

## The Relevance of Envy Freeness as Fairness Criterion

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This paper evaluates how relevant envy freeness (Foley 1967) is as an empirical concept of fairness. Several versions of an indivisible-good fair division problem are evaluated in a survey questionnaire. Participants had to determine the fairest allocations of the objects among individuals with different preferences. Each problem features two allocations that are identical in all aspects but envy freeness. Across all treatments and versions of the problem, the envy free allocation is chosen 3.5 times as frequently as the allocation with envy. However, as is shown, only some these choices are based on a conscious use of the criterion of envy freeness. The relevance of other criteria for the choice of the envy free allocation is evaluated.

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## 1. Introduction

The recent experimental literature<sup>2</sup> has suggested and tested various fairness criteria in decision problems, in particular inequality aversion (the smaller the differences between payoffs, the better the allocation). Most of these criteria are based on the assumption that individuals compare what they themselves receive to what others receive. Frequently, an unspecified notion of envy is invoked to explain such fairness criteria. That discussion, however, has so far not been connected to the well-defined notion of envy in the axiomatic and theoretical literature.<sup>3</sup> The question investigated here is whether that notion of envy plays an empirically relevant role in determining the fairness of allocations.

Foley (1967) introduced<sup>4</sup> the criterion of *envy freeness*, which, in combination with (Pareto) efficiency, is often considered the definition of fairness. An allocation is called *envy free* if every person is *envy free* meaning that nobody prefers the bundle someone else receives to his or her own bundle. Such an envy free allocation has several appealing theoretical features, among them is the fact that no interpersonal utility comparisons are required to find an envy free allocation. This notion of envy is different from the common use of the word envy – the relevant comparison here is with the objects another person receives, not with how happy another person is. The existing experimental literature generally does not permit testing for the relevance of envy freeness a la Foley because individuals are faced with monetary payoffs that are the same for everybody – in such a context unequal payoffs always imply envy (all individuals prefer the higher to the lower payoff). Envy freeness can therefore not be distinguished from inequality aversion. To test for the relevance of envy freeness, different individuals need to have different preferences over the same bundles, as is the case in the examples considered in this paper.

This paper is based on earlier work with Clemens Puppe on the role of envy-freeness in free-form bargaining experiments, see Herreiner/Puppe (2004, 2006). Our results there show that

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<sup>2</sup> See among others Fehr/Schmidt (1999), Bolton/Ockenfels (2000), Charness/Rabin (2002), Engelmann/Strobel (2004), Bereby-Meyer/Niederle (2003), and also earlier work by for instance Güth/Schmittberger/Schwarze (1982) and Kirchsteiger (1994). Bar-Hillel/Yaari (1984, 1993) investigates how different aspects, for instance need or taste, influence the choice of allocations in division problems. Their work is also one of very few where individuals have different preference rankings over bundles like the example investigated in this project here and in my earlier joint work with Clemens Puppe, such as Herreiner/Puppe (2004, 2006, 2007). The specific numeric examples used in Bar-Hillel/Yaari (1984), though, do not allow for an evaluation of envy-freeness as fairness criterion.

<sup>3</sup> See Brams/Taylor (1996), Thomson (2003), and Moulin (2003) for an overview.

<sup>4</sup> See also Tinbergen (1953).

other criteria, like inequality aversion, dominate envy-freeness. We also present some evidence for the relevance of envy-freeness if other criteria do not discriminate between different allocations. Here, I follow up on that evidence by investigating different variations of a fair division problem where several indivisible objects have to be allocated among different individuals in the fairest manner. The relevant feature of all situations considered here is that there are two focal allocations that are indistinguishable except for the fact that one is envy-free whereas the other is not. The relevance of envy-freeness can thus be evaluated without interference by any other criteria. Nevertheless, the effect of other criteria on the choice of an envy free allocation can be evaluated based on the differences between the focal allocations in the different situations considered.

The situations considered in this paper were presented in a questionnaire in which participants had to assume the role of an independent arbiter whose task it was to pick the fairest allocation for each problem. Participants were instructed to act as impartial judges who had to identify the allocation they considered to be the fairest. [discuss questionnaire method Gaertner, Gaertner/Jungeilges, Konow]

## 2. Survey

The survey was conducted with undergraduate students at Loyola Marymount University in March, April, November, and December 2006. The participants were drawn from subject pools in the Economics and Psychology Departments to which most introductory classes contribute – in those classes students are required to participate in research activities for class credit. A total of 347 individuals participated making 2776 unconstrained choices (sheet 1 and 3, see below) yielding 2660 valid observations, and 1388 constrained choices (sheet 2, see below) yielding 1345 valid observations.

Seven different treatments of the survey were run (on different colored paper) with 10 different situations of a fair division problem with 5 indivisible object and 3 individuals. The first three treatments (pink, green, white) presented the same 4 situations. The next two treatments (yellow, orange) relied on 2 situations from the first three treatments and included two additional situations. The last two treatments (blue, salmon) presented four new situations. Each set of

treatments presented the same situations in the same order but in different permutations of the situations' payoff matrices (for details see the appendix).<sup>5</sup>

The following ten situations shown on the left were considered:

#### Situation 1

	A	B	C	D	E	#	Allocation	Payoffs	PO	EF	U	%
<b>I</b>	40	2	3	25	30	<b>139</b>	A,BD,CE	40,52,52	x	x	-4	37
<b>II</b>	14	26	8	26	26	269	A,DE,BC	40,52,52	x	-15	-4	15
<b>III</b>	10	26	26	12	26	(282)	Ratio: 2.48					

#### Situation 2

	A	B	C	D	E	#	Allocation	Payoffs	PO	EF	U	%
<b>I</b>	48	1	2	23	26	<b>167</b>	A,BD,CE	48,48,48	x	x	-2	56
<b>II</b>	18	24	10	24	24	369	A,DE,BC	48,48,48	x	-1	-2	16
<b>III</b>	12	24	24	16	24	(386)	Ratio: 4.17					

#### Situation 3

	A	B	C	D	E	#	Allocation	Payoffs	PO	EF	U	%
<b>I</b>	44	4	6	22	24	<b>276</b>	A,BD,CE	44,44,44	x	x	-2	59
<b>II</b>	20	22	14	22	22	369	A,DE,BC	44,44,44	x	-2	-2	16
<b>III</b>	16	22	22	18	22	(386)	Ratio: 3.53					

#### Situation 4

	A	B	C	D	E	#	Allocation	Payoffs	PO	EF	U	%
<b>I</b>	48	1	2	21	28	<b>165</b>	A,BD,CE	48,42,42	x	x	-7	47
<b>II</b>	20	21	17	21	21	272	A,DE,BC	48,42,42	x	-1	-7	14
<b>III</b>	18	21	21	19	21	(282)	Ratio: 3.85					

#### Situation 5

	A	B	C	D	E	#	Allocation	Payoffs	PO	EF	U	%
<b>I</b>	40	5	10	23	22	<b>62</b>	A,BD,CE	40,52,52	x	x	x	52
<b>II</b>	14	26	8	26	26	97	A,DE,BC	40,52,52	x	-5	x	12
<b>III</b>	10	26	26	12	26	(104)	Ratio: 3.60					

#### Situation 6

	A	B	C	D	E	#	Allocation	Payoffs	PO	EF	U	%
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<sup>5</sup> Due to the different permutations, situations were usually not presented in the order shown here. In particular, depending on the permutation the qualitatively same allocation was based on different combinations of bundles.

<b>I</b>	44	4	5	24	23	<b>63</b> 97 (104)
<b>II</b>	12	24	16	24	24	
<b>III</b>	10	24	24	18	24	

A,BD,CE	44,48,48	x	x	x	52
A,DE,BC	44,48,48	x	-3	x	13
Ratio: 3.34					

## Situation 7

	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>	#
<b>I</b>	40	3	5	25	27	<b>160</b>
<b>II</b>	14	26	8	26	26	297
<b>III</b>	10	26	26	12	26	(308)

Allocation	Payoffs	PO	EF	U	%
A,BD,CE	40,52,52	x	x	-1	43
A,DE,BC	40,52,52	x	-12	-1	11
Ratio: 4.00					

## Situation 8

	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>	#
<b>I</b>	44	1	2	27	26	<b>168</b>
<b>II</b>	12	24	16	24	24	294
<b>III</b>	10	24	24	18	24	(308)

Allocation	Payoffs	PO	EF	U	%
A,BD,CE	44,48,48	x	x	-5	48
A,DE,BC	44,48,48	x	-9	-5	9
Ratio: 5.46					

## Situation 9

	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>	#
<b>I</b>	44	3	2	25	26	<b>204</b>
<b>II</b>	20	22	14	22	22	302
<b>III</b>	16	22	22	18	22	(308)

Allocation	Payoffs	PO	EF	U	%
A,BD,CE	44,44,44	x	x	-7	53
A,DE,BC	44,44,44	x	-7	-7	15
Ratio: 3.64					

## Situation 10

	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>	#
<b>I</b>	46	1	2	23	28	<b>197</b>
<b>II</b>	20	21	17	21	21	294
<b>III</b>	18	21	21	19	21	(308)

Allocation	Payoffs	PO	EF	U	%
A,BD,CE	46,42,42	x	x	-9	50
A,DE,BC	46,42,42	x	-5	-9	17
Ratio: 3.02					

The right side indicates the focal allocations and an overview of the results. The bold number under “#” indicates for each situation how many times the two focal allocations were chosen. The total number of valid observations for each situation is indicated next; the number in brackets shows the total number of times this situation was presented as an unconstrained choice (sheet 1 and 3). The tables on the right show the two allocations, the frequency of their choice, and their basic characteristics: payoff vector, PO = Pareto Optimality, EF = Envy Freeness, U = Utilitarian, i.e. the maximal payoff sum. An “x” indicates that the criterion holds and a negative number indicates the extent of the shortfall of that criterion. In all situations with envy, it was experienced by the first person because person II’s bundle DE is worth more to person I than

good A. The ratio shown at the bottom of each situation's result table on the right indicates how much more frequently the envy free allocation was chosen than the other focal allocation.

Each participant was given a letter upon arrival as participant identifier and a one-page instruction explaining the survey (see appendix). The instructions explained the basic set-up and presentation of the problem with an example. Participants were instructed that their task would be to identify the fairest allocation in five-good, three-person indivisible allocation problems. They had to imagine themselves in the role of an independent arbiter who was approached by the individuals involved in the allocation problem because they want an impartial person to determine a fair allocation.

Having read the instructions, participants were given the opportunity to ask questions and then received the first answer sheet with the four situations. Each situation was presented in a table analogous to the ones shown above (depending on the treatment in different permutations of the versions shown here), followed by a two-row table where participants had to indicate the allocation they chose (by objects given to I, to II, and to III), and several lines for an explanation. To keep situations as separate as possible, two problems were presented on the front page, two on the back of each sheet; on each side one problem was upside down (see appendix). Participants were also instructed to consider the problems as independent of each other and to work on them subsequently.

Once the first sheet was completed, students returned that sheet, got the instructions for the second sheet (see appendix) and the second sheet. On the second sheet the same four problems were presented in the same order and layout. Instead of a table to indicate their allocation choices, the second sheet had a two-row table where candidates could choose one of the two allocations shown above. Participants were told that the three individuals faced with the allocation problem had identified these two allocations as the relevant ones relying on the independent arbiter to pick one of the two.

Upon completion the second sheet was returned to the organizer along with its instructions, and a third sheet was handed to the students with one more page of instructions (see appendix). The third sheet had the same four problems as the earlier two and had the same layout as sheet one. At the top of the front page of sheet the participants were asked to respond to the question "What do you think about this criterion of envy-freeness? Is it relevant for fairness?" In the instructions

to sheet 3 envy freeness was defined and applied to the example situation from the initial instructions. Participants were then instructed to reconsider the problems and to choose the fairest allocation (which could be the same or different from earlier choices).

Participants never had more than one sheet at any given time. They worked on the sheets in the order in which they were handed out. Participants' sheets were matched once they had completed all three sheets based on the letter id they had been assigned at the beginning.

### 3. The Role of Envy Freeness based on Sheets 1 and 3

Sheets 1 and 3 gave participants free reign in choosing the allocation they considered to be the fairest. Sheet 2 forced participants to choose among the two focal allocations – the results from that sheet will be discussed later. Sheet 1 and sheet 3 presented the same problems in the same order and same permutation. The three most important differences between sheet 1 and 3 are

- the experience participants gained by having worked on similar and the same problems,
- the presentation of the two focal allocations on sheet 2, and
- the introduction of envy freeness as a fairness criterion.

Participants were instructed to consider all problems as independent and to choose allocations based only on what they considered to be the fairest irrespective of what they may have chosen earlier. Nevertheless, sheets 1 and sheets 3 obviously presented very different and related decision environments, an aspect that will be discussed shortly.

First, the following table clearly shows the main result: No matter what the exact treatment, the envy free allocation is chosen significantly more frequently than the allocation with envy:

		Payoffs	U <sup>6</sup>	E <sup>7</sup>	%EF	% –EF	P-Value	#
Sheet 1	<b>S1</b>	<b>40,52,52</b>	<b>-4</b>	<b>15</b>	<b>30</b>	<b>14</b>	<b>0.004321</b>	<b>134</b>
	S2	48,48,48	-2	1	51	14	0.000000	182
	S3	44,44,44	-2	2	48	19	0.000001	183
	S4	48,42,42	-7	1	39	14	0.000038	135
	<b>S5</b>	<b>40,52,52</b>	<b>0</b>	<b>5</b>	<b>44</b>	<b>15</b>	<b>0.006270</b>	<b>48</b>
	S6	44,48,48	0	3	48	10	0.000273	50
	<b>S7</b>	<b>40,52,52</b>	<b>-1</b>	<b>12</b>	<b>29</b>	<b>13</b>	<b>0.001845</b>	<b>150</b>
	S8	44,48,48	-5	9	38	8	0.000000	146
	S9	44,44,44	-7	7	42	16	0.000012	151
	S10	46,42,42	-9	5	42	16	0.000025	148

<sup>6</sup> “U” indicates the shortfall from the maximal payoff sum.

<sup>7</sup> “E” indicates the amount of envy person I experiences in the allocation that carries envy.

	Average				41	14	0.000000	1327
Sheet 3	S1	40,52,52	-4	15	44	16	0.000013	135
	S2	48,48,48	-2	1	62	18	0.000000	187
	S3	44,44,44	-2	2	69	14	0.000000	186
	S4	48,42,42	-7	1	54	14	0.000000	137
	S5	40,52,52	0	5	59	10	0.000019	49
	S6	44,48,48	0	3	55	17	0.001468	47
	S7	40,52,52	-1	12	57	8	0.000000	147
	S8	44,48,48	-5	9	58	9	0.000000	148
	S9	44,44,44	-7	7	64	13	0.000000	151
	S10	46,42,42	-9	5	59	17	0.000000	146
	Average				48	11	0.000000	1333
Average				50	14	0.000000	2660	

This table shows for each sheet and situation how frequently the two focal allocations were chosen: “%EF” indicates the share of choices of the envy free focal allocation and “% –EF” shows how frequently the focal allocation with envy was chosen. As the  $p$ -values (binomial tests) indicate, the envy free allocation was chosen significantly more frequently in all cases. The bold entries in the table above indicate the first tasks that were presented to participants in the respective three sets of treatments (S1, S5, and S7). These are the only truly independent observations.<sup>8</sup> Also here the envy free allocation was chosen significantly more frequently. Although the three situations have different characteristics, choice behavior among the two focal allocations for these three situations is not significantly different ( $p$ -value=0.7798,  $\chi^2$  test), with the envy free allocation being chosen 2.28 times as frequently on average as the other focal allocation.

On sheet 1, on average the envy free allocation is chosen 2.88 as frequently as the other allocation. For sheet 3 that ratio is 4.29. Overall, that averages to the envy free allocation being chosen 3.56 as frequently as the allocation with envy. All other allocations were chosen in less than 10% of the cases – see appendix D for more details.

Based on the above results, it is obvious that overall participants pick the envy free allocation significantly more frequently on sheet 3 than on sheet 1 ( $p$ -value=0.0005,  $\chi^2$ -test). The increase in choices of the envy free allocations is mostly due to more frequent switches from other allocations to the envy free allocation than to the other focal allocation, and to a lesser extent due

<sup>8</sup> As far as observable, participants followed the instructions of working on the problems in sequence.

to participants switching between the two focal allocations. As columns 5, 6, and 7 (binomial tests) in the table below show, there is an overall significant difference in switching behavior between the two focal allocations, however, the results are weaker on the basis of each situation. Columns 8, 9, and 10 (binomial tests) indicate that there are significant differences in switching behavior from other allocations towards the two focal allocations, both at the situation and the aggregate level.<sup>9</sup> When switching to one of the two focal allocations, participants switch more frequently to the envy free allocation than to the other allocation.<sup>10</sup>

	Payoffs	U	E	$\neg$ EF $\Rightarrow$ EF	EF $\Rightarrow$ $\neg$ EF	P-Value	other $\Rightarrow$ EF	other $\Rightarrow$ $\neg$ EF	P-Value
S1	40,52,52	-4	15	8	7	0.5000	24	9	0.0068
S2	48,48,48	-2	1	(18)	(20)	(0.6864)	31	7	0.0001
S3	44,44,44	-2	2	27	12	0.0119	30	10	0.0011
S4	48,42,42	-7	1	11	8	0.3238	25	9	0.0045
S5	40,52,52	0	5	5	3	0.3633	10	0	0.0010
S6	44,48,48	0	3	3	3	0.6563	8	4	0.1938
S7	40,52,52	-1	12	12	1	0.0017	38	7	0.0000
S8	44,48,48	-5	9	8	5	0.2905	36	7	0.0000
S9	44,44,44	-7	7	16	6	0.0262	27	7	0.0004
S10	46,42,42	-9	5	18	7	0.0216	22	11	0.0401
Total				126	72	0.0001	251	71	0.0000

When focusing only on the consistent choices on sheets 1 and 3, i.e. the situations where individuals chose the same allocation on both sheets, the results are even starker. A total of 72% of individuals made some consistent choice with a total of 508 pairs of consistent choices.<sup>11</sup> 391 of these consistent choices are of the envy free allocation and 38 are the other focal allocation – a significant difference ( $p$ -value=0.0000 in a binomial test). The consistent choices of the envy free allocation account for 59% of its total choices, whereas the consistent choices of the other focal allocation account for only 20% of total choices. Not only is the envy free allocation chosen significantly more frequently, but also consistently so.

[related to understanding envy freeness?]

<sup>9</sup> Columns 8 and 9 show in how many cases individuals switched from any other valid allocation on sheet 1 to either of the two focal allocations in the corresponding situation on sheet 3. The results are comparable when considering allocation switches from all other valid *and invalid* allocations on sheet 1.

<sup>10</sup> When considering switches from all allocations and invalid choices to one of the two focal allocations, the result is again significant based on a  $\chi^2$ -test with a  $p$ -value of 0.0026.

<sup>11</sup> 22% made one consistent choice, 25% two, 18% three, and 6% four consistent choices.

[how frequently used as argument?]

#### 4. The Role of Envy Freeness based on Sheet 2

Results on sheet 2 do not allow a straightforward test of comparison between the two focal allocations as expected. Most participants recognize that the two allocations yield the same payoffs in all four situations and therefore choose one of the two (or both) allocations in different irrelevant ways, like switching back and forth, or always picking the first or second.<sup>12</sup> This reinforces a point already made by Herreiner/Puppe (2004), when attention is focused on payoff differences, then other criteria lose importance. Here, most participants do not look past the (same) payoffs individuals receive in both allocations. However, a closer inspection of the explanations provided shows that some participants come up with relevant aspects.

Approximately 10% [get exact number] rely on the order of the objects to decide which allocation to pick, either focusing on the visual pattern that is manifest in the matrix, or on the sound/combination of letters in bundles or the whole allocation. Although, this clearly has no direct relevance for the choice of the envy free allocation<sup>13</sup>, it makes clear that neutral framing aspects do have an influence on choice behavior. Overall, these “aesthetic” aspects prove to be neutral in terms of the two focal allocations – it favors neither [exact numbers, significance]. More interestingly, over 10% of participants [get exact number] provide explanations that imply choosing the envy free allocation, although, but for very few cases [number], the argument is not directly based on envy freeness. Participants notice that some goods have higher “average values”, “group values”, or are “more competitive” or “more valuable”, i.e. the sum of valuations for some goods are larger than others. Based on this “metric”, these goods are considered “more valuable”, as if the true value of a good is a combination of one’s own values and the values attributed by others.<sup>14</sup> Such considerations, obviously, void one of the main arguments in favor of envy freeness, namely that no interpersonal utility comparisons are required – augmenting one individual’s valuations by other individuals’ values requires such comparison. Nevertheless, the underlying reasoning is exactly the same as the one used by envy freeness. The goods are “more valuable” because person I assigns high value causing person I to be envious if the goods are

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<sup>12</sup> Overall, x% of the decisions are based on wrong calculations.

<sup>13</sup> The order in which the two allocations were presented on sheet 2 was treatment-dependent: [...]

<sup>14</sup> One individual goes as far as considering the resale market value of an object ... [find quote]

jointly assigned to the same person. In all 10 situations there were 2 goods that were “more valuable”, D and E, and 2 goods that were “less valuable”, B and C. Participants following this line of reasoning then decided to allocate one of each to individuals II and III, thereby splitting bundle D and E and thus avoiding envy.

## 5. Reactions, Evaluations and Applications of Envy Freeness by Participants

A very preliminary analysis of the participants’ thoughts about envy freeness yields some interesting aspects. The majority of the students (64%) [include S7-S10] states that envy freeness matters.

Among those rejecting envy freeness as a relevant criterion, several students reject the counterfactual notion of envy freeness. Some argue that allowing to consider swapping bundles, would open the door to consider as reference points also getting other, larger bundles, or even everything. Considering other individuals’ bundles seems to be no more obvious or justified than considering any arbitrary bundle to compare the actual bundle with.

### Quotes

“No. It is a means of having individuals accept a justifiable reason for not getting their choices met, as they might have liked them to be. [... It] neutralizes 'the envy' to a point, but does not eliminate the desire created by envy.”

“I think it plays a small factor, but it isn’t too good, because you’ll always be thinking ‘what if I got ...’ and so there will always be a chance of being envious.”

“Envy freeness is relevant for fairness because if nobody cared what they received (hence were not envious), then there would be no point in a distribution process.”

[...]

## 6. Relevance of Other Criteria for Choice of Envy Free Allocation

To assess the relevance of other fairness criteria for the choice of the envy free or its matching allocation with envy, several regressions were run based on the allocation choices yielding one of these two allocations. 1701 such choices were observed among 314 individuals (see the appendix for details). No relevant differences were observed between linear probability models, probits, and logits – the analysis here focuses on regular probits and random-effect probits over the cross-section of individuals for the 8 rounds in which they made unconstrained choices (rounds 1–4, and 9–12).<sup>15</sup> The dependent variable “Alloc” being one indicates that the envy free allocation is chosen; the following independent variables were considered:<sup>16</sup>

- Envy - envy person I experiences relative to person II’s bundle
- Envysq - person I’s envy squared
- Sum - sum of all three individuals’ payoffs
- Util - shortfall of the utilitarian allocation
- Utilsq - Util squared
- Inequ - difference between smallest and largest payoff
- Inequsq - Inequ squared
- Round x - Dummy for round x
- After - Dummy for rounds 9–12, after introduction of envy freeness
- Situation x - Dummy for situation x
- Version x - Dummy for version x

	Probit Estimation	Probit Marginal Effects	RE Probit <sup>17</sup> Estimation	RE Probit <sup>18</sup> Marginal Effects
Envy	3.6829*** (0.4789)	0.9091*** (0.0951)	3.8622*** (0.5185)	0.9218*** (0.0982)
Envysq	-0.2132*** (0.0275)	-0.0526*** (0.0054)	-0.2236*** (0.0298)	-0.0533*** (0.0056)
Sum	0.0035 (0.0260)	0.0009 (0.0064)	0.0007 (0.0291)	0.0002 (0.0067)
Util	-2.8645*** (-0.3705)	-0.7071*** (0.0778)	-3.0035*** (0.4209)	-0.7169*** (0.0803)
Utilsq	-0.3705*** (0.0526)	-0.0915*** (0.0105)	-0.3890*** (0.0569)	-0.0929*** (-0.0109)
Inequ	2.3306***	0.5753***	2.4419***	0.5829***

<sup>15</sup> Here  $\rho=0.05387$ : the unobserved random effect plays a minor, although significant role ( $\chi^2$ -based p-value=0.043).

<sup>16</sup> Round and situation variables that are not listed were dropped due to collinearity.

<sup>17</sup> Refitting the model using a quadrature check shows that the log-likelihood approximation is robust – variations are of order  $10^{-7}$  or smaller.

<sup>18</sup> Calculated at the mean of the independent variables – see appendix for numbers.

	(0.3093)	(0.0620)	(0.3336)	(0.0639)
Ineqsq	-0.0838*** (0.0120)	-0.0207*** (0.0025)	-0.0877*** (0.0128)	-0.0209*** (0.0025)
Round 2	0.3650* (0.2048)	0.0777* (0.0370)	0.3802* (0.2097)	0.0774** (0.0357)
Round 3	12.0193*** (1.4444)	0.6829*** (0.0525)	12.5840*** (1.5635)	0.6951*** (0.0558)
Round 4	12.6155*** (1.5146)	0.6662*** (0.0517)	13.2126*** (1.6396)	0.6781*** (0.0550)
Round 11	11.9277*** (1.4412)	0.8120*** (0.0530)	12.4933*** (1.5600)	0.8264*** (0.0544)
Round 12	11.9185*** (1.5105)	0.7651*** (0.0575)	12.4958*** (1.6345)	0.7798*** (0.0598)
After	0.4162*** (0.1489)	0.1055*** (0.0390)	0.4371*** (0.1524)	0.1075*** (0.0388)
Situation 2	21.0614*** (2.7906)	0.9900*** (0.0109)	22.0782*** (3.0186)	0.9929*** (0.0087)
Situation 3	6.2710*** (0.6581)	0.5150*** (0.0344)	6.5406*** (0.7064)	0.5190*** (0.0370)
Situation 7	-2.9159*** (0.4516)	-0.8468*** (0.0512)	-3.0627*** (0.4852)	-0.8644*** (0.0481)
Version 1	0.3545*** (0.1212)	0.0798*** (0.0259)	0.3587*** (0.1243)	0.0778*** (0.0257)
Version 2	0.0775 (0.1330)	0.0188 (0.0318)	0.0783 (0.1360)	0.0183 (0.0315)
Version 3	-0.1846 (0.1547)	-0.0475 (0.0407)	-0.1935 (0.1597)	-0.0483 (0.0408)
Constant	-29.0261		-29.9965	
# Obs	1701	1701	1701	1701
# Groups			314	314
<i>p-value</i> <sup>19</sup>	0.0000	0.0000	0.0000	0.0000
Obs Probability		0.7807		0.7807
Pred Probability		0.8354		0.8446 <sup>20</sup>
Log-Likelihood	-845.02	-845.02	-843.54	-843.54
Pseudo R-squared	0.0556	0.0556		

\*\*\* Significant at 1%, \*\* at 5%, and \* at 10% levels. Standard errors are in parentheses.

The amount of envy turns out to be one of the most important determinants of the choice of the envy free allocation. At the average envy of 5.62 a small increase in the amount of envy, keeping all other variables constant, increases the probability of the envy free allocation being chosen by more than 90%. The shortfall from the utilitarian allocation contributes significantly to the choice of the envy free allocation – a small decrease in the shortfall at the average of -4.11 increases the probability of the envy free allocation being chosen by approximately 70%. Lastly, also the extent of payoff inequality matters – a small increase in inequality at the average of 4.11 raises the probability of the envy free allocation being chosen by over 50%.

<sup>19</sup> The *p*-value is against the null-hypothesis of all variables being zero ( $\chi^2$ ).

<sup>20</sup> Probability for the envy-free allocation to be chosen, assuming that the random effect is zero.

The effect of envy on the choice probability for the envy free allocation has an obvious interpretation – the less attractive the other allocation on envy grounds, the more likely the envy free allocation is chosen. Interpreting the effect of the other two criteria is less straightforward – why would the envy free allocation be chosen more frequently if the two otherwise identical allocations become less attractive from an inequality and utilitarian point of view? It seems that the less attractive these allocations the more the criterion of envy freeness makes one of the two allocations stand out favoring its choice.

For all three, envy, the shortfall of the utilitarian payoff sum, and payoff inequality, their effect on the probability of choosing the envy free allocation levels off the larger the variable. [discuss sign of linear vs nonlinear part] The payoff sum turns out to have only a very small and insignificant effect – the 95% confidence interval is so large that not even the sign of the payoff sum’s effect can be determined.<sup>21</sup>

As the estimates for the round parameters show, what has been apparent already earlier, the later the round, i.e. the more experience the participants have with the allocation problems, the more likely the choice of the envy free allocation among the two focal allocations – the marginal effect is quite substantial for all later rounds. Moreover, as also seen earlier, there is a significant difference in choice behavior between the early rounds before envy freeness was introduced and the later rounds when envy freeness had been introduced and attention had been focused on the two relevant allocations.

Based on the low pseudo R-squared values, it is clear that the regressions here explain choice behavior only to some extent. Nevertheless, the explanatory variables are significant individually and jointly in explaining choice behavior. Given that situation and version variables are significant and have a noticeable impact on the choice probabilities suggests that other aspects of the allocation problems do matter for choice behavior, although no clear pattern can be established between the order of goods and individuals in the matrix and allocation choices.

[does sheet 2 matter?]

## 7. Conclusion

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<sup>21</sup> Including sum as a dependent variable or not does not change estimates significantly – a nested model log-likelihood ratio test yields a  $p$ -value of 0.9797. Aspects of “Sum” are captured by the other three non-dichotomous variables – correlation coefficients with “Util”, “Envy” and “Inequ” are 0.5467, 0.4194, and 0.3864 respectively.

XXX

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## APPENDIX

## A) Treatments and Number of Observations

Version 0	Original, as shown in text.
Version 1	Columns A and B, and columns C and D are exchanged.
Version 2	Columns A and D, and rows I and II are exchanged.
Version 3	Columns A and E, and rows I and III are exchanged.

## Number of Observations

The numbers in brackets at the top of the table indicate the total number of questionnaires for each treatment (color), whereas the numbers in the table indicate the valid observations per scenario. The situation numbers “S1”, “S2”, etc., refer to the situations described in the text. The version number refers to the version described above (V0, V1, ...). The task number refers to the problems presented in each treatment – each of the three sheets showed the same four problems (numbered Situation 1 through 4 on each sheet, irrespective of treatment); they are numbered sequentially as tasks here, 1 through 12 (= 3 sheets \* 4 situations).

Sheet	Task	Pink (47)	Green (47)	White (47)	Yellow (26)	Orange (26)	Blue (75)	Salmon (79)	Total (347)
Situation		S1	S1	S1	S5	S5	S7	S7	
Version		V0	V1	V0	V0	V1	V0	V1	
1	1	45	44	45	23	25	73	77	332
2	5	47	44	46	26	26	75	77	341
3	9	45	46	44	25	24	72	75	331
Situation		S2	S2	S2	S2	S2	S8	S8	
Version		V1	V2	V3	V1	V2	V1	V2	
1	2	45	44	44	24	25	72	74	328
2	6	47	40	45	26	25	75	77	335
3	10	46	45	46	25	25	73	75	335
Situation		S3	S3	S3	S6	S6	S9	S9	
Version		V2	V0	V1	V2	V0	V3	V0	
1	3	45	45	44	25	25	73	78	335
2	7	45	41	44	26	25	75	76	332
3	11	45	46	46	23	24	74	77	335
Situation		S4	S4	S4	S3	S3	S10	S10	
Version		V3	V3	V2	V3	V3	V2	V3	
1	4	45	46	44	23	26	71	77	332
2	8	46	44	46	26	25	75	75	337
3	12	46	47	44	24	25	72	74	332
Total		547	532	538	296	300	880	912	4005

## B) Regression Data – Descriptive Statistics

Variable	Mean	Std Dev	Min	Max	Count	Cum %
Alloc	0.7807	0.4138	0	1	1701	
Envy	5.6208	4.4291	1	15	1701	
Envysq	51.1987	67.1504	1	225	1701	
Sum	138.0482	5.7423	130	144	1701	
Util	-4.1151	2.8701	-9	0	1701	
Utilsq	25.1581	27.1304	0	81	1701	
Inequ	4.1352	4.5816	0	12	1701	
Inequsq	38.0788	56.0602	9	144	1701	
Round			1	8	1701	
R1	0.0888	0.2845	0	1	151	8.88
R2	0.1093	0.3121	0	1	186	19.81
R3	0.1211	0.3263	0	1	206	31.92
R4	0.1117	0.3150	0	1	190	43.09
R9	0.1235	0.3291	0	1	210	55.44
R10	0.1464	0.3536	0	1	249	70.08
R11	0.1564	0.3633	0	1	266	85.71
R12	0.1424	0.3500	0	1	243	100.00
After	0.5691	0.4953	0	1	1701	
Situation			1	10	1701	
S1	0.0817	0.2749	0	1	139	8.17
S2	0.1570	0.3639	0	1	267	23.87
S3	0.1623	0.3688	0	1	276	40.09
S4	0.0970	0.2960	0	1	165	49.79
S5	0.0364	0.1875	0	1	62	53.44
S6	0.0370	0.1889	0	1	63	57.14
S7	0.0940	0.2920	0	1	160	66.55
S8	0.0988	0.2984	0	1	168	76.43
S9	0.1199	0.3250	0	1	204	88.42
S10	0.1158	0.3201	0	1	197	100.00
Version			1	4	1701	
V0	0.2352	0.4242	0	1	400	23.52
V1	0.2451	0.4303	0	1	417	48.03
V2	0.2557	0.4364	0	1	435	73.60
V3	0.2640	0.4409	0	1	449	100.00

## C) Allocation Choices – Summary Table

I	II	III	Sheet	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total	%	Cum	%
A	BD	CE	1	40	21	92	24	87	53	44	56	64	62	1328	50	1328	50
			3	59	29	116	26	129	74	84	86	96	86				
A	DE	BC	1	19	7	26	5	34	19	20	12	24	24	373	14	1701	64
			3	21	5	33	8	26	19	12	14	20	25				

AE	BD	C	1	20	0	21	0	16	15	28	2	4	3	159	6	1860	70
			3	6	0	10	0	11	8	9	2	2	2				
A	BC	DE	1	11	4	1	3	1	5	16	6	2	6	121	5	1981	74
			3	22	5	1	4	2	6	11	8	5	2				
ADE	B	C	1	0	0	2	0	1	1	1	20	21	26	107	4	2088	78
			3	1	0	0	0	0	1	0	11	11	11				
AE	D	BC	1	6	1	16	0	20	19	8	3	3	4	99	4	2187	82
			3	6	0	3	0	0	2	6	0	0	2				
A	CE	BD	1	9	3	1	2	0	0	3	9	2	1	51	2	2238	84
			3	2	2	3	2	1	1	4	3	2	1				
A	CD	BE	1	0	1	1	1	3	5	2	4	2	3	47	2	2285	86
			3	1	1	5	1	3	5	0	4	3	2				
A	BE	CD	1	1	0	1	0	2	3	1	3	3	0	31	1	2316	87
			3	4	0	0	1	2	4	2	3	1	1				

#### D) Survey Instructions

##### PART 1

Today's activity consists of three parts. Once you are done with one part, please get up and collect the next part from me. If I am talking with another participant, please wait until we are done. Please indicate on the top right of each answer sheet the letter that you were assigned when you arrived for today's activity.

Today's activity asks you to consider several Situations in which five different objects have to be allocated to three individuals. Assume that these three individuals approached you because they are looking for an independent arbiter who picks a fair distribution of the five objects among them; they are looking for someone who does not benefit from the distribution and therefore takes an impartial decision. Your task is therefore to analyze the Situation and then to determine the distribution of the objects that you consider the fairest. You do not know any of the three individuals and should take as impartial a decision as possible. What matters is what you consider a fair distribution – there is no “right” or “wrong” answer.

Your decision is final. The three individuals cannot swap or otherwise trade the objects or money once you have made a decision. Please think carefully about the task at hand. Once you have identified the fairest allocation, write it down and then explain why you chose this distribution, i.e. explain why you consider that distribution the fairest possible.

The objects that need to be distributed are indivisible, i.e. every object has to be given to one person in its entirety. All five objects need to be distributed among the three individuals. The three individuals are called I, II and III. The five objects are called A, B, C, D, and E.

For each Sit you are given a payoff table. The entries in that table tell you how much each individual likes each object. Consider, for instance, this case:

##### Example Situation

A	B	C	D	E
---	---	---	---	---

<b>I</b>	20	20	5	25	30
<b>II</b>	14	26	24	10	26
<b>III</b>	30	7	17	26	20

Here, person I likes getting A or getting B equally much, but prefers getting D or even better E. Person II, for instance, likes getting objects A and D together as much as getting object C, etc. If you decide, for instance, that you want to give A, C and D to person I, B to person II and E to person III, then you indicate this as follows:

**Distribution**

<b>Individual</b>	<b>I</b>	<b>II</b>	<b>III</b>
<b>Objects</b>	A, C, D	B	E

Please provide an explanation for your choice in the space underneath the distribution on the answer sheet.

This example here is only for illustrational purposes. It does not imply or suggest any judgment about what would constitute a fair allocation in this or any other case.

In the first part of today's activity you will have to make a decision in four different Situations which are independent of each other. This means, that what you decided for an earlier Situation is irrelevant for a later Situation. Please work on the Situations in the order in which they are presented, 1 through 4; finish analyzing and deciding one Situation before you move on to the next.

Any questions? Please raise your hand.

Please think carefully, write legibly, and provide detailed explanations.

Please do not talk to the other participants.

[Participants returned the instructions and received Sheet 1 with four problems; two on the front, two on the back – see below, showing front and back of Sheet 1 next to each other.]



### Example Situation

	A	B	C	D	E
I	20	20	5	25	30
II	14	26	24	10	26
III	30	7	17	26	20

Let's assume the chosen distribution is as suggested in the introduction:

### Distribution

Individual	I	II	III
Objects	A, C, D	B	E

Would such a distribution be envy-free?

Person I gets objects A, C, and D, whereas person II only gets B. Person II receives a value of 26 from object B, but would be getting a value of  $14+24+10=48$  if person II managed to get person I's bundle of A, C, and D. Person II would clearly be better off with person I's objects. Person II is therefore envious of person I. The distribution is not envy-free because there is one person, person II, who is envious.

As a matter of exercise, let's see whether anyone else is envious. Person III gets E and therefore a value of 20. If person III got person II's object B, then that would be worth only 7. Person III is therefore not envious of person II. However, person III is envious of person I – the combination of A, C, and D is worth  $30+17+26=73$  to person III, which clearly is a lot more than the 20 person III gets from object E.

Person I is not envious of either of the other. Objects A, C, and D are worth  $20+5+25=50$  for person I, whereas getting B with a value of 20 or E with a value of 30 is worse.

Obviously, there may be many other reasons why someone could consider the suggested distribution of giving A, C, and D to I, B to II, and E to III as fair or unfair.

What do you think about this criterion of envy-freeness? Is it relevant for fairness? Briefly explain your point of view on the answer sheet.

Have another look at the four Situations considered before. If you found yourself again in the position of an independent arbiter where the three individuals approach you with the request of identifying the fairest distribution for them as in part one – what would you choose in each Situation now? You are no longer limited to only two choices as in part 2. Feel free to pick the same choices as earlier or to change your mind. Whatever you pick, it should be the distribution YOU consider the fairest. Please explain your choice briefly.

[Participants got Sheet 3 together with these instructions upon returning Sheet 2 and the accompanying instructions to the organizer. Sheet 3 is identical to Sheet 1 except for the question

“What do you think about this criterion of envy-freeness? Is it relevant for fairness?” and some lines for an answer at the top of the first page]