignoring the motive for giving (i.e., pure versus warm glow) will lead to the over-estimation of altruism among individuals motivated by pure altruism relative to those motivated by warm glow. In a third example, we show that ignoring background wealth will also lead to the over-estimation of altruism among wealthier individuals relative to less wealthy individuals. This example echoes the results from Andreoni et al. (2017). In a field experiment Andreoni et al. (2017) found wealthier households make more pro-social choices than less wealthy households. Ignoring differences in wealth, their results suggest more altruism among the wealthier households. However, once they control for the marginal utility of money and the hardship that comes from being poor, they find no difference in social preferences between rich and poor households.

In Section 5, we propose two potential solutions to address this bias. First, we propose to adapt the methodology put forth by Andersen et al. (2008) to estimate time preferences to the estimation of social preferences. Second, we propose a calibration task which determines whether the assumption that the curvatures of $u(\cdot)$ and $v(\cdot)$ are identical is valid. The suitability of these two approaches depends on the question the researcher aims to address.

Our paper builds off of two seminal papers: Andersen et al. (2008) and Exley (2015). Andersen et al. (2008) demonstrates how a similar type of problem occurs in the estimation of discount rates

²There is a large literature that looks at differences in altruism between groups. For example, older children versus younger children (Benenson et al., 2007) or individuals exposed to violent conflict or not (Voors et al., 2012).

if incorrect assumptions are made about the curvature of the utility function. In particular, using a similar CRRA utility framework, they show the estimated discount factors are twice as large if risk-neutrality is assumed rather than jointly estimating the parameter of risk aversion with the discount factor. Exley (2015) presents striking evidence of differences in the curvature of the utility over own payoffs versus utility over other payoffs when decision-makers make trade-offs between themselves and others. These results suggest that there are important differences between u and v that must be taken into account to avoid potentially significant bias when estimating social preference parameters.

2 Modeling Altruism

The dictator game is widely used to elicit altruism (Camerer, 2010; Engel, 2011). In the earliest dictator game experiments, the dictator chooses to divide an endowment between himself (self) and another person (other). Building on Eckel and Grossman (1996b), Andreoni and Vesterlund (2001) and Andreoni and Miller (2002) extend this simple game by varying the price of giving to the other and decision-makers choose how much of an endowment to split between self and other at various prices.

In this paper, we consider the modified dictator game, where the decision-maker’s objective is to maximize

$$U(s, o) = (1 - \alpha) * \frac{s^{(1-r_s)}}{(1 - r_s)} + \alpha * \frac{o^{(1-r_o)}}{(1 - r_o)}, \text{ with } r_s, r_o < 1,^3 \alpha \in [0, 1] \quad (3)$$

subject to a budget constraint, $Y = s + p \times o$.

Our departure from the existing literature is to allow the decision-maker to have different curvatures over self payoffs and other’s payoffs. As previously mentioned, one exception is DellaVigna et al. (2012) and DellaVigna et al. (2013), which assume utility is linear over own payoffs (i.e., $r_s = 0$) and concave over the charity’s payoff (i.e., $r_o \in [0, 1]$). We consider this case in Appendix B and show the bias in estimated altruism that results from this assumption. Allowing decision-makers to have different curvatures over own and other’s payoffs means we cannot use the CES functional form (Andreoni and Miller, 2002; Fisman et al., 2007), which is popular in this literature, and instead we opt for the CRRA functional form. As we show in Appendix C, when $r_s = r_o$ the CRRA functional form reduces to the CES functional form.

³We restrict, $r_s, r_o < 1$ so that the functional form is well-defined $\forall s, o \geq 0$.

2.1 Behavioral Motivations for Differing Curvatures of Utility

The vast majority of literature that models altruism does so assuming that utility over “own” consumption is additively separable from the utility the decision-maker receives from altruism (Andreoni et al., 1996; DellaVigna et al., 2012, 2013; Null, 2011; Brown et al., 2013; Lilley and Slonim, 2014; Heger and Slonim, 2019). While most papers remain agnostic about the difference in curvatures, Exley (2015) structurally estimates differences in curvatures and DellaVigna et al. (2012), DellaVigna et al. (2013) and Null (2011) make explicit assumptions about the differences. Exley (2015) reports results from an experiment in which she finds that when subjects must make a trade-off between money for self and money for charity, subjects are significantly more risk-averse over money to charity than money for self. However, even in the absence of risk, the literature has argued that the curvatures are likely to differ. For example, DellaVigna et al. (2012) and DellaVigna et al. (2013) assume that the utility over own consumption is linear, while the curvature over the utility one gets from altruism is concave. DellaVigna et al. (2012) argues that the degree of concavity of the utility function for altruism depends on the motives for giving—pure altruism motives are better reflected by a more linear function while warm glow motives are better represented by a function with greater diminishing marginal utility. Similarly, Null (2011) models pure altruism with a linear utility function and warm glow with a concave utility function. Conceptually, pure motives may be closer to linear reflecting that the additional benefit from giving may not diminish rapidly given there almost always remains a “need” (e.g., providing food, educational and health services to people in less developed countries). On the other hand, utility stemming from impure motives or warm glow may imply a rapidly diminishing marginal utility, as making a first donation may dramatically increase warm glow, while subsequent donations could add very little in terms of warm glow (e.g., donating blood once, and then seeing oneself as a “blood donor”).

3 Simulation and Estimation

In the present paper, we simulate data from a modified dictator game. Dictators successively face J randomly generated decisions in which they have to divide an endowment Y given the budget constraint $s + p * o = Y$, where s and o denote the amount allocated to self and other and p denotes the price of giving to the other. In each decision, the decision maker must choose from one of 51 choices on the budget line. We refer to each choice on the budget line as i ; ($i = 1$ to 51). The 51 choices on the budget line i that the decision-maker must choose from are equally spaced out across the budget line from keeping nothing for himself to keeping everything for himself. Figure D4a in the Appendix shows one randomly generated budget line and the 51 choices that the dictator has to choose among, and Figure D4b displays a graphical example of 50 randomly

generated budget lines that a dictator could face.⁴ In our simulation, we use $J=3,000$ decisions, which corresponds to 60 dictators making 50 decisions.

In this section, we describe the Monte Carlo simulations and the estimation that we perform to demonstrate that altruism and the curvature of utility function are confounded, leading to erroneous conclusions regarding altruism.

3.1 Simulation

We denote the true preference values (i.e., the values from the Data Generating Process, DGP) of altruism and the curvature over self payoffs and the curvature of other's payoffs as α_{DGP} , and $r_{s,DGP}$, $r_{o,DGP}$, respectively. We model the decision-makers' choices over the 51 i choices on each of the J budget lines (i.e., decisions) as a multinomial logit. The DM's probability to pick the i^{th} choices on the j^{th} budget line (i.e., for decision j) is given by:

$$P_j(i|\alpha_{DGP}, r_{s,DGP}, r_{o,DGP}, \mu_{DGP}) = \frac{e^{\frac{u_i}{\mu_{DGP}}}}{\sum_{l=1}^{51} e^{\frac{u_l}{\mu_{DGP}}}} \quad (4)$$

where μ_{DGP} is the decision error (or noise) associated with each choice. When $\mu \rightarrow \infty$ each choice i become equally likely to get selected and when $\mu \rightarrow 0$ the choice with the highest utility is chosen with certainty (see Harrison and Rutström (2008); Wilcox (2008) for reviews of stochastic models of choice).

The step-by-step process for each simulation with α_{DGP} , $r_{s,DGP}$, $r_{o,DGP}$ and μ_{DGP} is as follows⁵

1. Set $\alpha_{DGP} = .5$, $r_{s,DGP}$ and $r_{o,DGP}$ to some given value in $r_{s,DGP} \in \{0, 0.01, \dots, 0.9\} \times r_{o,DGP} \in \{0, 0.01, \dots, 0.9\}$.^{6,7}
2. We then run $K = 1,000$ trials. Each trial will be designated as trial k , $k = 1$ to K , and each trial k consists of the following steps 2a to 2d:
 - (a) Set $\mu_{k,DGP} \sim U[(0.8, 1.2)]$.
 - (b) Randomly generate $J = 3,000$ budget lines.
 - (c) For each decision j :

⁴We generate the budget lines using a procedure similar to Fisman et al. (2007). First, we randomly pick one of the axis (self or other's payoffs) with equal probability. Second, we randomly pick the intersect of this axis with the budget line from $U(50, 85)$. And finally, we randomly pick the intersect of the remaining axis and the budget line from $U(5, 85)$.

⁵The Stata code used to perform the simulation and estimation is available upon request.

⁶Our results are robust to the choice of α_{DGP} . In Appendix E, we perform the same exercise with $\alpha_{DGP} = .25$ and $\alpha_{DGP} = .75$.

⁷We choose to simulate data for $r_{s,DGP}$ and $r_{o,DGP}$ over the range $[0, 0.9]$ as it is the values commonly found in the literature. For instance, Harrison and Rutström (2008) estimate curvature over self payoff and Chakravarty et al. (2011) estimate curvature over other's payoffs.

- i. Calculate $P_j(i|\alpha_{DGP}, r_{s,DGP}, r_{o,DGP}, \mu_{k,DGP}) \forall i$.
 - ii. Randomly choose one choice on the budget line i , $A_j(\alpha_{DGP}, r_{s,DGP}, r_{o,DGP}, \mu_{k,DGP})$ where the probability that i is chosen is equal to $P_j(i|\alpha_{DGP}, r_{s,DGP}, r_{o,DGP}, \mu_{k,DGP})$.
- (d) Using these $A_j(\cdot)$ s, we estimate the parameters of the utility function from equation 3, denote estimated values as $(\tilde{\alpha}_k, \tilde{r}_{s,k}, \tilde{r}_{o,k}, \tilde{\mu}_k)$. We estimate (see Section 3.2 below) the utility function under two main cases by maximizing the log-likelihood of those $J = 3,000$ decisions using the Stata's modified Newton-Raphson (NR) algorithm.
3. From the K estimates of α , compute the percentage of over/under estimation and statistical power of the estimates.
 4. Repeat steps 1 to 3 for $(r_{s,DGP}, r_{o,DGP}) \in \{0, 0.01, \dots, 0.9\} \times \{0, 0.01, \dots, 0.9\}$.

3.2 Estimation

We begin by estimating the model without making any restrictions on the values of r_s , r_o , α and μ . The detailed results from the unrestricted model are presented in Appendix F. The estimates from the unrestricted model show that we are always able to recover the DGP parameters; that is, at the 5 percent significance level we reject that $\tilde{r}_s = r_{s,DGP}$, $\tilde{r}_o = r_{o,DGP}$, and $\tilde{\alpha} = \alpha_{DGP}$ in 5% of the trials. In other words, any bias in the estimates that arises when we estimate models with restrictions on the parameters cannot be attributed to sample size or our estimation method, and will thus be due to the model assumptions that are (in)correctly imposed.

Next, we turn to the main exercise, where we estimate the model given in (3) assuming that $r_s = r_o$, as is commonly done in the literature.⁸ We show that this commonly used assumption results in biased estimates. We also show that when this restriction imposed on the parameters coincidentally matches the data generating process (i.e., when $r_{s,DGP} = r_{o,DGP}$) then the estimates on α are unbiased. After performing the estimation, we calculate the bias in the estimated α , investigate confidence intervals and issues surrounding hypothesis testing, including Type I and Type II errors.

3.2.1 Assuming identical curvature over self and other's payoffs.

Following the bulk of the literature, we consider the case when the curvatures of utility over self and other's payoffs are assumed to be identical. Therefore, we estimate the parameters of the following utility function:

⁸In Appendix B we also consider the case examined in DellaVigna et al. (2012) and DellaVigna et al. (2013), where they assume linear utility over self payoffs, $r_s = 0$, and concavity over other's payoff o , $r_o \in [0, 1]$. Again, we obtain biased estimates.

$$u(s, o) = (1 - \alpha) * \frac{s^{(1-r)}}{(1-r)} + \alpha * \frac{o^{(1-r)}}{(1-r)}, \text{ with } r < 1, \alpha \in [0, 1] \quad (5)$$

by maximizing the log-likelihood of the generated choices.

3.2.2 Bias

We first examine the percentage by which the estimated level of altruism, $\tilde{\alpha}$, is under and overestimated. Recall, we defined $\tilde{\alpha}_k$ as the value at which the parameter α is estimated in trial k and α_{DGP} the true value of α used to generate the data. This bias is defined as:

$$\%_{bias}(\alpha) = \frac{1}{K} \sum_{k=1}^K \frac{\tilde{\alpha}_k - \alpha_{DGP}}{\alpha_{DGP}} * 100 \quad (6)$$

where K is the number of trials. Figure 1 reports the percentage of over/under estimation in $\tilde{\alpha}$ depending on the true value of coefficient of risk aversion. Figure 1a shows that there is 0 bias from assuming $r_s = r_o$ in our estimation when, in fact, $r_{s,DGP} = r_{o,DGP}$.

In Figure 1b, we hold the value of $r_{o,DGP}$ constant (at $r_{o,DGP}=.3$) and report the percentage of bias depending on the true value of $r_{s,DGP}$. For example, when $r_{s,DGP} = .7$ and $r_{o,DGP} = .3$, but the estimated model incorrectly restricts that $r_s = r_o$, we will over-estimate α by 47.5%.^{9,10} On the other hand, when $r_{s,dgp} = .1$, we under-estimate α by 29.2%.

Figure 1c provides a more general perspective and allows both $r_{o,DGP}$ and $r_{s,DGP}$ to vary simultaneously. The x-axis represents the coefficient of risk aversion over self payoffs $r_{s,DGP}$ and the y-axis represents the coefficient of risk aversion over other's payoffs $r_{o,DGP}$. The z-axis represents the percentage of over- or under-estimation of $\tilde{\alpha}$. The blue plane represents the area on the z-axis where the bias is equal to 0, while the area above and below this plane represents an upward and downward estimated bias on $\tilde{\alpha}$, respectively. When $r_{s,DGP} = r_{o,DGP}$, along the diagonal, note that we estimate no bias and the shaded estimates exactly cross this diagonal line. However, when $r_{s,DGP}$ does not equal $r_{o,DGP}$, there is bias.

More specifically, assuming identical curvature over self and other's payoffs, we overestimate altruism when $r_{s,DGP} > r_{o,DGP}$. The intuition is as follows. When the decision-maker's utility is more concave over self payoffs than over other's payoffs, but we do not account for this additional concavity in our estimation, we attribute higher levels of giving to a higher level of altruism rather than the greater concavity over self payoffs than other's payoffs. Similarly, we underestimate altruism when $r_{o,DGP} < r_{s,DGP}$ because we attribute the lower level of giving to differences in

⁹The value chosen for $r_{s,DGP}$ and $r_{o,DGP}$ in this example are realistic. Indeed, Chakravarty et al. (2011) eliciting risk preferences from multiple price list, estimated a CRRA coefficient of .689 over self payoffs and .248 over other's payoffs.

¹⁰In that case, \tilde{r} is on average estimated to .48.

altruism rather than differences in concavity over self payoffs and other's payoffs.

Result 1. *When we assume $r_s = r_o$, but $r_{s,DGP} \neq r_{o,DGP}$, then estimates of altruism, $\tilde{\alpha}$, are biased.*

(i) *When $r_{s,DGP} > r_{o,DGP}$, $\tilde{\alpha} > \alpha_{DGP}$.*

(ii) *When $r_{s,DGP} < r_{o,DGP}$, $\tilde{\alpha} < \alpha_{DGP}$.*

3.2.3 Hypothesis Testing: Significance Levels and Statistical Power

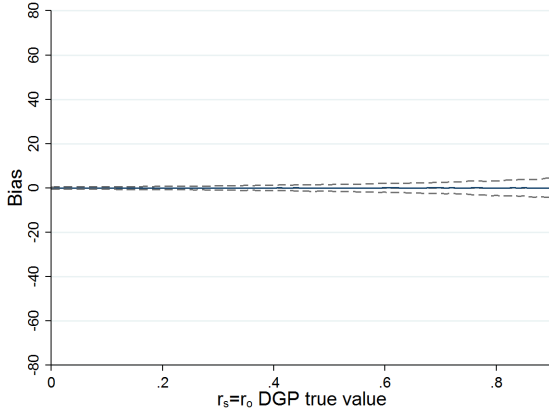
Next, we investigate the confidence intervals obtained on the biased estimates and examine the likelihood of rejecting the null hypothesis when true (Type I error) and the likelihood of failing to reject a null when untrue (Type II error).

First, we test the null hypothesis that the level of altruism is equal to its true value, $H_0 : \tilde{\alpha} = \alpha_{DGP} = .5$.¹¹ Figure 2 shows the probability of a Type I error. Figure 2c allows $r_{s,DGP}$ and $r_{o,DGP}$ to vary simultaneously while Figures 2a and 2b show two-dimensional slices of Figure 2c. We should reject the null in 5% of the trials, but when the curvatures over self and other's payoffs are distinct from each other, we reject the null in a majority of trials even though the null is true. When risk aversion over self and other's payoffs are approximately equal, the statistical test is of correct size and we reject the null in 5% of the trials. For instance, in Figure 2a $r_{o,DGP}$ is fixed to .3, when $r_{s,DGP}$ is also equal to .3 the null is rejected in 5.9% of the trials, but when $r_{s,DGP} = .31$ it is rejected in 91.4% of the trials and when $r_{s,DGP} = .32$ it is rejected in 100% of the trials. Figure 2c shows that when $r_{s,DGP}$ and $r_{o,DGP}$ differ by more than a few percents, then the null that estimated $\tilde{\alpha} = \alpha_{DGP}$ is rejected in 100% of the trials.

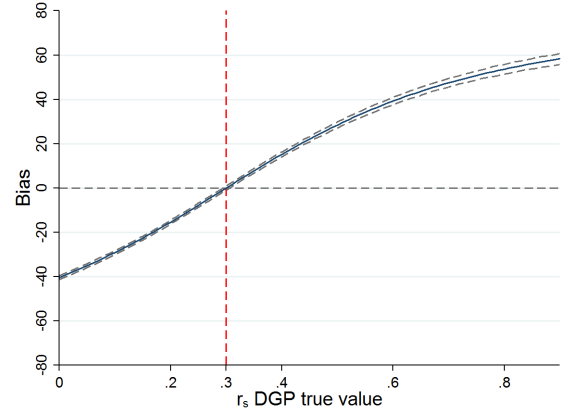
Second, we examine Type II error by testing the probability of rejecting a null hypothesis that $\tilde{\alpha}$ is equal to a value distinct from its true value. In particular, we test $H_0 : \tilde{\alpha} = .4$ and $H_0 : \tilde{\alpha} = .6$, when the true value of $\alpha_{DGP} = .5$. Figure 3 reports the results. Figure 3c shows the probability to reject $H_0 : \tilde{\alpha} = .4$ and Figure 3d the probability to reject $H_0 : \tilde{\alpha} = .6$. Figure 3a and 3b represents 2-dimensional slices of Figure 3c and 3d. In these figures the blue line is the probability to reject $H_0 : \tilde{\alpha} = .4$ and the green line the probability to reject $H_0 : \tilde{\alpha} = .6$. By construction, we should reject the null hypotheses in the majority of trials but we fail to reject the null in 95% of the trials for several set of values $(r_{s,DGP}, r_{o,DGP})$. For instance, as shown by the green line in Figure 3a, if we assume $r_s = r_o$, but $r_{s,DGP} = .169$ and $r_{o,DGP} = .3$, we reject the null that $\tilde{\alpha}$ equals .4 in only 5.5% of the trials despite the fact that α_{DGP} is in fact equal to .5. In Figure 3c, we fail to reject the null $H_0 : \tilde{\alpha} = .4$ when $r_{s,DGP} \approx r_{o,DGP} - 0.13$ and in Figure 3d we fail to reject the null that $H_0 : \tilde{\alpha} = .6$ when $r_{s,DGP} \approx r_{o,DGP} + 0.13$. Hence, we do not only reject the null hypothesis when true but, in some cases, we also fail to reject it when false.

¹¹Standard errors are clustered by subjects (i.e., by group of 50 decisions.). Recall that we simulate 60 dictators

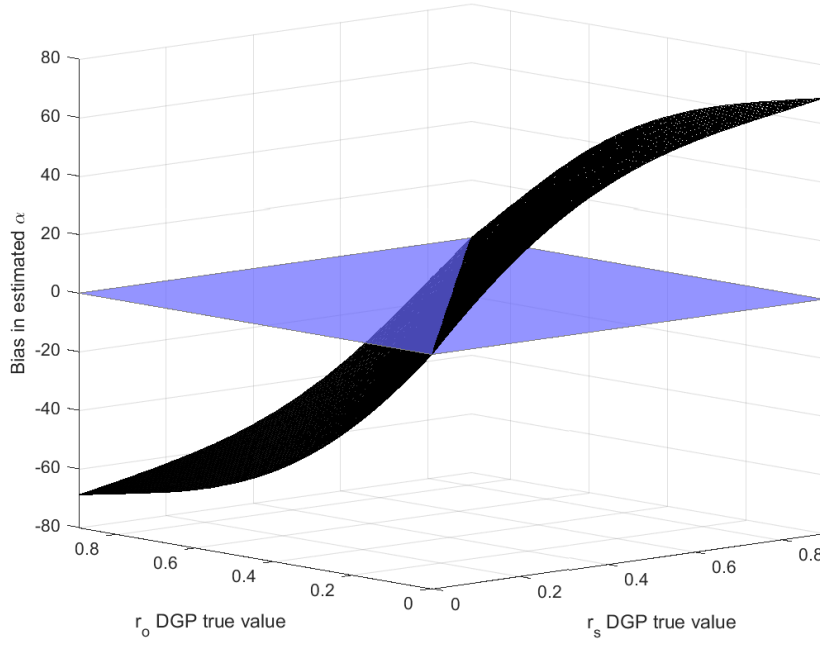
FIGURE 1: BIAS IN ESTIMATED ALTRUISM, $\tilde{\alpha}$



(A) $r_{o,DGP} = r_{s,DGP}$



(B) $r_{o,DGP} = 0.3$



(C) 3-DIMENSIONAL

Percentage of under/over estimation of altruism, $\tilde{\alpha}$. In Figures 1b and 1a the dash line is the corresponding 95% Monte Carlo confidence interval.

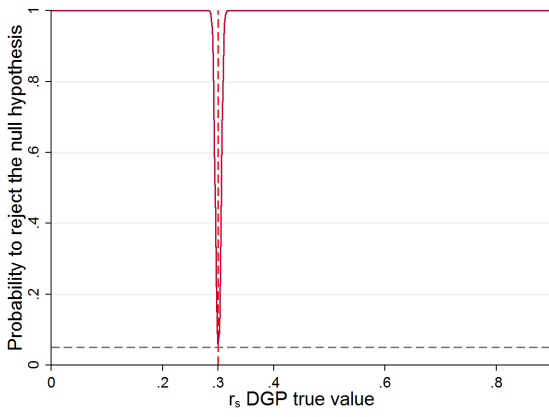
Result 2. *When we assume $r_s = r_o$, but $r_{s,DGP} \neq r_{o,DGP}$, then statistical tests reach erroneous conclusions:*

(i) *Type I error: We reject the null, $H_0 : \tilde{\alpha} = \alpha_{DGP}$, when true in too many trials.*

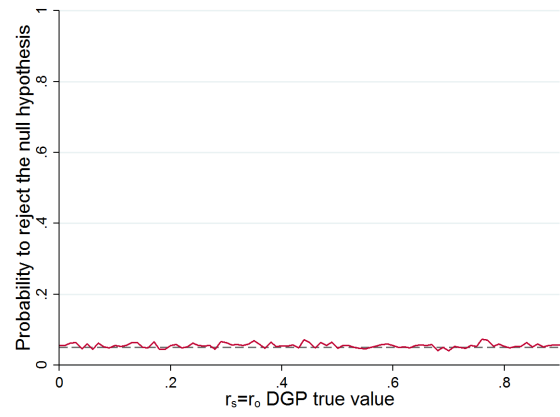
(ii) *Type II error: In some cases, we fail to reject the null, $H_0 : \tilde{\alpha} = \alpha$, when it is not true in*

which each make 50 decisions.

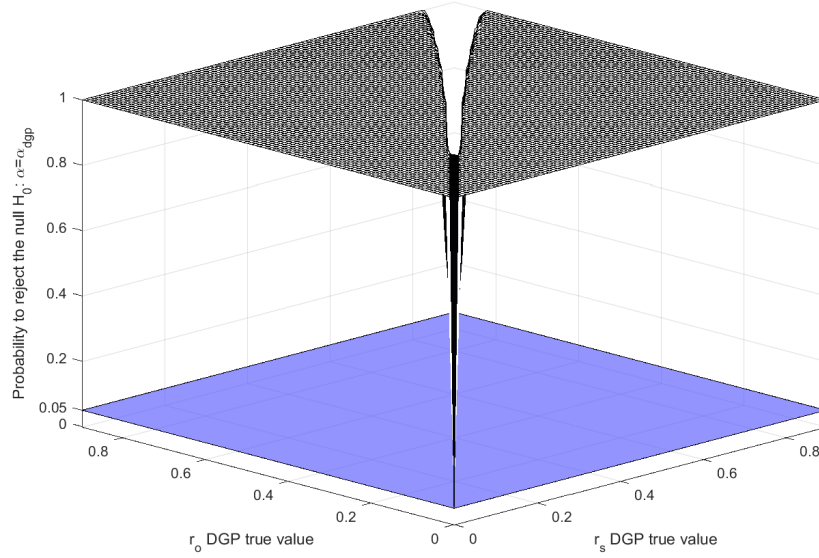
FIGURE 2: POWER CALCULATIONS, TYPE I ERROR



(A) $r_{o,DGP}$ IS FIXED TO .3



(B) $r_{s,DGP} = r_{o,DGP}$

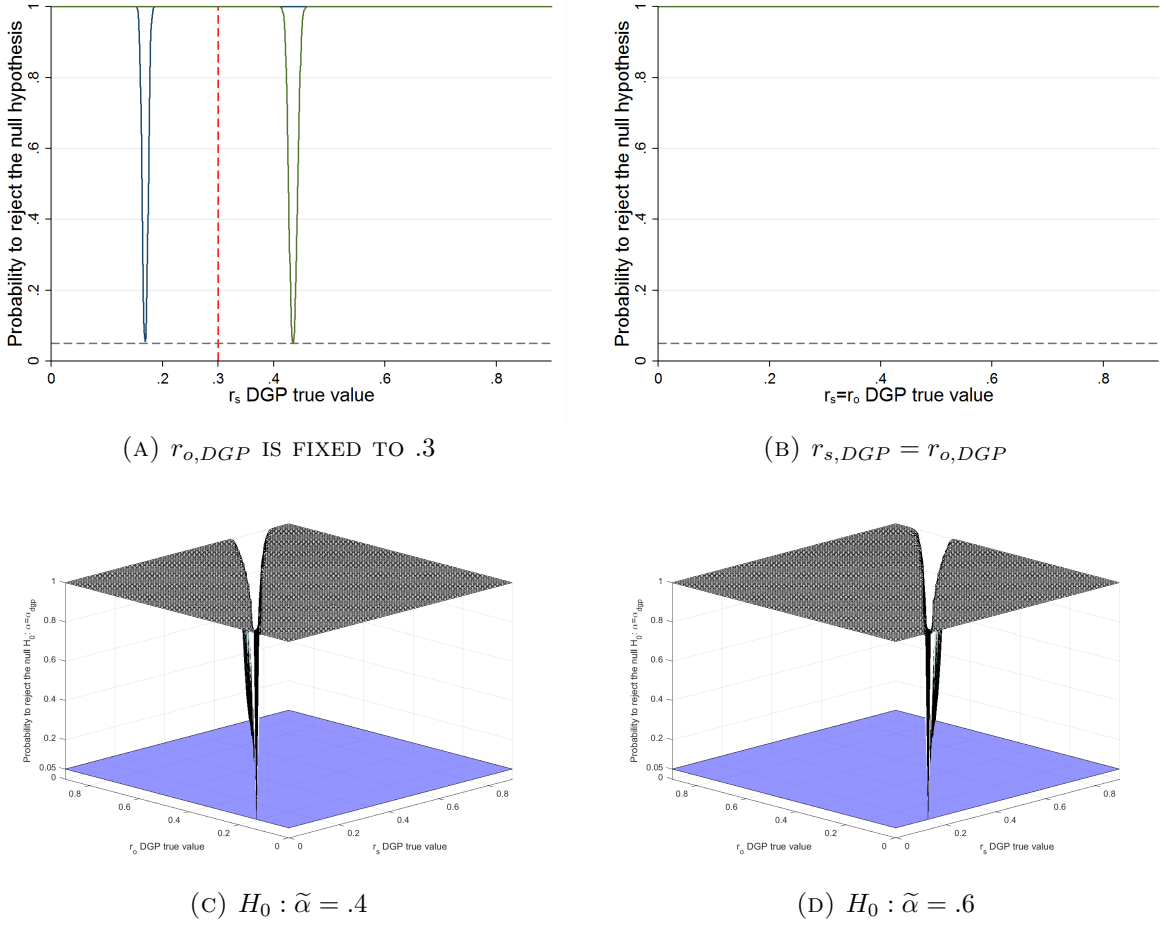


(C) 3-DIMENSIONAL

Probability to reject the null hypothesis $H_0 : \tilde{\alpha} = \alpha_{DGP}$ at the 5% level. 1,000 trials per set of parameters $(r_{s,DGP}, r_{o,DGP})$. In panel (A), $r_{s,DGP} \in \{0, 0.001, \dots, 0.9\}$.

too many trials.

FIGURE 3: POWER CALCULATIONS, TYPE II ERROR



Probability to reject the null hypotheses at the 5% level. In Figures 3a and 3b, $H_0 : \tilde{\alpha} = .4$ (blue) and $H_0 : \tilde{\alpha} = .6$ (green). Estimated assuming $r_s = r_o$. 1,000 trials per set of parameters $(r_{s,DGP}, r_{o,DGP})$. In panel (A), $r_{s,DGP} \in \{0, 0.001, \dots, 0.9\}$.

4 Implications

In this section, we consider three examples that highlight how the common assumption that $r_s = r_o$ can lead to erroneous conclusions. First, we examine gender differences in altruism. Second, we look at the motives for giving. Third, we look at wealth effects and altruism. In each of our examples, we set $\alpha_{DGP} = .5$ for each considered group (e.g., men versus women) and impose assumptions on either the curvature of $r_{s,DGP}$ or on the curvature of $r_{o,DGP}$. That is, we generate data where there is no difference in altruism between the two groups and show how the empirically incorrect assumption that $r_s = r_o$ leads to differences in estimates of altruism between the two groups. We then test the null hypothesis that the level of altruism between each of the two considered groups are equal. In each example, we incorrectly reject the null in 100% of trials.

We then consider a fourth example in which we show that assuming individuals put equal

weight on self and other payoffs, i.e., $\alpha = .5$, when α_{DGP} leads to incorrect inferences about the differences between r_s and r_o . This incorrect assumption can lead researchers to conclude that individuals are more risk-averse towards others and provide a more inelastic labor supply when working for charity payoffs than working for self payoffs.

4.1 Gender

Suppose we have a sample of 30 men and 30 women with the same level of altruism, $\alpha_{male,DGP} = \alpha_{female,DGP} = .5$. The women in our sample are more risk-averse than men over self payoffs, $r_{s,female,DGP} = .9$, $r_{s,male,DGP} = .1$, but men and women have the same level of risk aversion over other's payoffs, $r_{o,female,DGP} = r_{o,male,DGP} = .6$.¹² In other words, the only difference between men and women in our simulation is their degree of risk aversion. In our simulation, we assume women are more risk-averse to reflect a number of experimental results (see Croson and Gneezy (2009)) though other experimental evidence does not find this difference (e.g., see Harrison et al. (2007)). If we analyze this sample restricting risk aversion to be identical over self and other's payoffs but allowing altruism to differ by gender, we estimate the coefficient of altruism to be .22 for men and .69 for women.¹³ We reject the null hypothesis of the absence of gender difference in altruism ($H_0 : \alpha_{male} = \alpha_{female}$) in 100% of the trials. To illustrate Figure 4 represents the values at which $\tilde{\alpha}$ are estimated for men and women on a 3-dimensional figure.

4.2 Motives for Giving

Next, we examine the estimated level of altruism based on two distinct motives for giving: pure altruism and warm glow. Suppose our sample consists of two groups of decision-makers with equal levels of altruism, $\alpha_{PA,DGP} = \alpha_{WG,DGP} = .5$, but who differ in their motive for giving. Group PA is driven by pure altruism, $r_{o,PA,DGP} = .1$ and group WG is driven by warm glow, $r_{o,WG,DGP} = .9$.¹⁴ Further, assume that the two groups have similar curvatures over self payoffs, $r_{s,PA,DGP} = r_{s,WG,DGP} = .6$. In this case, we estimate the coefficient of altruism to be .77 for the individuals motivated by pure altruism and .31 for the individuals motivated by warm glow.¹⁵ We, therefore, over-estimate the altruism of the pure altruist and under-estimate the altruism of the individual motivated by warm glow. Again, we incorrectly reject the null hypothesis

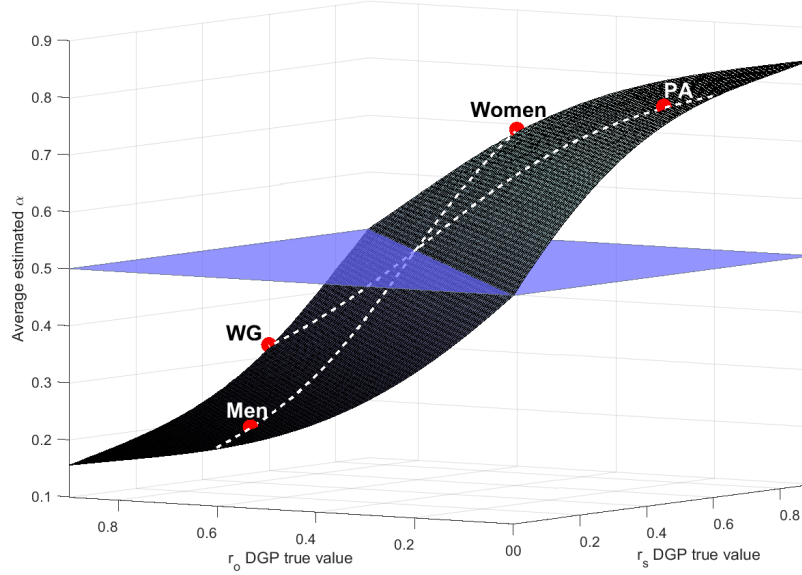
¹²We chose values for $r_{s,female,DGP}$ and $r_{s,male,DGP}$ that are found in the literature. For instance, using the data from Harrison and Rutström (2009) and performing the same estimation, but using the CRRA utility function $u(x) = \frac{x^{1-r}}{1-r}$ instead the power utility function $u(x) = x^r$, we estimated $r_{s,female} = .91$ and $r_{s,male} = .06$.

¹³ \tilde{r} is on average estimated to .35 for men and 0.74 for women.

¹⁴Null (2011) models pure motives with linear utility and warm glow with concave utility. The results are not sensitive to the exact values chosen for $r_{o,DGP}$.

¹⁵ \tilde{r} is on average estimated to .35 for individuals motivated by pure altruism and 0.74 for individuals motivated by warm glow.

FIGURE 4: MEAN OF THE ESTIMATED LEVEL OF ALTRUISM $\tilde{\alpha}$



The red dots represents the values at which $\tilde{\alpha}$ is estimated in the gender and motives for giving illustrative examples.

($H_0 : \tilde{\alpha}_{PA} = \tilde{\alpha}_{WG}$) in 100% of the trials.¹⁶ Figure 4 represents the values at which $\tilde{\alpha}$ are estimated for both groups on a 3-dimensional figure.

Result 3. *Assuming $r_{s,group1} = r_{o,group1}$ and $r_{s,group2} = r_{o,group2}$, when $r_{s,DGP,group1} \neq r_{o,DGP,group1}$ or $r_{s,DGP,group2} \neq r_{o,DGP,group2}$, can lead to incorrect inferences about the relative levels of altruism between groups.*

One interesting point for future research regarding the motives for giving, is to better understand the relationship between the curvature of v and α . Are warm glow givers (i.e., more concave v) more altruistic than individuals driven by pure motives (i.e., more linear v) or vice versa?

4.3 Wealth Effects

In our third example, we examine how unobserved wealth may affect the estimated level of altruism. The CRRA utility function displays decreasing absolute risk aversion, meaning that, ceteris paribus, wealthier individuals are willing to take on more risk. Thus, suppose we are comparing two groups of subjects. Group W (Wealthy) is given \$20 before playing the dictator game and group P (Poor) is not given anything. Both groups are otherwise identical, with the same level of altruism,

¹⁶In this test statistic we again assume 30 dictators which each make 50 decisions in each group. The standard errors are clustered by dictator.

$\alpha_{W,DGP} = \alpha_{P,DGP} = .5$, the same curvature of utility over other's payoffs, $r_{o,W,DGP} = r_{o,P,DGP} = .6$, and the same curvature of utility over self payoffs, $r_{s,W,DGP} = r_{s,P,DGP} = .6$. In this case, ignoring the initial wealth of both groups we estimate $\tilde{\alpha}$ to .62 for the group which received the \$20 and $\tilde{\alpha}_P = .5$ for the other group.¹⁷ We reject the null hypothesis ($H_0 : \tilde{\alpha}_W = \tilde{\alpha}_P$) in 100% of the trials. If we do take into account the initial wealth of both groups in the estimation we reject the null hypothesis that the level of altruism is different in both groups in 5% of the trials.

Result 4. *Ignoring difference in wealth can lead to incorrectly inferring that wealthier individuals are more altruistic than less wealthy individuals.*

4.4 Risk and Elasticity

Our fourth example addresses the problem of confounding α with the curvature of the utility functions from a different perspective. Here, we show how incorrectly assuming that the utility of \$1 in self payoffs is equivalent to the utility of \$1 in other's payoffs will lead to the conclusion that the curvature between $u(\cdot)$ and $v(\cdot)$ differ, when in truth, they do not. Using the CRRA utility framework, this problem manifests as concluding that individuals have different risk preferences for payoffs to self than payoffs to other (Chakravarty et al., 2011) or that individuals respond differently to incentives when working for self than working for charity (Imas, 2014). Suppose, that $\alpha_{DGP} = \frac{1}{3}$, $r_{s,DGP} = r_{o,DGP} = .6$ and in the estimation we wrongly assume that $\alpha = 0.5$ while allowing r_s and r_o to differ. In that case, \tilde{r}_s is, on average, estimated to .46 and \tilde{r}_o to .69. The null $H_0 : \tilde{r}_s = \tilde{r}_o$ is rejected in 100% of the trials. We thus underestimate risk aversion over self payoffs and overestimate it over other's payoffs.

Result 5. *Assuming $\alpha = .5$, when $\alpha \neq .5$, can lead to incorrect inferences about r_s and r_o .*

5 Two Approaches to Address Bias

Our simulations demonstrate that estimates of social preferences can be biased if we do not take into consideration the shape of the utility function over both own payoffs and other's payoffs. We suggest two potential solutions to address this. A first approach follows the structural estimation put forth in Andersen et al. (2008), but adapting it to social preferences. An alternative approach follows the calibration exercise in Exley (2015) and allows the researcher to assess whether the assumption of $r_s = r_o$ is innocuous and suggests an upper or lower bound on the social preference parameter. The appropriateness of each of the two approaches we propose below greatly depends on the aims of the researcher.

¹⁷ \tilde{r} is on average estimated to .46 in group W and 0.6 in group P.

5.1 A Structural Approach

One method to estimate altruism that accounts for curvature is to experimentally generate data to identify curvature over own payoffs, curvature over other payoffs and altruism and then estimate all three parameters in a structural model. This follows closely from the time preference literature (Andersen et al., 2008). In fact, Harrison (2018) discuss the numerous applications and advantages of joint estimation of parameters of the utility function and mention the advantages of jointly estimating utility over self and other payoffs in the estimation of social preferences.

In Appendix F, we show that when one allows the curvature over self and other payoffs to differ the coefficient of altruism is estimated without bias. We estimated all parameters of our model on simulated data using the modified dictator game used in Fisman et al. (2007). While we used values of the parameters as found in the literature, and a sample size to simulate the data that is common in many laboratory experiments, we can expect the structural estimation to be more demanding on actual experimental data.

To address the increased demand we propose that an additional direction for research is to develop an experiment that can identify all three parameters, which mimics the design proposed by Andersen et al. (2008). For example, the design would include three distinct tasks: (1) a task to elicit curvature over self-payoffs; (2) an analogous task to elicit curvature over others' payoffs; and (3) a task to elicit the coefficient of altruism, such as a modified dictator game.

Using this experimental design, it would be particularly interesting to empirically investigate the examples discuss in Section 4. For instance, numerous studies have found women to be more altruistic than men (see Croson and Gneezy (2009) for a review). But are these differences due to differences in utilities' curvatures or due to differences in the altruism coefficient? By jointly estimating those three parameters, and investigating whether they differ by gender, such experiment could answer this question.

While jointly estimating the parameters of the utility function has many advantages (see Harrison (2018)), it requires experimental subjects to make many decisions which might not be possible if the researcher has time or budget constraints. Next, we turn to an alternative approach.

5.2 A Calibration Approach

In this section, we propose a simple calibration exercise to help researchers test for the validity of the assumption $r_s = r_o$ and provides either an upper or lower bound on α . The goal of the calibration exercise is to find points of indifference between amounts of money for self and money to the other person or charity for each subject. While we build closely off of Exley (2015)'s easy-to-implement approach, it is closely related to the Bayesian approach employed by Harrison (1990) to infer risk attitudes from bidding choices in a first-price auction conducted in the laboratory.

Exley (2015) finds the amount a subject would give to a charity, $\$X$, that is indifferent to receiving $\$1$ for themselves, i.e., where $u(\$1) = v(\$X)$, by presenting subjects with a multiple price list in which the amount to self is held constant ($\$1$) and the amount given to charity increases incrementally. Subjects are then asked, on each line, whether they prefer $\$1$ to self (and $\$0$ to charity) or $\$0$ for self and some amount $\$X$ for charity, and uses the line where they switch to determine the point of indifference.

Suppose an individual has preferences over payoffs to self (s) and payoffs to another person or charity (o), where we will denote o_n as the o such that the individual is indifferent between s_n and o_n . The idea is to use a multiple price list calibration approach to find the o_n for each s_n contained in the relevant payoff space, S . For example, suppose our decision-maker has CRRA utility and let $S \in s_1 = 1, s_2 = 2, s_3 = 3$ and denote $O \in o_1, o_2, o_3$. We now consider the three relevant assumptions about curvature: (1) $r_s = r_o$; (2) $r_s > r_o$; and (3) $r_s < r_o$. If case 1 is true, then $o_2 = 2 \times o_1$ and $o_3 = 3 \times o_1$. If case 2 is true, then $o_2 < 2 \times o_1$ and $o_3 < 3 \times o_1$. Finally if case 3 is true, then $o_2 > 2 \times o_1$ and $o_3 > 3 \times o_1$. Let the corresponding α for each case be $\bar{\alpha}$, α_{lo} and α_{hi} , respectively. Thus, when o_i is increasing at a slower (faster) rate than s_i , then it must be that $r_s < (>)r_o$ and $\bar{\alpha}$ is an upper (lower) bound on the true α .

6 Conclusion

This paper has demonstrated that imposing an incorrect restriction of the equality on the curvature of the utility function for self and other, which is ubiquitous in the economics literature, leads to systematically biased estimates of the relative intensity of social preferences. While point estimates are usually taken with "a grain of salt" due to many factors associated with laboratory data, the current paper also demonstrates that extensive comparative static inferences on social preferences, such as based on gender differences, should also be broadly questioned. More generally, the current paper provides a blunt reminder of the critical importance of combining theory, experimental evidence, and econometric analysis to avoid generating seemingly robust yet potentially incorrect inferences across substantive research agendas (such as gender differences in social preferences). The current results stress the critical need for future empirical research on social preferences to relax assumptions on the curvature of preferences over self and other.

References

- Ahmed, A. M. (2009). Are religious people more prosocial? a quasi-experimental study with madrasah pupils in a rural community in india. *Journal for the Scientific Study of Religion* 48(2), 368–374.
- Andersen, S., J. Fountain, G. W. Harrison, and E. E. Rutström (2014). Estimating subjective probabilities. *Journal of Risk and Uncertainty* 48(3), 207–229.

- Andersen, S., G. W. Harrison, M. I. Lau, and E. E. Rutström (2008). Eliciting risk and time preferences. *Econometrica* 76(3), 583–618.
- Andersen, S., G. W. Harrison, M. I. Lau, and E. E. Rutström (2018). Multiattribute utility theory, intertemporal utility, and correlation aversion. *International Economic Review* 59(2), 537–555.
- Andersson, O., H. J. Holm, J.-R. Tyran, and E. Wengström (2014). Deciding for others reduces loss aversion. *Management Science* 62(1), 29–36.
- Andreoni, J., W. G. Gale, J. K. Scholz, and J. Straub (1996). Charitable contributions of time and money. *University of Wisconsin–Madison Working Paper*.
- Andreoni, J. and J. Miller (2002). Giving according to garp: An experimental test of the consistency of preferences for altruism. *Econometrica* 70(2), 737–753.
- Andreoni, J., N. Nikiforakis, and J. Stoop (2017). Are the rich more selfish than the poor, or do they just have more money? a natural field experiment. Technical report, National Bureau of Economic Research.
- Andreoni, J. and L. Vesterlund (2001). Which is the fair sex? gender differences in altruism. *Quarterly Journal of Economics*, 293–312.
- Benenson, J. F., J. Pascoe, and N. Radmore (2007). Children’s altruistic behavior in the dictator game. *Evolution and Human Behavior* 28(3), 168–175.
- Benz, M. and S. Meier (2008). Do people behave in experiments as in the field? evidence from donations. *Experimental Economics* 11(3), 268–281.
- Brown, A. L., J. Meer, and J. F. Williams (2013). Why do people volunteer? an experimental analysis of preferences for time donations. Technical report, National Bureau of Economic Research.
- Camerer, C. (2010). *Behavioral Game Theory*. New Age International.
- Carpenter, J., C. Connolly, and C. K. Myers (2008). Altruistic behavior in a representative dictator experiment. *Experimental Economics* 11(3), 282–298.
- Chakravarty, S., G. W. Harrison, E. E. Haruvy, and E. E. Rutström (2011). Are you risk averse over other people’s money? *Southern Economic Journal* 77(4), 901–913.
- Charness, G., R. Cobo-Reyes, and A. Sanchez (2016). The effect of charitable giving on workers’ performance: Experimental evidence. *Journal of Economic Behavior & Organization* 131, 61–74.
- Cox, J. C. and C. A. Deck (2006). When are women more generous than men? *Economic Inquiry* 44(4), 587–598.
- Croson, R. and U. Gneezy (2009). Gender differences in preferences. *Journal of Economic Literature*, 448–474.
- DellaVigna, S., J. List, and U. Malmendier (2012). Testing for altruism and social pressure in charitable giving. *The Quarterly Journal of Economics* 127(1), 1.
- DellaVigna, S., J. A. List, U. Malmendier, and G. Rao (2013). The importance of being marginal: Gender differences in generosity. *American Economic Review* 103(3), 586–90.
- Eckel, C. C. and P. J. Grossman (1996a). Altruism in anonymous dictator games. *Games and Economic Behavior* 16(2), 181–191.
- Eckel, C. C. and P. J. Grossman (1996b). The relative price of fairness: Gender differences in a punishment game. *Journal of Economic Behavior & Organization* 30(2), 143–158.
- Eckel, C. C. and P. J. Grossman (1998). Are women less selfish than men?: Evidence from dictator experiments. *The Economic Journal* 108(448), 726–735.

- Engel, C. (2011). Dictator games: A meta study. *Experimental Economics* 14(4), 583–610.
- Eriksen, K. W. and O. Kvaløy (2010). Myopic investment management. *Review of Finance* 14(3), 521–542.
- Exley, C. L. (2015). Excusing selfishness in charitable giving: The role of risk. *The Review of Economic Studies* 83(2), 587–628.
- Fisman, R., P. Jakiela, and S. Kariv (2015). How did distributional preferences change during the great recession? *Journal of Public Economics* 128, 84–95.
- Fisman, R., P. Jakiela, and S. Kariv (2017). Distributional preferences and political behavior. *Journal of Public Economics*.
- Fisman, R., P. Jakiela, S. Kariv, and D. Markovits (2015). The distributional preferences of an elite. *Science* 349(6254), aab0096.
- Fisman, R., S. Kariv, and D. Markovits (2007). Individual preferences for giving. *The American Economic Review* 97(5), 1858–1876.
- Fong, C. M. and E. F. Luttmer (2009). What determines giving to hurricane katrina victims? experimental evidence on racial group loyalty. *American Economic Journal: Applied Economics* 1(2), 64–87.
- Fong, C. M. and E. F. Luttmer (2011). Do fairness and race matter in generosity? evidence from a nationally representative charity experiment. *Journal of Public Economics* 95(5), 372–394.
- Harrison, G. W. (1990). Risk attitudes in first-price auction experiments: A bayesian analysis. *The Review of Economics and Statistics*, 541–546.
- Harrison, G. W. (2018). The methodologies of behavioral econometrics. In M. Nagatsu and A. Ruzzene (Eds.), *Contemporary Philosophy and Social Science: An Interdisciplinary Dialogue*. London: Bloomsbury.
- Harrison, G. W. and L. T. Johnson (2006). Identifying altruism in the laboratory. In R. M. Isaac and D. D. Davis (Eds.), *Experiments Investigating Fundraising and Charitable Contributors*, Volume 11 of *Research in Experimental Economics*. Emerald Group Publishing Limited.
- Harrison, G. W., M. I. Lau, and E. E. Rutström (2007). Estimating risk attitudes in denmark: A field experiment. *The Scandinavian Journal of Economics* 109(2), 341–368.
- Harrison, G. W. and E. Rutström (2008). Risk aversion in the laboratory. In J. Cox and G.W.Harrison (Eds.), *Risk Aversion in Experiments*, Volume 12 of *Research in Experimental Economics*. Emerald Group Publishing Limited.
- Harrison, G. W. and E. E. Rutström (2009). Expected utility theory and prospect theory: One wedding and a decent funeral. *Experimental Economics* 12(2), 133–158.
- Heger, S. A. and R. Slonim (2019). Altruism begets altruism: Nudging our way to a more virtuous society? Technical report.
- Hofmeier, J., T. Neuber, et al. (2019). Motivated by others’ preferences? an experiment on imperfect empathy. Technical report, University of Bonn and University of Mannheim, Germany.
- Imas, A. (2014). Working for the “warm glow”: On the benefits and limits of prosocial incentives. *Journal of Public Economics* 114, 14–18.
- Imas, A. and Loewenstein (2018). Is altruism sensitive to scope? the role of tangibility. *Working Paper*.
- Jacobsen, K. J., K. H. Eika, L. Helland, J. T. Lind, and K. Nyborg (2011). Are nurses more altruistic than real estate brokers? *Journal of Economic Psychology* 32(5), 818–831.
- Lilley, A. and R. Slonim (2014). The price of warm glow. *Journal of Public Economics* 114, 58–74.

- Null, C. (2011). Warm glow, information, and inefficient charitable giving. *Journal of Public Economics* 95(5), 455–465.
- Rogers, J. (2017). Nothing to lose: Charitable donations as incentives in risk preference measurement. *Journal of Experimental Political Science* 4(1), 34–56.
- Slonim, R. and E. Garbarino (2008). Increases in trust and altruism from partner selection: Experimental evidence. *Experimental Economics* 11(2), 134–153.
- Tonin, M. and M. Vlassopoulos (2014). Corporate philanthropy and productivity: Evidence from an online real effort experiment. *Management Science* 61(8), 1795–1811.
- Voors, M. J., E. E. Nillesen, P. Verwimp, E. H. Bulte, R. Lensink, and D. P. Van Soest (2012). Violent conflict and behavior: a field experiment in burundi. *The American Economic Review* 102(2), 941–964.
- Wilcox, N. T. (2008). Stochastic models for binary discrete choice under risk: A critical primer and econometric comparison. In J. C. Cox and G. W. Harrison (Eds.), *Risk Aversion in Experiments*, Volume 12 of *Research in Experimental Economics*, pp. 197–292. Emerald Group Publishing Limited.

Appendix A Past Literature

TABLE A1: EXAMPLE OF PAST EXPERIMENTAL LITERATURE ESTIMATING ALTRUISM FROM DICTATOR GAME

Paper	Setting	Recipient	Assumption	Finding
Measuring Altruism				
Andreoni and Miller (2002)	Laboratory	Other subject	$r_s = r_o$	Choices are consistent with generalized axiom of revealed preferences.
Harrison and Johnson (2006)	Laboratory	Other subject & Charity	$r_s = r_o$	Revealed altruism depends upon the identity of the residual claimant.
Fisman et al. (2007)	Laboratory	Other subject	$r_s = r_o$	Choices are consistent with generalized axiom of revealed preferences.
Comparing Altruism Between Decision Makers				
Andreoni and Vesterlund (2001)	Laboratory	Other subject	$r_s = r_o$	Men are more sensitive to the price of giving.
Eckel and Grossman (1998)	Laboratory	Other subject	$r_s = r_o$	Women are more altruistic.
Cox and Deck (2006)	Laboratory	Other subject	$r_s = r_o$	Women are more sensitive to the price of giving.
Benenson et al. (2007)	Laboratory	Other subject	$r_s = r_o$	Older children and children from higher SES environments are more altruistic.
Carpenter et al. (2008)	Laboratory	Charity	$r_s = r_o$	Students are less altruistic than non student subjects.
Ahmed (2009)	Laboratory	Other subject	$r_s = r_o$	Religious students are more altruistic.
Jacobsen et al. (2011)	Laboratory	Charity	$r_s = r_o$	Nurses are more altruistic than real estate brokers.
Voors et al. (2012)	Laboratory in the Field	Other subject	$r_s = r_o$	Victims of conflict are more altruistic toward their neighbors.
DellaVigna et al. (2012)	Field	Charity	$r_s = 0, r_o > 0$	Social pressure is a determinant of giving.
DellaVigna et al. (2013)	Field	Charity	$r_s = 0$ $r_o \in [0, 1]$	Women are more altruistic.
Fisman et al. (2015)	Laboratory	Other subject	$r_s = r_o$	Subjects exposed to economic recession are less altruistic and more sensitive to the price of giving.
Fisman et al. (2015)	Laboratory & Online Laboratory	Other subject	$r_s = r_o$	Elite students are less altruistic and more sensitive to the price of giving than the average American.
Fisman et al. (2017)	Online Laboratory	Other subject	$r_s = r_o$	Republicans are more sensitive to price of giving than democrats. No significant relationship between voting behavior and altruism.
Comparing Altruism Between Recipients				
Eckel and Grossman (1996a)	Laboratory	Other subject & Charity	$r_s = r_o$	Recipients' perceived worthiness increases giving.
Slonim and Garbarino (2008)	Laboratory	Other subject	$r_s = r_o$	Choosing the recipient increases altruism.
Fong and Luttmer (2009)	Online Laboratory	Charity	$r_s = r_o$	On average, recipient's race does not influence giving.
Fong and Luttmer (2011)	Online Laboratory	Charity	$r_s = r_o$	Recipients' perceived worthiness increases giving.
Comparing Altruism Across contexts				
Benz and Meier (2008)	Laboratory & Field	Charity	$r_s = r_o$	Altruism is more pronounced in the laboratory. Altruism in the laboratory and in the field correlate.

TABLE A2: EXAMPLE OF PAST EXPERIMENTAL LITERATURE COMPARING CURVATURE OVER SELF AND OTHER'S PAYOFFS.

Paper	Setting	Recipient	Experimental task	Assumption	Finding
Comparing Risk Aversion over self and other's payoffs					
Eriksen and Kvaløy (2010)	Laboratory	Other subject	Investment Task	$\alpha = 0.5$	More risk averse over other's than self payoffs.
Chakravarty et al. (2011)	Laboratory	Other subject	Multiple Price List	$\alpha = 0.5$	Less risk averse over other's than self payoffs.
Andersson et al. (2014)	Online Laboratory	Other subject	Multiple Price List	$\alpha = 0.5$	No difference in utility's curvature over self and other's payoffs. More loss averse over other's than self payoffs.
Exley (2015)	Laboratory	Other subject & Charity	Multiple Price List / Dictator Game	-	More risk averse over other's than self payoffs when decision forces trade-off between self and other's payoffs. But no difference in the absence of trade-off.
Rogers (2017)	Laboratory	Charity	Multiple Price List & Bomb Risk Elicitation Task	$\alpha = 0.5$	No difference in risk aversion over self and other's payoffs.
Comparing response to incentives toward self and other's payoffs					
Imas (2014)	Laboratory	Charity	Real Effort Task	$\alpha = 0.5$	When incentives increase, effort toward self payoffs increases but effort toward other's payoffs remain constant.
Tonin and Vlassopoulos (2014)	Online Laboratory	Charity	Real Effort Task	$\alpha = 0.5$	Incentives toward other's payoffs are less effective than incentive toward self payoffs to increase effort but the difference is not large.
Charness et al. (2016)	Laboratory	Charity	Real Effort Task	$\alpha = 0.5$	With high incentives more effort is exerted for self than other's payoffs. With low incentives less effort for self than other's payoffs.
Imas and Loewenstein (2018)	Laboratory	Charity	Real Effort Task	$\alpha = 0.5$	Sensitivity to incentives' scope on effort expenditure toward other's payoffs depends on the tangibility of the outcomes.

Appendix B Assuming linear utility over self and concave utility over other's payoffs.

DellaVigna, List, and Malmendier (2012) assumed linear utility over self payoffs and concave utility over other's payoffs. In particular, they estimated the utility function:

$$u(s, o) = s + \alpha * \log(\Gamma + o), \text{ with } \Gamma \geq 0 \quad (7)$$

We investigate whether this assumption could lead to biased estimates by performing the same simulation as in Section 3¹⁸ but estimating the utility function:

$$u(s, o) = s + \alpha * \frac{o^{(1-r_o)}}{(1-r_o)}, \text{ with } r_o < 1 \quad (8)$$

instead of (5).

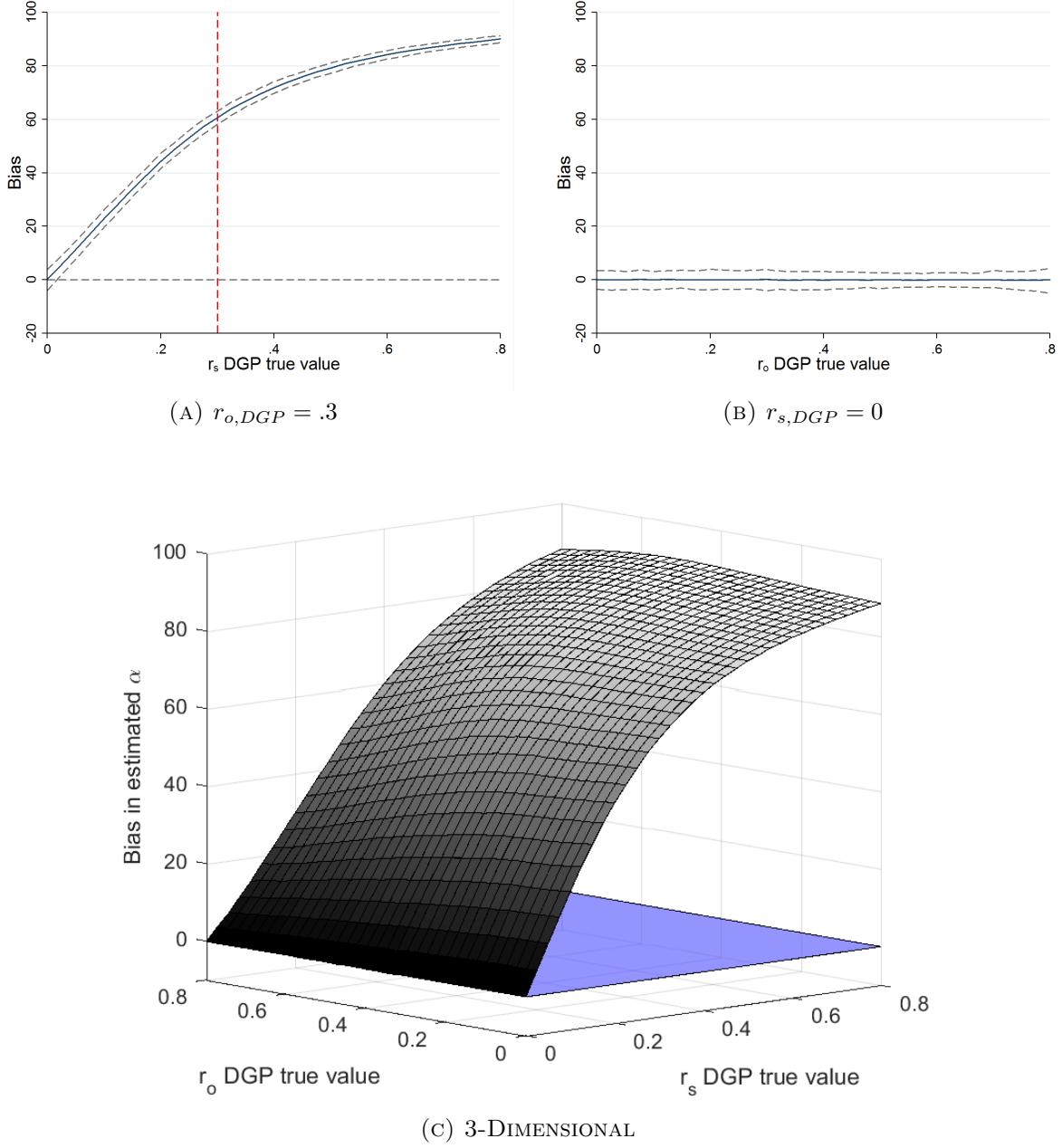
Appendix B.1 Bias

Figure B1 reports the percentage of under/over estimation in the level of altruism given $r_{s,DGP}$ and $r_{o,DGP}$. Figure B1a and B1b show two-dimensional slices of Figure B1c. In Figure B1a, $r_{o,DGP}$ is fixed to .3 and in Figure B1b, $r_{s,DGP}$ is fixed to 0. When the utility over self payoffs is not linear (i.e., when $r_{s,DGP} > 0$), the estimated level of altruism exhibit a substantial upward bias. For instance, when $r_{s,DGP} = .7$ and $r_{o,DGP} = .3$ the altruism level is, on average, estimated to 0.94 which represents an overestimation of 88%.¹⁹ However when $r_{s,DGP} = 0$ (e.g., as in Figure B1b) there is no bias.

¹⁸In this section we perform our simulation $K = 500$ times for each case $(r_{s,DGP}, r_{o,DGP}) \in \{0, 0.025, \dots, 0.8\} \times \{0, 0.025, \dots, 0.8\}$ instead of $K = 1,000$ times for each case $(r_{s,DGP}, r_{o,DGP}) \in \{0, 0.01, \dots, 0.9\} \times \{0, 0.01, \dots, 0.9\}$ as in Section 3. We reduce the number of cases and trials per cases to save computing time. We restrained our simulation to the cases where $r_{s,DGP} \leq 0.8$ and $r_{o,DGP} \leq 0.8$ because the Maximum Likelihood is difficult to maximize when we assume $r_s = 0$ and $r_{s,DGP} > 0.8$ or $r_{o,DGP} > 0.8$.

¹⁹In that case r_o is, on average, estimated to 0.54.

FIGURE B1: BIAS IN ESTIMATED ALTRUISM, $\tilde{\alpha}$



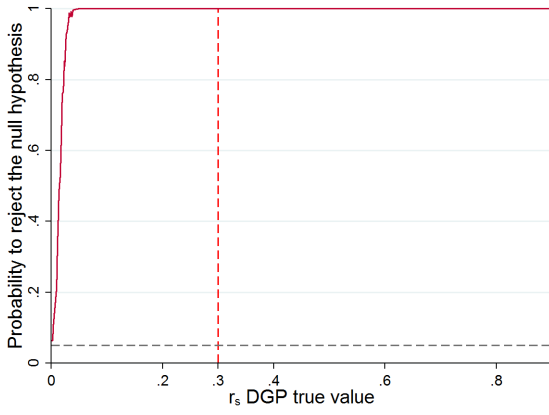
Percentage of under/over estimation of altruism $\tilde{\alpha}$. In Figures 1b and 1a the dash line is the corresponding 95% Monte Carlo confidence interval.

Appendix B.2 Statistical Power

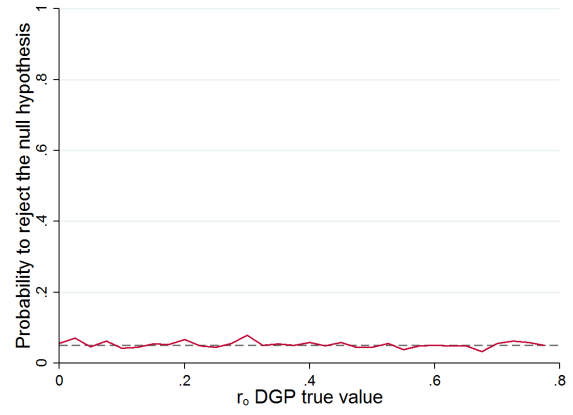
We now turn to the probability of Type I error. Figure B2 shows the probability to reject the null hypothesis that the estimated altruism level is equal to its true value ($H_0 : \tilde{\alpha} = \alpha_{DGP}$) given $r_{s,DGP}$ and $r_{o,DGP}$. Figure B2a and B2b show two-dimensional slices of Figure B2c. When $r_{s,DGP}$ is equal to 0 (e.g., in Figure B2b) the statistical test is of correct size; we do reject the null in 5% of the trials. But when the utility over self payoffs is concave ($r_{s,DGP} > 0$) we reject the null in too many trials. For instance, when $r_{s,DGP} = .7$ and $r_{o,DGP} = .3$ we reject the null in 100% of the trials. We therefore reject the null even when it's true.

We have seen that $\tilde{\alpha}$ exhibit a large upward bias. We now explore how likely we are to fail to reject the null that $\tilde{\alpha}$ is equal to values above its true value. We consider the null hypothesis $H_0 : \tilde{\alpha} = .6$ and $H_0 : \tilde{\alpha} = .8$. That is, we test whether the estimated level of altruism is estimated at 20% and 60% above its true value. Figure B3 reports the results. For a large set of parameters ($r_{s,DGP}, r_{o,DGP}$) we do not reject the null that $\tilde{\alpha} = .6$ or that $\tilde{\alpha} = .8$ in a sufficient number of trials. For instance, when $r_{s,DGP} = .293$ and $r_{o,DGP} = .3$ we reject $H_0 : \tilde{\alpha} = .8$ in only 5% of the trials. Therefore, assuming linear utility over self payoffs comes at a price; if the utility over self payoffs is instead concave the altruism level will be substantially over-estimated.

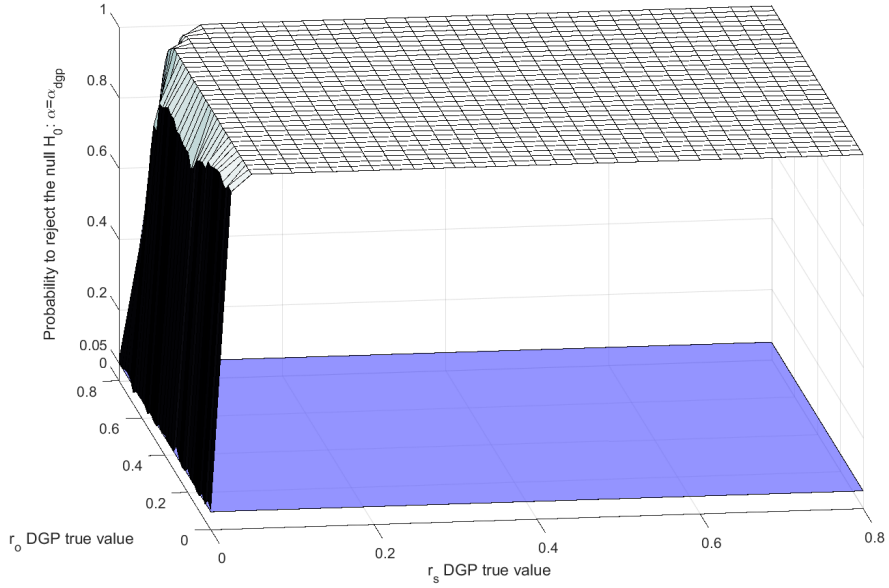
FIGURE B2: POWER CALCULATIONS, TYPE I ERROR



(A) $r_{o,DGP}$ IS FIXED TO .3



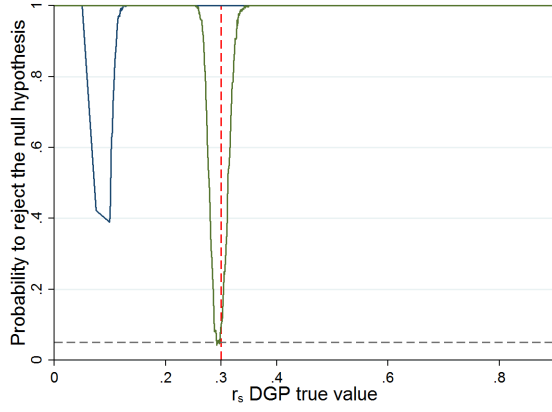
(B) $r_{s,DGP}$ IS FIXED TO 0



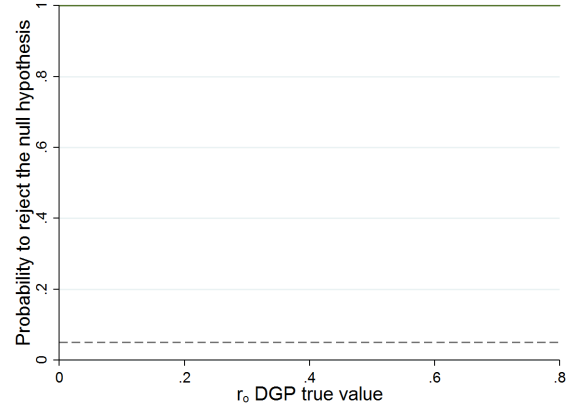
(C) 3-DIMENSIONAL

Probability to reject the null hypothesis $H_0 : \tilde{\alpha} = \alpha_{DGP}$ at the 5% level. 500 trials per set of parameters $(r_{s,DGP}, r_{o,DGP})$. In panel (A), $r_{s,DGP} \in \{0, 0.001, \dots, 0.9\}$.

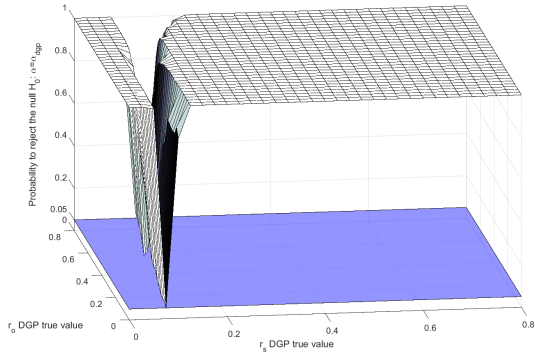
FIGURE B3: POWER CALCULATIONS, TYPE II ERROR



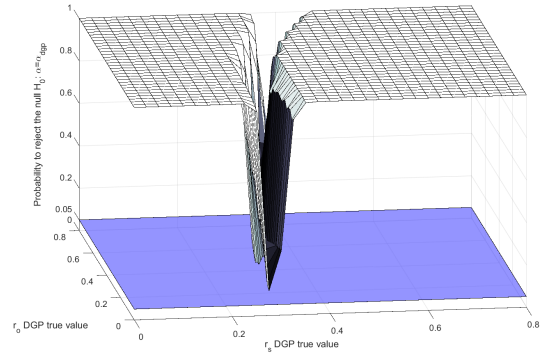
(A) $r_{o,DGP}$ IS FIXED TO 0.3



(B) $r_{s,DGP}$ IS FIXED TO 0



(C) $H_0 : \tilde{\alpha} = .6$



(D) $H_0 : \tilde{\alpha} = .8$

Probability to reject the null hypotheses at the 5% level. In Figures B3a and B3b, $H_0 : \tilde{\alpha} = .4$ (blue) and $H_0 : \tilde{\alpha} = .6$ (green). 500 trials per set of parameters $(r_{s,DGP}, r_{o,DGP})$. In panel (A), $r_{s,DGP} \in \{0, 0.001, \dots, 0.9\}$.

Appendix B.3 An Illustrative Example

DellaVigna, List, Malmendier, and Rao (2013) found women to be more altruistic than men by allowing the distribution of altruism to differ by gender in DellaVigna et al.'s (2012) estimation. To investigate whether this gender difference could be due to the specific assumption made on the utility's curvature we re-investigate the sample examined in Section 4.1.²⁰ Estimating the level of altruism assuming utility to be linear over self payoffs, we estimate the coefficient of altruism at .59 for men and .95 for women. We reject the null hypothesis of the absence of gender difference in 100% of the trials. The gender difference observed in DellaVigna et al. (2013), may, therefore, be due to the specific assumption they made over self and other's curvature of utility.

²⁰In this sample, there is 30 men and 30 women with $\alpha_{male,DGP} = \alpha_{female,DGP} = .5$, $r_{s,female,DGP} = .9$, $r_{s,male,DGP} = .1$ and $r_{o,female,DGP} = r_{o,male,DGP} = .6$.

Appendix C Proof: Relationship between CES and CRRA functional form

In this section, we show that the CES functional form and the CRRA functional form, when $r_s = r_o$, give the same optimal allocation.

Optimal allocation with the CES utility function

We define the CES utility function as:

$$u_{ces}(s, o) = [(1 - \gamma)s^\rho + \gamma o^\rho]^{\frac{1}{\rho}}, \text{ with } \rho < 1, \gamma \in [0, 1] \quad (9)$$

The DM maximizes (9) subject to $Y = s + p \times o$

The Lagrangian is

$$\mathcal{L}_{ces}(s, o, \lambda) = u_{ces}(s, o) - \lambda(s + p * o - Y) \quad (10)$$

The first order conditions are given by,

$$\frac{\partial \mathcal{L}_{ces}(s, o, \lambda)}{\partial s} = \frac{1}{\rho}(1 - \gamma)\rho * s^{\rho-1}[(1 - \gamma)s^\rho + o^\rho]^{\frac{1-\rho}{\rho}} - \lambda = 0 \quad (11)$$

$$\frac{\partial \mathcal{L}_{ces}(s, o, \lambda)}{\partial o} = \frac{1}{\rho}\gamma * \rho * o^{\rho-1}[(1 - \gamma)s^\rho + o^\rho]^{\frac{1-\rho}{\rho}} - \lambda * p = 0 \quad (12)$$

$$\frac{\partial \mathcal{L}_{ces}(s, o, \lambda)}{\partial \lambda} = s + p * o - Y = 0 \quad (13)$$

Which gives

$$s_{ces}^* = \frac{Y}{1 + p^{\frac{\rho}{\rho-1}} \left(\frac{\gamma}{1-\gamma}\right)^{\frac{1}{1-\rho}}} \quad (14)$$

$$o_{ces}^* = \frac{Y}{p + \left(\frac{1-\gamma}{\gamma}\right)^{\frac{1}{1-\rho}} p^{\frac{1}{1-\rho}}} \quad (15)$$

Optimal allocation with the CRRA functional form

The DM maximizes the utility function

$$u_{crra}(s, o) = (1 - \alpha) * \frac{s^{(1-r)}}{(1 - r)} + \alpha * \frac{o^{(1-r)}}{(1 - r)}, \text{ with } r < 1, \alpha \in [0, 1] \quad (16)$$

subject to $Y = s + p \times o$

The Lagrangian is

$$\mathcal{L}_{crra}(s, o, \lambda) = u_{crra}(s, o) - \lambda(s + p * o - Y) \quad (17)$$

The first order conditions are given by,

$$\frac{\partial \mathcal{L}_{crra}(s, o, \lambda)}{\partial s} = (1 - \alpha)s^{-r} - \lambda = 0 \quad (18)$$

$$\frac{\partial \mathcal{L}_{crra}(s, o, \lambda)}{\partial o} = \alpha * o^{-r} - \lambda * p = 0 \quad (19)$$

$$\frac{\partial \mathcal{L}_{crra}(s, o, \lambda)}{\partial \lambda} = s + p * o - Y = 0 \quad (20)$$

Which gives

$$s_{crra}^* = \frac{Y}{1 + p^{\frac{r-1}{r}} \left(\frac{\alpha}{1-\alpha} \right)^{\frac{1}{r}}} \quad (21)$$

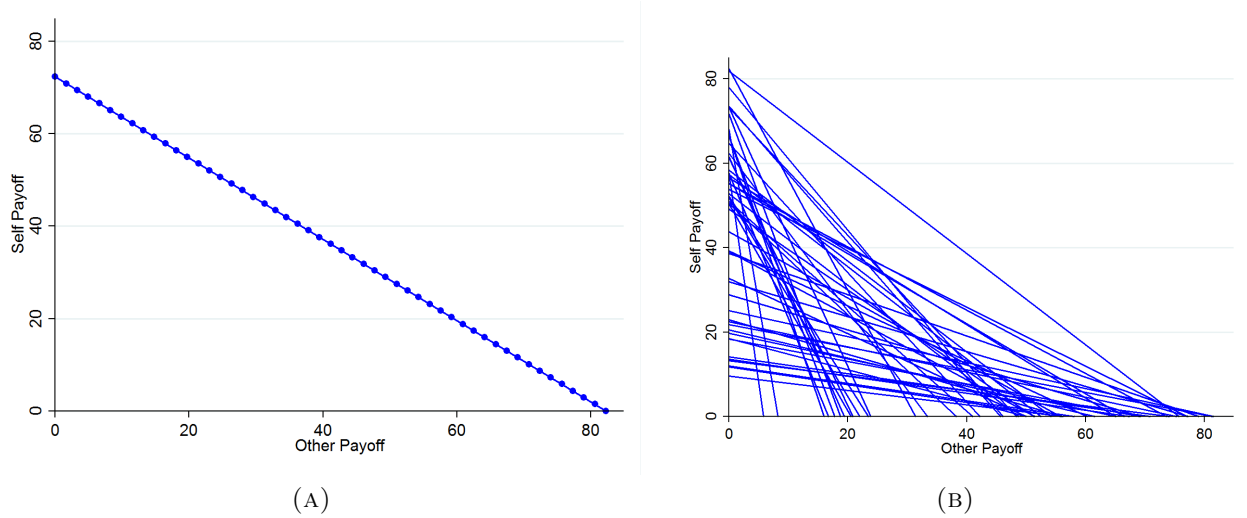
$$o_{crra}^* = \frac{Y}{p + \left(\frac{1-\alpha}{\alpha} \right)^{\frac{1}{r}} p^{\frac{1}{r}}} \quad (22)$$

Mapping between the two sets of optimal allocation

When $r = 1 - \rho$, and $\alpha = \gamma$ then $(s_{ces}^*, o_{ces}^*) = (s_{crra}^*, o_{crra}^*)$

Appendix D Budget lines

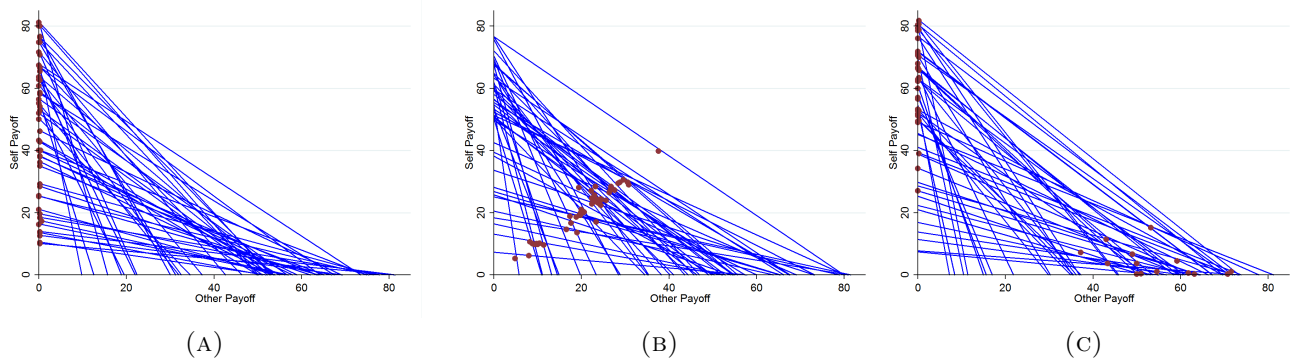
FIGURE D4: GRAPHICAL EXAMPLE OF RANDOMLY GENERATED BUDGET LINES



One randomly generated budget line and the 51 choices that the dictator has to choose among (Panel A). Graphical example of 50 randomly generated budget lines that a dictator could face (Panel B). On the x-axis payoffs for other and on the y-axis payoffs for self.

Figure D5 shows the choices made by representative subjects in FKM07 experiment. On panel A the subject exhibit selfish preference, on panel B preference for decreasing difference in payoffs, and on panel C preference for maximizing total payoff.

FIGURE D5: GRAPHICAL EXAMPLE OF CHOICES MADE BY SUBJECTS IN THE FKM07 EXPERIMENT



Selfish preference (Panel A), preference for decreasing difference in payoffs (Panel B), preference for maximizing total payoffs (Panel C). On the x-axis payoffs for other and on the y-axis payoffs for self.

Appendix E Robustness to the value of α_{DGP}

In the body of the paper, we used the value $\alpha_{DGP} = .5$ to simulate the data. Here we perform the same exercise with $\alpha_{DGP} = .25$ and $\alpha_{DGP} = .75$. Our results are robust to the choice of α_{DGP} . In this Section, we perform our simulation $K = 500$ times for each case in $(r_{s,DGP}, r_{o,DGP}) \in \{0, 0.025, \dots, 0.9\} \times \{0, 0.025, \dots, 0.9\}$.

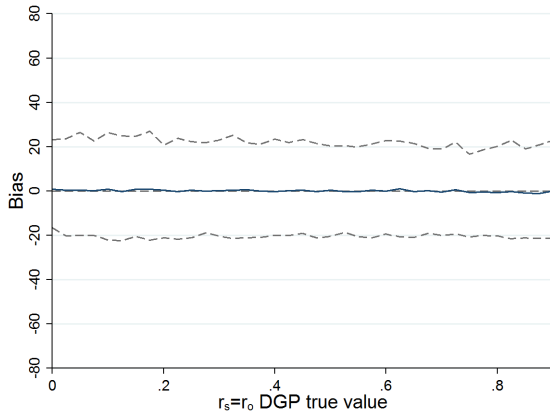
Appendix E.0.1 Unrestricted model: Allowing Different Curvatures of Utility over self and other's payoffs.

First, we reproduce the estimation made in Appendix F. We estimate the utility function:

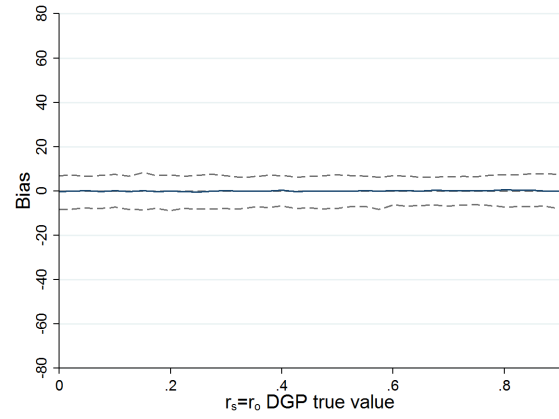
$$u(s, o) = (1 - \alpha) * \frac{s^{(1-r_s)}}{(1 - r_s)} + \alpha * \frac{o^{(1-r_o)}}{(1 - r_o)}, \text{ with } r_s, r_o < 1, \alpha \in [0, 1] \quad (23)$$

Figure E6 shows the percentage of under/overestimation of altruism $\tilde{\alpha}$ depending on the true value of $r_{s,DGP}$ and $r_{o,DGP}$. On the Left panel, the figures represent the results for $\alpha_{DGP} = .25$ and on the Right the results for $\alpha_{DGP} = .75$. In all cases, there is no bias in the estimation; we accurately retrieved the true parameters when estimating the unrestricted model.

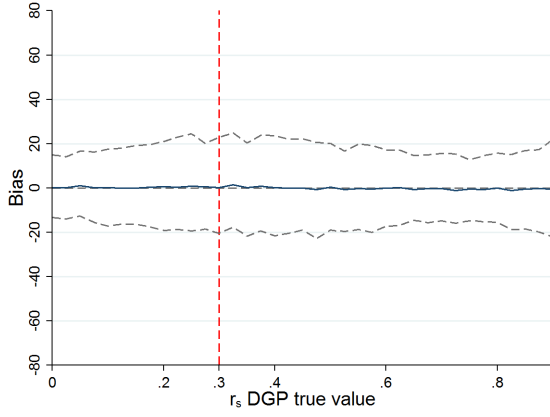
FIGURE E6: BIAS IN ESTIMATED ALTRUISM, $\tilde{\alpha}$ for $\alpha_{DGP} = .25$ (Left) and $\alpha_{DGP} = .75$ (Right)



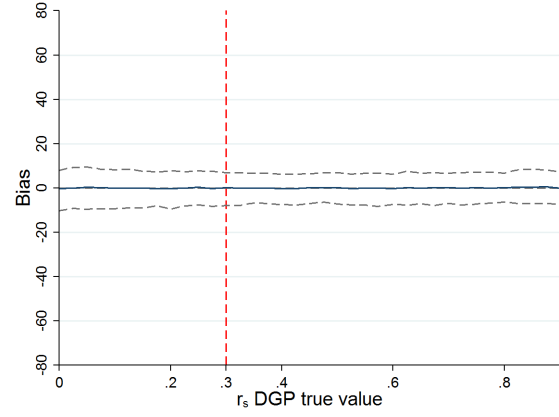
(A) $r_{o,DGP} = r_{s,DGP}$



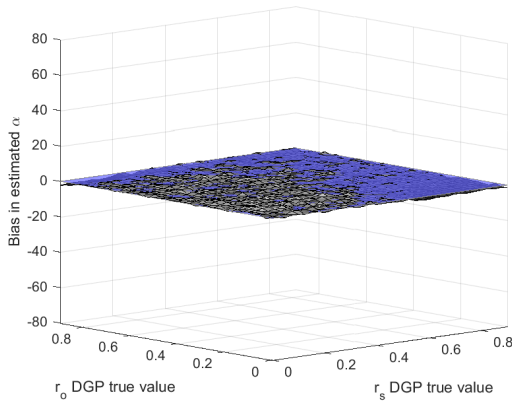
(B) $r_{o,DGP} = r_{s,DGP}$



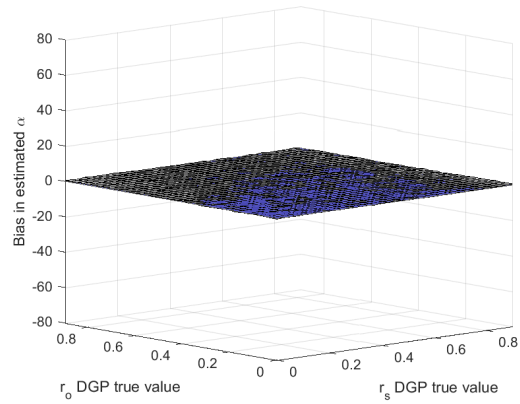
(C) $r_{o,DGP} = .3$



(D) $r_{o,DGP} = .3$



(E) 3-DIMENSIONAL



(F) 3-DIMENSIONAL

Percentage of under/over estimation of altruism $\tilde{\alpha}$ for the unrestricted model with $\alpha_{DGP} = .25$ (Left) and $\alpha_{DGP} = .75$ (Right). In Figures E6a, E6b, E6c and E6d the dash line is the corresponding 95% Monte Carlo confidence interval.

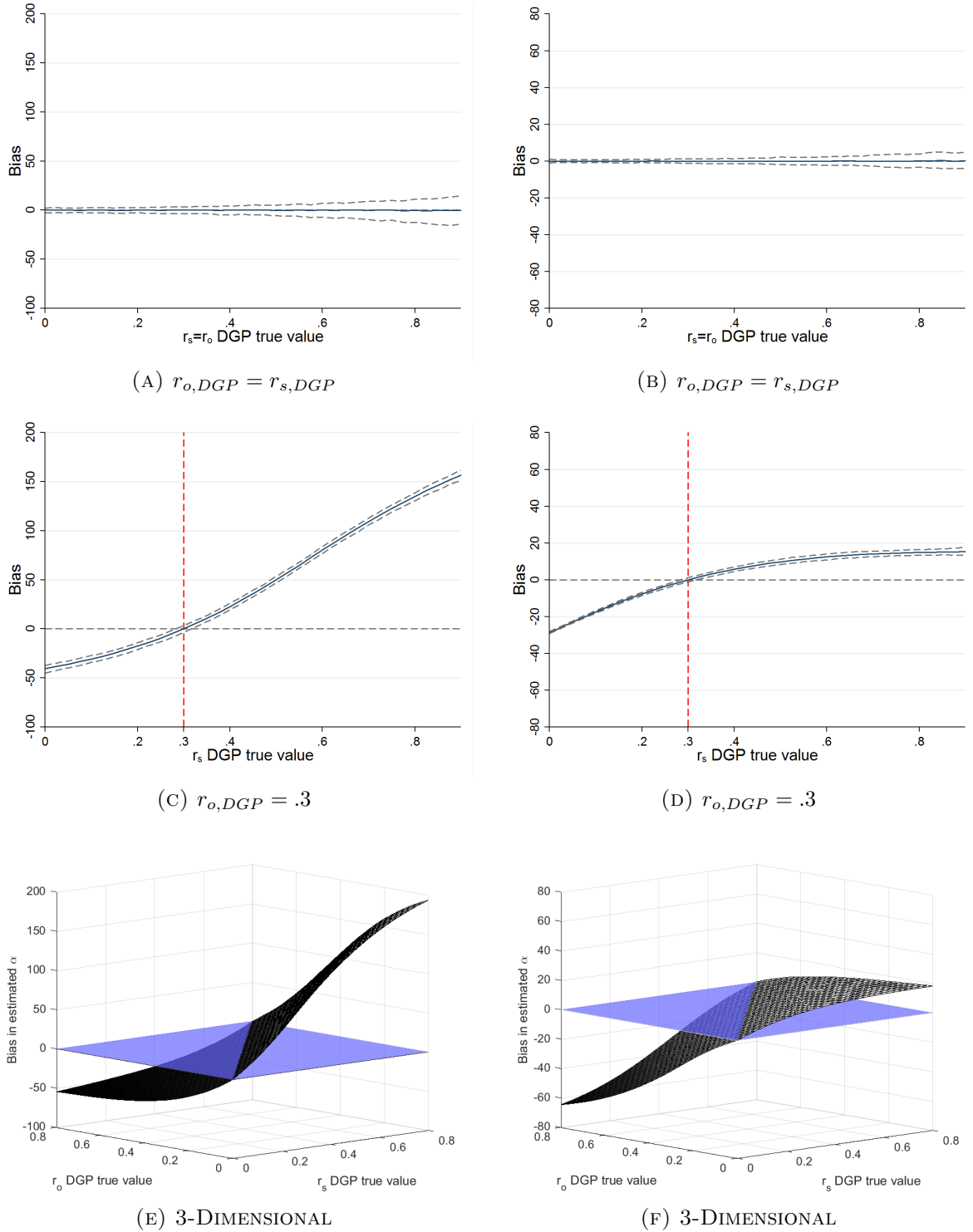
Appendix E.0.2 Assuming identical curvature over self and other's payoffs.

We now impose the restriction $r_s = r_o$ in the estimation to reproduce the estimation made in Section 3.2.1 where we used $\alpha_{DGP} = .5$. We estimate the utility function:

$$u(s, o) = (1 - \alpha) * \frac{s^{(1-r)}}{(1-r)} + \alpha * \frac{o^{(1-r)}}{(1-r)}, \text{ with } r < 1, \alpha \in [0, 1] \quad (24)$$

Figure E7 shows the results. On the Left panel $\alpha_{DGP} = .25$ and on the Right panel $\alpha_{DGP} = .75$. Our conclusions are robust to the choice of α_{DGP} ; we overestimate altruism when $r_{s,DGP} > r_{o,DGP}$, underestimate it when $r_{s,DGP} < r_{o,DGP}$ and there is no bias when $r_{s,DGP} = r_{o,DGP}$.

FIGURE E7: BIAS IN ESTIMATED ALTRUISM, $\tilde{\alpha}$ for $\alpha_{DGP} = .25$ (Left) and $\alpha_{DGP} = .75$ (Right)



Percentage of under/over estimation of altruism $\tilde{\alpha}$ when imposing the restriction $r_s = r_o$ in the estimation with $\alpha_{DGP} = .25$ (Left) and $\alpha_{DGP} = .75$ (Right). Note that the scale on the z-axis is not the same on the Left and Right panel. In Figures E7a, E7b, E7c and E7d the dash line is the corresponding 95% Monte Carlo confidence interval.

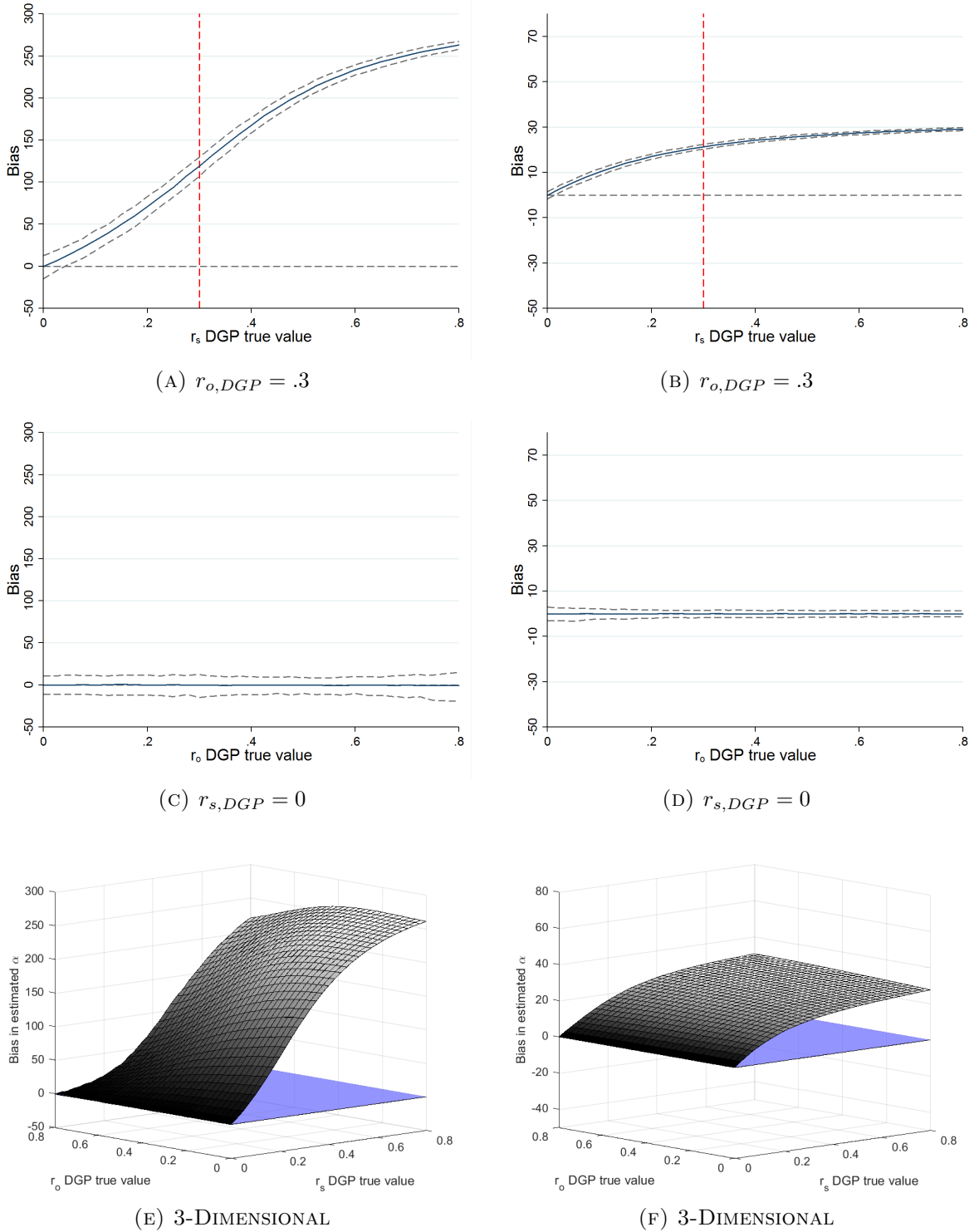
Appendix E.0.3 Assuming linear utility over self and concave utility over other's payoffs.

Finally, we test the robustness of the results presented in Appendix B. We assume linear utility over self payoffs and concave utility over other's payoffs in the estimation. In particular, we estimate the utility function:

$$u(s, o) = s + \alpha * \frac{o^{(1-r_o)}}{(1-r_o)}, \text{ with } r_o < 1, \alpha \in [0, 1] \quad (25)$$

Figure: E8 shows the results. On the Left panel $\alpha_{DGP} = .25$ and on the Right panel $\alpha_{DGP} = .75$. Our conclusions are robust to the choice of α_{DGP} ; if $r_{o,DGP} > 0$ we overestimate altruism.

FIGURE E8: BIAS IN ESTIMATED ALTRUISM, $\tilde{\alpha}$ for $\alpha_{DGP} = .25$ (Left) and $\alpha_{DGP} = .75$ (Right)



Percentage of under/over estimation of altruism $\tilde{\alpha}$ when imposing the restriction $r_s = 0$ in the estimation with $\alpha_{DGP} = .25$ (Left) and $\alpha_{DGP} = .75$ (Right). Note that the scale on the z-axis is not the same on the Left and Right panel. In Figures E8a, E8b, E8c and E8d the dash line is the corresponding 95% Monte Carlo confidence interval.

Appendix F Unrestricted model: Allowing Different Curvatures of Utility over self and other's payoffs

In this Section, we show that we are able to accurately retrieve the true parameters when estimating the model used in the DGP. We perform the same simulation as in Section 3 and re-estimate the parameter of the utility function used to generated dictators' choices.²¹ We therefore estimate the utility function:

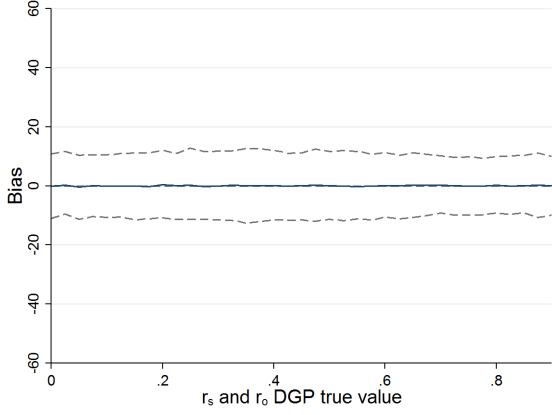
$$u(s, o) = (1 - \alpha) * \frac{s^{(1-r_s)}}{(1 - r_s)} + \alpha * \frac{o^{(1-r_o)}}{(1 - r_o)}, \text{ with } r_s, r_o < 1, \alpha \in [0, 1] \quad (26)$$

Appendix F.1 Bias

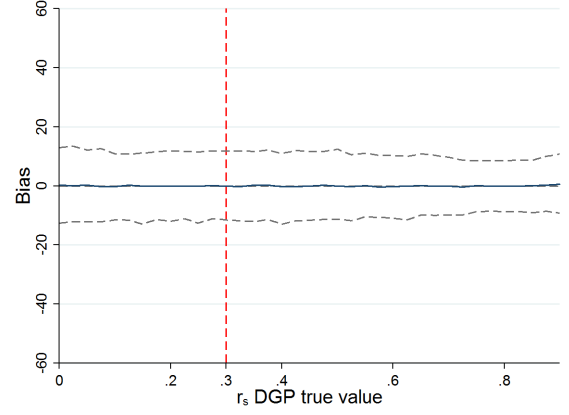
Figure F9 displays the percentage of bias in the estimated $\tilde{\alpha}$ depending on the true value of $r_{s,DGP}$ and $r_{o,DGP}$. Figure F9c allows $r_{s,DGP}$ and $r_{o,DGP}$ to vary simultaneously while Figure F9a and F9b show two-dimensional slices of Figure F9c. In Figure F9a, $r_{s,DGP} = r_{o,DGP}$ and in Figure F9b, $r_{o,DGP}$ is fixed to 0.3. In all cases, there is no bias; we accurately recover the parameter α .

²¹In this section we perform our simulation $K = 1,000$ times for each case $(r_{s,DGP}, r_{o,DGP}) \in \{0, 0.025, \dots, 0.9\} \times \{0, 0.025, \dots, 0.9\}$ instead of $K = 1,000$ times for each case $(r_{s,DGP}, r_{o,DGP}) \in \{0, 0.01, \dots, 0.9\} \times \{0, 0.01, \dots, 0.9\}$ as in Section 3. We reduce the number of cases to save computing time.

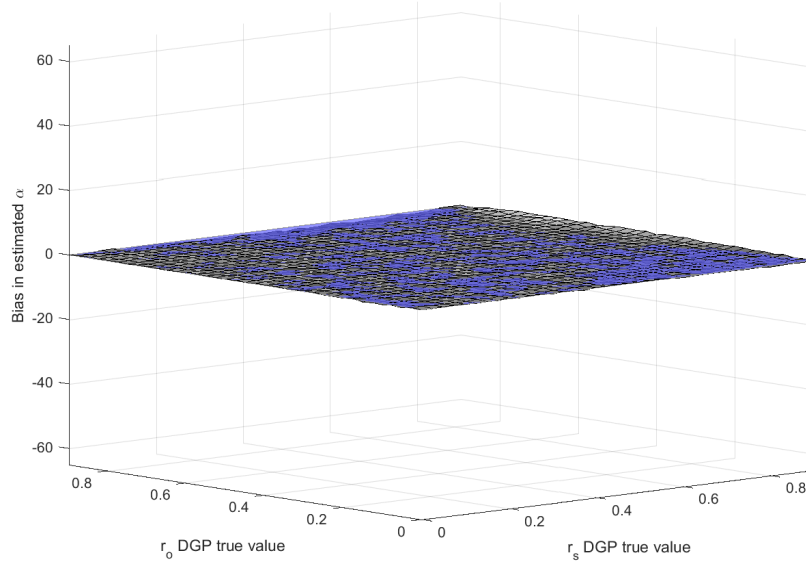
FIGURE F9: BIAS IN ESTIMATED ALTRUISM, $\tilde{\alpha}$



(A) $r_{o,DGP} = r_{s,DGP}$



(B) $r_{o,DGP} = .3$



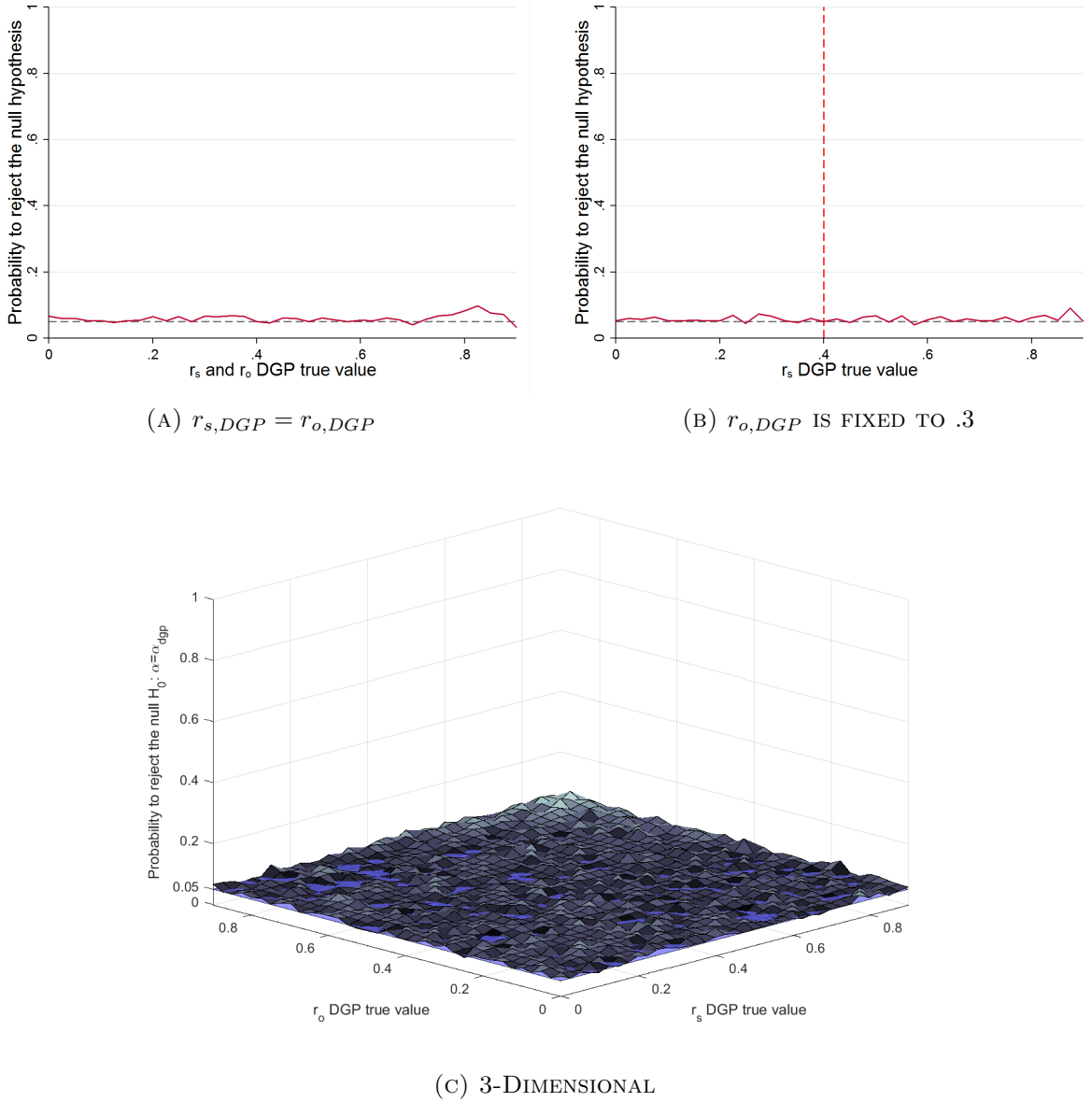
(C) 3-DIMENSIONAL

Percentage of under/over estimation of altruism $\tilde{\alpha}$ for the unrestricted model. In Figures F9b and F9a the dash line is the corresponding 95% Monte Carlo confidence interval.

Appendix F.2 Statistical Power

Figure F10 reports the probability of Type I error. We test the null hypothesis that $\tilde{\alpha}$ equals its true value ($H_0 : \tilde{\alpha} = \alpha_{DGP}$). In all cases, the test statistics is of correct size; we reject the null that $\tilde{\alpha}$ is equal to its true value in 5% of the trials at the 5% level.

FIGURE F10: POWER CALCULATIONS, TYPE I ERROR

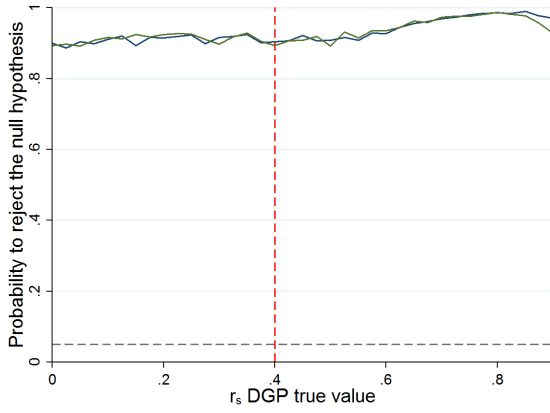


Probability to reject the null hypothesis $H_0 : \tilde{\alpha} = \alpha_{DGP}$ at the 5% level. 1,000 trials per set of parameters $(r_{s,DGP}, r_{o,DGP})$.

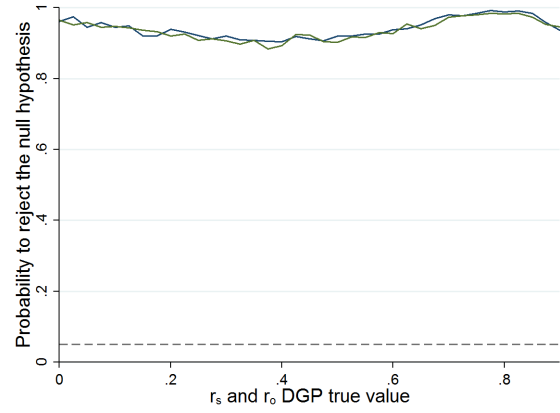
Figure F11 reports the probability of Type II error. We test two null hypotheses that $\tilde{\alpha}$ is equal to values distinct from its true value. We report the probability to reject the null $H_0 : \tilde{\alpha} = .4$ and $H_0 : \tilde{\alpha} = .6$ at the 5% level. We reject these null hypotheses in at least 85% of the trials in

all cases. We, therefore, have enough power to reject the null when false.

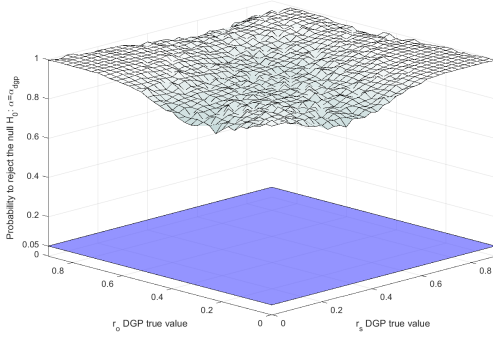
FIGURE F11: POWER CALCULATIONS, TYPE II ERROR



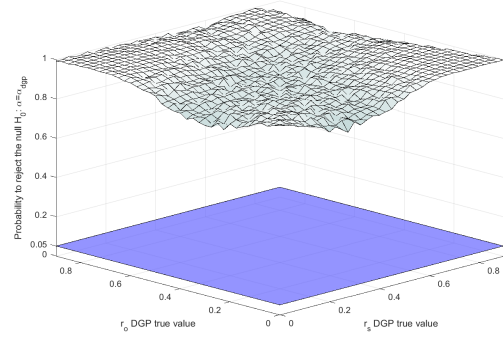
(A) $r_{o,DGP}$ IS FIXED TO .3



(B) $r_{s,DGP} = r_{o,DGP}$



(C) $H_0 : \tilde{\alpha} = .4$



(D) $H_0 : \tilde{\alpha} = .6$

Probability to reject the null hypotheses at the 5% level. In Figures F11a and F11b, $H_0 : \tilde{\alpha} = .4$ (blue) and $H_0 : \tilde{\alpha} = .6$ (green). Estimated assuming $r_s = r_o$. 1,000 trials per set of parameters $(r_{s,DGP}, r_{o,DGP})$.