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Justice Under Uncertainty

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Abstract. Uncertain outcomes are an inevitable feature of policy choices and their public support often depends on their perceived justice. We theoretically and experimentally explore just allocations when recipients are exposed to certainty and uncertainty. In the experiment, uninvolved participants unequivocally choose to allocate resources equally between recipients, when there is certainty. In stark contrast, with uncertainty just allocations are widely dispersed and recipients exposed to higher degrees of uncertainty are allocated less. The observed allocations can be well organized by four different theoretical views of justice, indicating that uninvolved participants differ fundamentally in their views on justice under uncertainty.

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Keywords: justice • uncertainty • experiment

1. Introduction

The perceived justice of policy choices is often of paramount importance for the public and political acceptance of the planned or implemented policy. This is exemplified by the vivid public debate surrounding reforms of pension, social security, or healthcare systems (e.g., Krugman 2009), and the political upheavals in countries undergoing tight reforms of their tax and governmental financing system (e.g., *The Economist* 2013). Importantly, due to uncertainty, the ultimate outcome of almost any policy choice is often unknown ex ante. Hence, the importance to understand how people perceive justice under uncertainty.[1]

People may differ in what they perceive as just under uncertainty. For instance, should one deliver a well-tested safe vaccine or a new vaccine that with some probability will save more lives but may also induce strong adverse reactions (see Adler and Sanchirico 2006, p. 282)? A similar question is prominently present in the debate on organ allocation criteria. The "maximum benefit criterion" proposes to rank potential receivers of an organ according to their probability of survival after the transplant, whereas opponents argue that information on patients' mortality risk should not affect the ranking (Childress 2001). Similarly, one may ask what constitutes a just compensation scheme for civil servants occupying risky jobs (e.g., firefighters, police) relative to other safer occupations. Or, what the just allocation of resources is between researchers proposing projects with relatively certain outcomes and researchers proposing projects with high benefit when lucky but low benefit when unlucky.

In this paper we theoretically and experimentally investigate the fundamental question underlying these problems. What constitutes a just allocation of resources when recipients of these resources are exposed to uncertainty? Specifically, we are interested whether otherwise similar people differ in their views on justice when the outcome of an allocation is uncertain.

That uncertainty introduces the potential of disagreement into justice considerations can be most cleanly exemplified when considering equally deserving recipients. Under certainty it seems natural that any just allocation would comprise an equal distribution of resources. However, when at least one of the recipients is faced with uncertainty prominent justice ideas may imply diverging just allocations.[2] A utilitarian approach would allocate resources such that the sum of expected utilities is maximized but would be indifferent to the possibility of resulting inequalities. Alternatively, principles of equality can be applied ex ante or ex post. In the ex ante view, focusing on initial symmetry of recipients, a just allocation would either equalize expected outcomes or expected utilities, depending on whether or not risk preferences of recipients are taken into account in the evaluation. In the ex post view, the distribution of final outcomes determines how just the allocation is. It is clear that, in general, the application of these different principles will lead to different just allocations.

We report results of the first experiment exploring individuals' distributive justice views when a recipient is exposed to various degrees of uncertainty. The experiment consists of a production phase followed by an allocation phase. In the production phase, two participants engage in a real effort task and produce a joint monetary surplus. The effort task is calibrated such that both participants are equally deserving. In the allocation phase, a third (otherwise uninvolved) person, henceforth called spectator (Konow 2009), is asked to distribute the produced surplus between the other two participants, henceforth called recipients.[3]

The spectator has to make decisions in several allocation problems, characterized by different degrees of uncertainty. One recipient always earns exactly what is allocated to him, whereas the other recipient's earnings are almost always uncertain. Specifically, for the latter, final earnings can be larger or smaller than the allocation but are in expectation equal to the allocation in all problems. To assess the role of risk preferences, we also elicit participants' own risk preferences as well as their beliefs about the risk preferences of recipients.

This design allows us to explore the pure effect of uncertainty on just allocations in a clean way. When there is no uncertainty for both recipients, we expect all spectators to choose the equal split. However, will this also be the case when a recipient is exposed to uncertainty? If not, several additional questions arise. Do just allocations respond to the riskiness of the problem? Are allocations under uncertainty guided by principles of justice like utilitarianism, ex post egalitarianism, or ex ante egalitarianism? Do differences in allocations reflect substantial disagreement regarding ideas of justice under uncertainty?

Our main findings can be summarized as follows. First, in the absence of uncertainty almost all spectators allocate resources equally between recipients, as expected. We take this as evidence that (i) our procedure indeed elicits just allocations and (ii) equal treatment of the prevalent justice view under certainty. Second, just allocations exhibit substantial heterogeneity in allocation problems characterized by uncertainty. Hence, people who implicitly agree on just allocations in certain environments, may hold conflicting justice views under uncertainty. Third, spectators tend to allocate less to the recipient facing uncertainty the higher the degree of uncertainty. Finally, we show that justice views derived from utilitarianism and egalitarianism can organize the observed just allocations. We find that a majority of spectators make choices consistent with some form of ex ante equality but that utilitarian and ex post egalitarian views also find considerable support. This plurality of justice views under uncertainty is consistent with a similar finding in a context with productivity differences between recipients (Cappelen et al. 2007). Importantly, the observed disagreement on justice under uncertainty emerges although our participants have very similar socioeconomic backgrounds.

Our paper builds on the tradition of empirical investigations of justice views initiated by the seminal papers of Yaari and Bar-Hillel (1984) and Kahneman et al. (1986). These early studies were employing surveys and vignettes and have initiated a literature that greatly improved our knowledge about peoples' justice views (see, e.g., Schokkaert and Overlaet 1989, Schokkaert and Capeau 1991, Gächter and Riedl 2006, Faravelli 2007, Konow 2009; see also Konow 2003, Tausch et al. 2013, for overviews).

Konow (2000) was the first to use incentivized experiments in justice research. He introduced a noninvolved subject, the spectator, who was asked to allocate to two anonymous recipients the joint product of their work (see also Dickinson and Tiefenthaler 2002). Cappelen et al. (2007) also explore individuals' justice ideas in situations involving production, but use allocation data from a standard dictator game. Taken together, the main findings of these studies are that individuals are held responsible for their outcomes whenever they can reasonably influence them and that asymmetries between recipients lead to a plurality of justice ideas.

Cappelen et al. (2013) investigate the allocations of both noninvolved subjects and stakeholders in situations where inequalities in output are the result of antecedent choices under risk. Similar to us, these authors allow for uncertainty but their study differs in important aspects from ours. Cappelen et al. (2013) look for allocation decisions *after* uncertainty is resolved and, hence, the consequences of any redistribution decision are known. In contrast, we study just allocations *before* uncertainty is resolved. Moreover, we study situations where recipients are equally deserving, whereas the cited study looks at issues of merit.

Two interesting recent studies that also allow for risk in allocation decisions are Rohde and Rohde (2011) and Brock et al. (2013). Both papers study decisions of *involved* decision makers who may or may not exhibit other-regarding preferences. The first study finds that even though people show concerns for inequality in a risk-free setting they do not respond to the risk exposure of other subjects. The latter paper explores ex ante and ex post fairness under uncertainty and finds that, both, expected value comparisons and ex post considerations matter to explain dictators' giving in risky situations. These results resonate well with our finding on the heterogeneity of justice views, as we find that spectators' choices also reflect concerns for both ex ante and ex post equality. Hence, taken together Brock et al. (2013) and our study strongly indicate that under uncertainty involved as well as uninvolved agents exhibit heterogeneity in, respectively, fairness and justice views and that both ex ante and ex post considerations are important.

In spite of these important similarities, our contribution is clearly distinct from these papers. First, these studies explore fairness considerations of stakeholders, whereas we study the unbiased justice views of uninvolved spectators. Second, neither of the previous studies relate observed behavior to theoretical justice views (as opposed to theoretical models of fairness and inequality aversion). Moreover, our investigation of the heterogeneity of justice views under uncertainty is not only interesting for justice research. It can also help in interpreting the behavior of stakeholders who trade off own earnings with deviations from their favorite justice view, as studied in Cappelen et al. (2007) for certain outcomes. Several decision-making models assume that individuals have a preference to implement just allocations derived from normative justice views (see, for instance, Karni and Safra 2002 and Konow 2000). Eliciting spectators' unbiased justice views is a necessary first step to assess the validity of these approaches.

The rest of the paper is organized as follows. In Section 2 we introduce the studied allocation problems and provide a theoretical framework for discussing justice under uncertainty. Section 3 describes the experimental design and procedures. Section 4 reports the empirical results, and Section 5 concludes.

2. General Setup and Theoretical Framework

2.1. General Setup

To study justice under outcome uncertainty, we explore allocation problems with varying degrees of uncertainty, denoted by $m \in \{1, \ldots, M\}$. In each allocation problem, an *uninvolved* third party, the spectator, has to divide between two recipients a monetary surplus X jointly produced by them. Importantly, the spectator has no stakes in the produced surplus. A crucial assumption here is that the spectator's choices indeed reflect just allocations. We discuss this issue in more detail in the design section (see Section 3).

To isolate the effect of uncertainty, the production task is calibrated such that equal productivity of recipients in the production of X is (almost certainly) guaranteed. Moreover, anonymity of the spectator as well as both recipients is ensured. Consequently, the spectator does not have any information about recipients' characteristics that would allow her to discriminate between recipients, implying that they should be viewed as equally deserving. Indeed, under anonymity (symmetry) basically all theoretical rules of justice imply equality (see, e.g., Young 1995).

Recipients only differ in that one of them, for convenience called U, is exposed to uncertainty whereas the other, for convenience called C, faces certainty. Importantly, whether a recipient is exposed to uncertainty or not is beyond her influence. Specifically, in each allocation problem m the uninvolved third party has to divide the amount X between recipients U and C, with $X = x_U + x_C$. Recipient U's final outcome depends on which of two possible events realizes *after* the allocation of x_U. The "good" event H realizes with probability p in which case the amount x_U allocated to U is multiplied by $k^H > 1$. With probability $1-p$ the "bad" event l realizes, with the consequence that x_U is multiplied by k^l $(1 > k^l \geq 0)$.

In addition to the effect of uncertainty per se, we are also interested in how different degrees of uncertainty affect just allocations. Therefore, the investigated allocation problems differ in the likelihoods $(p, 1-p)$ of the good and bad events as well as in the consequences (k^H, k^l) coupled with these events. To meaningfully compare allocations across different problems, we have to ensure that they are not confounded by other motives. We achieve this by choosing k^H, k^l, and p such that in each allocation problem m, it holds that

$$p x_U k^H + (1-p) x_U k^l = x_U. \tag{1}$$

Hence, in each allocation problem, U receives in expectation exactly what is allocated to her. This property ensures specifically that motivations related to risk exposure cannot be confounded with expected material efficiency concerns.[4]

The allocation problems are chosen such that for any constant relative risk aversion (CRRA) or constant absolute risk aversion (CARA) utility function for money, the expected utility of a given allocation x_U to a risk-averse recipient U in problem m is larger than the expected utility in problem $m+1$. Accordingly, we will call allocation problem $m+1$ riskier than problem m.[5] This variation in riskiness allows us to study if and how just allocations are influenced by the dispersion of final outcomes.[6]

2.2. Theoretical Framework

Scholars of distributive justice research invoked uncertainty as a means to discuss and rationalize justice principles (Rawls 1971, Konow 2003), and there is a long theoretical tradition discussing normative questions of how to assess social situations involving risk (see Endnote 2). The concepts proposed in this literature cannot be transferred one-to-one to our allocation problems but we will use them as guidance for the theoretical ideas regarding just allocations under uncertainty, developed below. We first derive just allocations based on three variations of the principle of "equal treatment of equals" and then consider justice from a utilitarian perspective, which takes efficiency considerations into account.

The principle of equal treatment of equals is relevant for the problems we study for two reasons.

First, recipients cannot be discriminated on the basis of any characteristic other than their exposure to uncertainty. Second, as exposure to uncertainty is exogenous and randomly assigned, recipients should not be held responsible for their position. However, equal treatment of equals cannot straightforwardly be implemented because the presence of uncertainty impedes full equality in ex post outcomes (i.e., after uncertainty is resolved). Therefore, the implementation of the equal treatment of equals principle is open to different interpretations. We propose three natural concepts that could be applied: equality in expected outcomes, equality in expected utilities, and equality in realized outcomes.

First, equality in expected outcomes can be defended as a principle of justice under uncertainty on the basis of equity considerations and the more recent idea of accountability (Konow 1996, 2003). Since in each allocation problem the expected value of an allocation is the allocation itself (cf. Equation (1)) equality in expected outcomes implies splitting X equally between the two recipients, in all allocation problems. That is,

$$x_U = x_C = \tfrac{1}{2}X. \tag{2}$$

This approach guarantees that U and C enjoy the same outcome in expected value. Therefore, we call it *EV-equality*.

Second, the justice idea of equality in expected utilities is related to Sen's (1997) Weak Equity Axiom, which states that those in a disadvantaged position should be compensated as well as Rawls's (1971) Difference Principle.[7] As most individuals are risk averse (Dohmen et al. 2011), recipients exposed to uncertainty can be considered to be disadvantaged and, hence, should be compensated by allocating them ex ante more resources than individuals facing certainty.

Formally, allocations x_U and x_C, satisfying equality of expected utilities $W(x)$,[8] have to solve

$$E[W(x_U)] = E[W(x_C)] \quad \text{s.t. } x_U + x_C = X.$$

To make quantitative statements, we assume that recipients can be characterized by a CRRA utility function for money $W(x) = x^\alpha$ that reflects their risk preferences. We make the CRRA assumption for convenience and because it is most common in the empirical literature on individuals' risk preferences (see, e.g., Holt and Laury 2002, Andersen et al. 2008, Wakker 2008, Dohmen et al. 2011).[9] Together with the definition of our allocation problems, the above condition can be rewritten as

$$p\,(x_U k^H)^\alpha + (1-p)(x_U k^l)^\alpha = (x_C)^\alpha.$$

Solving this equation with respect to x_U and x_C gives the just allocations

$$x_U = \frac{1}{\exp(Z\alpha^{-1})+1}X, \quad x_C = \frac{\exp(Z\alpha^{-1})}{\exp(Z\alpha^{-1})+1}X, \tag{3}$$

where $Z = \ln[p(k^H)^\alpha + (1-p)(k^l)^\alpha]$. This allocation of X guarantees that U and C enjoy the same expected utility and we call the corresponding justice idea *EU-equality*.[10]

From Equation (1) it follows that for all $\alpha \in\,]0,1[$, $Z < 0$ and, hence, $\exp(Z\alpha^{-1}) < 1$. Thus, for risk-averse recipients, the allocations in (3) imply that in all allocation problems characterized by uncertainty, recipient U should be allocated *more* than recipient C. Further, the just allocation to U increases with the riskiness of the allocation problem, which follows from the fact that Z is decreasing in the problems' riskiness. The allocations in (3) are also just according to *EU-equality* when we assume that risk is positively valued (i.e., $\alpha > 1$). In that case, U should be allocated *less* than C and the allocation to U decreases with the riskiness of the allocation problem.

Third, equality can also be sought ex post, that is, after uncertainty has been resolved, which is related to the idea of egalitarianism (see Deutsch 1985). With uncertainty, perfect equality is impossible to achieve, however. It can be best approximated by choosing allocations that minimize the expected difference between U's and C's final positions. In our setup this is equivalent to minimizing expected differences in individuals' final utility of money. Note that, ex post equal allocations do not depend on risk attitudes because the justice idea is applied after uncertainty is resolved. Consequently, ex post just allocations x_U and x_C have to satisfy

$$\min_{x_U, x_C} p|k^H x_U - x_C| + (1-p)|k^l x_U - x_C| \quad \text{s.t. } x_U + x_C = X.$$

The solution of the above minimization problem yields

$$\begin{aligned} x_U &= \frac{1}{k^H+1}X, \quad x_C = \frac{k^H}{k^H+1}X \qquad \text{if } k^H > \tfrac{1-p}{p}, \\ x_U &= \frac{1}{k^l+1}X, \quad x_C = \frac{k^l}{k^l+1}X \qquad \text{if } k^H < \tfrac{1-p}{p}. \end{aligned} \tag{4}$$

In the first case, when k^H is relatively large, this implies that the allocation to the recipient exposed to uncertainty is smaller than the allocation to the recipient facing certainty (recall that $k^H > 1 > k^l$) and in the second case, when k^H is relatively small, the allocation to the recipient exposed to uncertainty is larger than the allocation to the recipient facing certainty. We call this justice idea *ex post equality*.

The three justice principles discussed so far ignore efficiency considerations. However, efficiency is not necessarily at odds with justice, but can itself be considered a type of justice (see Konow 2003). To account for efficiency considerations, we assume a utilitarian allocation criterion that maximizes the aggregate level of (expected) utility.[11]

When recipients are identical and risk neutral the utilitarian principle does not select a unique allocation and any allocation of X would be considered as just. However, if recipients are risk averse, a given allocation yields less expected utility to U than to C and utilitarianism prescribes to allocate a smaller amount to U than to C. Formally, the allocations x_U and x_C have to satisfy

$$\max_{x_U, x_C} E[W(x_U) + W(x_C)] \quad \text{s.t. } x_U + x_C = X,$$

which, given our assumptions, is equivalent to

$$\max_{x_U, x_C} p(x_U k^H)^\alpha + (1-p)(x_U k^l)^\alpha + (x_C)^\alpha \quad \text{s.t. } x_U + x_C = X,$$

and gives the just allocations

$$x_U = \frac{1}{\exp(-Z(1-\alpha)^{-1}) + 1} X, \qquad x_C = \frac{\exp(-Z(1-\alpha)^{-1})}{\exp(-Z(1-\alpha)^{-1}) + 1} X, \tag{5}$$

with $Z = \ln[p(k^H)^\alpha + (1-p)(k^l)^\alpha]$. We call these just allocations *utilitarian*.

Note, that $\exp(-Z\ (1-\alpha)^{-1}) > 1$ for all $\alpha \in]0,1[$ implies that in the just allocations given by (5), U is allocated *less* than C. Further, it holds that the higher the riskiness of U's final earnings the less is allocated to U. If $\alpha > 1$, that is when recipients are characterized by risk-seeking preferences, the maximization of total welfare implies that all X is allocated to U.

Table 1 summarizes the distributional implications of these four views of justice under uncertainty. It also shows the relation of just allocations to U and C in dependence of whether risk-averse or risk-seeking preferences are assumed.

Table 1. Just Allocations Under Uncertainty

		Relation between x_U and x_C	
	x_U	Risk averse	Risk seeking
EV-equality	$\frac{1}{2}X$	$x_U = x_C$	$x_U = x_C$
EU-equality	$\frac{1}{\exp(Z\alpha^{-1})+1}X$	$x_U > x_C$	$x_U < x_C$
Ex post equality[a]	$\frac{1}{k^H+1}X$	$x_U < x_C$	$x_U < x_C$
	$\frac{1}{k^l+1}X$	$x_U > x_C$	$x_U > x_C$
Utilitarian	$\frac{1}{\exp(-Z(1-\alpha)^{-1})+1}X$	$x_U < x_C$	$x_U > x_C$

Note. $Z = \ln[p(k^H)^\alpha + (1-p)(k^l)^\alpha]$.

[a]Upper (lower) case holds if $k^H > (<)(1-p)/p$; in the experiment only the uppercase is implemented.

3. Experimental Design and Procedures

The experiment consists of three parts: (1) the production of the resource X by recipients C and U; (2) the allocation of X between by C and U by the uninvolved spectator; and (3) the elicitation of risk preferences, beliefs about risk preferences, and other individual characteristics. In the following we describe the different parts in more detail.

Part 1: *Production of resource X.* Each participant is randomly assigned a seat in a vision isolated cubicle equipped with a networked computer. After each participant is seated, instructions for the first and second part of the experiment are distributed and read aloud by the experimenter. Participants are randomly matched into groups of three and assigned the role of either recipient U, recipient C, or spectator. These roles are fixed throughout the experiment. In the experiment, subjects are assigned the neutral labels A, B, and C.

In the first part of the experiment U and C work individually on a real effort task, while the spectator is idle. The purpose of the task is to create a situation where U and C are equally entitled to a compensation for their effort. The spectator has the full responsibility to decide on this compensation. The real effort task consists of the so-called "slider task" introduced by Gill and Prowse (2012). In our version, 32 sliders on horizontal bars are displayed on the computer screen. Using the mouse, each slider can be moved to any point of the bar and the actual position of a slider is displayed as a number between 0 and 100 to the right of the bar. The task is to position as many sliders as possible exactly in the middle of a bar. The slider is correctly positioned when the number 50 is displayed next to the slider.[12] A recipient's score in the task, that is his or her productivity, is equal to the number of sliders positioned at 50 in 6 minutes time. During the task, the achieved score and the remaining time are displayed at the top of the screen. We chose the slider task because it is easy to explain and understand, is identical across repetitions, and does not leave room for guessing.

The slider task is incentivized. For each correctly positioned slider €0.25 are credited, implying that each recipient can get credited up to €8. After the time for the task has expired, all members of a group, including the spectator, are informed about the productivity of U and C and, hence, the total amount of money X generated, which is deposited in a joint account. To minimize the likelihood of productivity differences, and thus to maximize the likelihood of equally deserving recipients, we have chosen the number of sliders and the available time to complete the task such that maximum productivity should be achieved by both recipients.

Part 2: *Just allocation of X.* In this part of the experiment the spectator has to allocate the amount X in the group account between U and C, who are both not active in this part. Importantly, the spectator does not have any stakes in the joint account and neither U nor C do receive any compensation other than the one implied by the spectator's allocation. The spectator's payment for the allocation task is independent of her decision and randomly determined at the end of the experiment. Specifically, the spectator can earn 4, 6, 10, or 12 euros with equal chance. We have chosen this payment procedure in order to maximize the likelihood that the third party's only incentive is to implement her normative just allocation. Further, we strove to minimize a potential experimenter demand effect regarding the equal division by not including 8 as a possible outcome.

A crucial assumption here is that the spectator's choices indeed reflect just allocations. Specifically, one may wonder whether the spectator may not (only) have an incentive to act justly but that, due to missing direct monetary incentives, her choices may also involve a random component. We do not deny this possibility, but it should be noted that the elicitation of just choices requires by definition an uninvolved decision maker. In our opinion, the chosen implementation is as close as one can get to incentivizing just choices. Moreover, we do not think that randomness will play a major role in the spectator's decisions for the following reasons. First, there are theoretical arguments and empirical facts that support the assumption that participants will indeed decide according to their view of justice. Theoretically, Konow (2000), Karni and Safra (2002), and Birkeland and Tungodden (2014), for instance, argue that individuals suffer some disutility when actual allocations deviate from what they deem to be just and thus have an (intrinsic) incentive to choose just allocations. Empirically, it has been shown that uninvolved third parties indeed implement just choices (see, e.g., Konow 2000, Cappelen et al. 2013). Second, we show in the results section that it is unlikely that in our experiment spectators made random choices. Third, in answers of subjects to open postexperiment questions, we do not find any evidence that subjects' choices where guided by randomness. For all these reasons and for brevity, throughout the paper we refer to the spectator's allocation choices with the expression just allocations.

The spectator faces allocation problems that satisfy the assumptions discussed above and are summarized in Table 2.[13] The allocation problem 1-Certainty serves as a benchmark where the final earnings of both, U and C, are certain and thus equal to the amounts x_U and x_C allocated to them. In the other four allocation problems, recipient U is exposed to uncertainty while C faces certainty. In 2-Risk, recipient U earns $k^H = 1.5$ times what is allocated to her with probability $p = 0.5$ and with probability $1 - p = 0.5$ she earns only half her allocation ($k^l = 0.5$). The remaining allocation problems are constructed similarly. For instance, in 4-Risk $p = 0.5$, $k^H = 2$, and $k^l = 0$, implying that U earns either twice what is allocated to her or nothing, both events having a chance of 50%. It is easy to see that expected earnings of U are exactly x_U in all allocation problems and that the riskiness monotonically increases from allocation problem 1-Certainty to 5-Risk.

Table 2. Allocation Problems

Allocation problem	Final earnings of U	Final earnings of C
1-Certainty	x_U	x_C
2-Risk	$(0.5\colon x_U \cdot 1.5, x_U \cdot 0.5)$	x_C
3-Risk	$(0.8\colon x_U \cdot 1.25, x_U \cdot 0)$	x_C
4-Risk	$(0.5\colon x_U \cdot 2, x_U \cdot 0)$	x_C
5-Risk	$(0.2\colon x_U \cdot 5, x_U \cdot 0)$	x_C

Note. $(p\colon x_U \cdot k^H, x_U \cdot k^l)$ denotes the uncertain outcome U is facing; $x_U + x_R = X$.

In the experiment, these allocation problems appear on the screen one by one and each spectator has to make an allocation decision in each problem. To control for sequencing effects, the order in which allocation problems appear is randomized in each group. At the end of the experiment one problem is randomly selected to be relevant for payment of U and C, and uncertainty is resolved by using a stack of cards numbered from 1 to 100. For instance, for an allocation problem where U faces a 50% chance that her allocation is doubled, this indeed happens if a card with a number smaller than 51 is drawn. The determination of earnings took place publicly at the end of the experiment so that subjects could witness how uncertainty was resolved. Subjects were informed about this procedure before they made any decisions.

Part 3: *Elicitation of individual characteristics.* In the last part of the experiment, we gather data on risk preferences, beliefs about risk preferences, and other individual characteristics that could be related to allocation decisions of the spectator. To measure risk preferences, we elicit the certainty equivalents of six, two outcomes lotteries (see Fehr-Duda et al. 2006). For each lottery, subjects are asked to choose between the lottery and a number of decreasing sure payments. Certainty equivalents are calculated as the arithmetic mean of the smallest sure amount preferred to the lottery and the consecutive sure amount on the list. Subjects are forced to switch from the sure payment to the lottery only once, as consistency is crucial for the successive elicitation of beliefs about others' preferences. Details of the used lotteries are presented in Table S3.1 of Online Appendix S3 and a screen shot of a typical lottery can be found in the experiment instructions (Online Appendix S1). The parameters of the lotteries are chosen such that they allow to measure risk preferences for the same outcome ranges as used in the allocation problems. At the end of the experiment, one decision is randomly selected to be relevant for payment and earnings are added to those of the first part.

Subjects' beliefs about others' risk preferences are elicited by letting them estimate the choices of a randomly matched group member in four lotteries. Belief elicitation is incentivized with the interval scoring rule (Schlag and van der Weele 2015). Each participant is asked to indicate what he or she believes is the minimum and the maximum certainty equivalent of the matched participant for each lottery.[14]

At the end of the third part of the experiment subjects are asked some socioeconomic questions and spectators are in addition asked questions regarding their decisions in the first part of the experiment. Thereafter subjects are privately payed out in cash and dismissed.

The computerized experiment was conducted in the Behavioral and Experimental Economics laboratory (BEElab) at Maastricht University School of Business and Economics, using the z-tree software (Fischbacher 2007). In total, 90 students from Maastricht University participated in the experiment. Most of them (82%) were enrolled in the School of Business and Economics and the rest came from a variety of studies such as law, medicine, and arts. A total of 47% of the subjects were male and the average age was 23.5 years. An experimental session lasted approximately 80 minutes and the average earnings per subject were €17.

4. Results

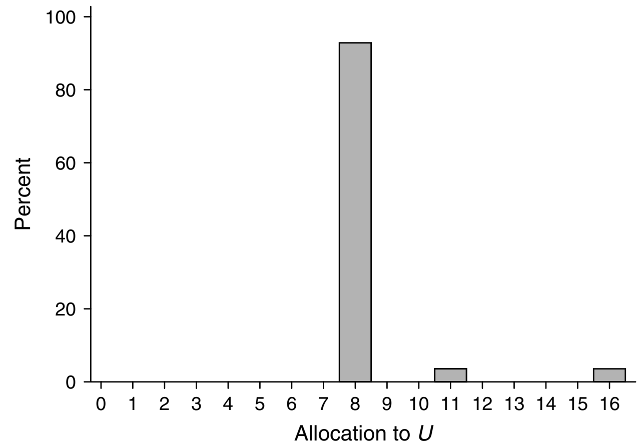
In this section, we first present descriptive statistics and statistical tests on allocation behavior of spectators. We then proceed by estimating the distribution of the theoretically derived justice views in our sample.

4.1. Just Allocations Under Uncertainty

Our design of the production phase successfully induced maximum performance of both U and C in almost all of the 30 groups. Only in two groups maximum performance was not achieved. In the following analysis we exclude these two groups in order to rule out confounding effects on spectators' allocation decisions due to recipients' productivity differences. Consequently, for all analyzed groups the amount X that has to be allocated equals €16.

To set the stage, we first consider allocation problem 1-Certainty in which there is no uncertainty about final earnings. In this problem treating U and C equally unambiguously implies to split the group account in two equal shares, which is also efficient. Figure 1 depicts the distribution of allocations to U (that is, x_U). It shows that, except for two outliers, spectators split the amount in the group account indeed equally between U and C. This clearly indicates that (almost all of) our spectators care about treating equally deserving individuals equally.

Figure 1. Allocations to Recipient U in 1-Certainty



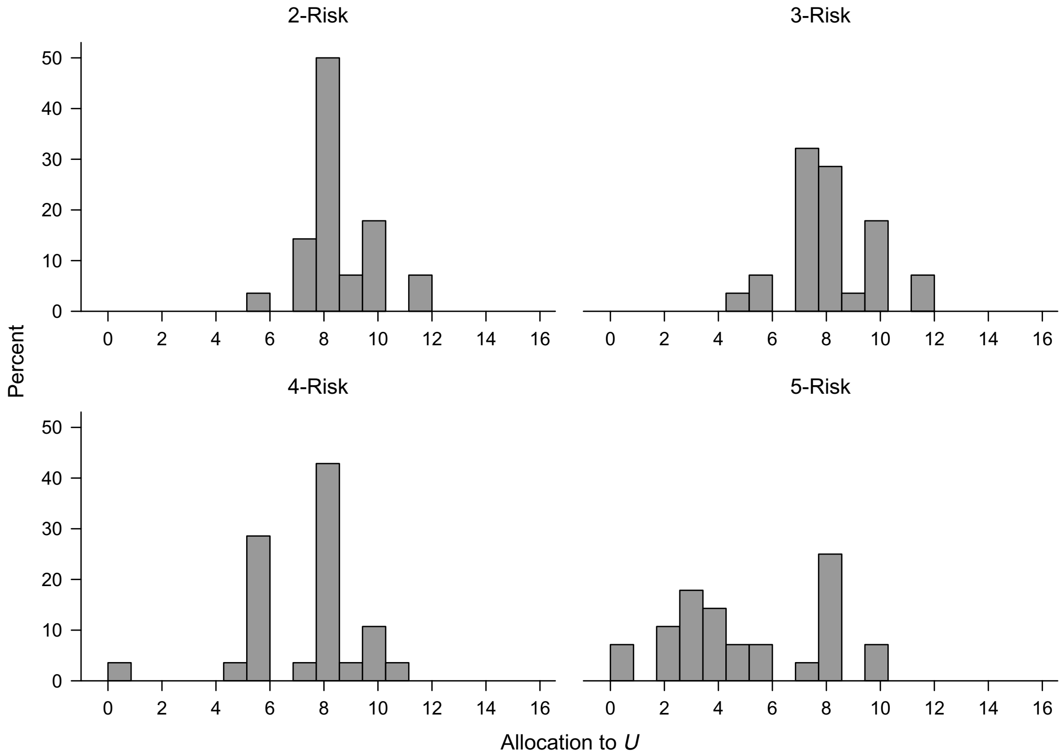
Result 1. *When there is no uncertainty, just allocations amount to splitting the monetary output equally between recipients.*

This result also indicates that our setup successfully elicits just allocations. Alternatively, as discussed in Section 3, spectators may not care much about justice and allocate resources more or less randomly. In that case, however, we would expect more widely dispersed allocation decisions. Additional evidence that allocations in 1-Certainty elicit just allocations, and are not the outcome of random or unreflected choices, comes from the two groups where one of the recipients, namely, U, did not achieve maximum performance in the real effort task. There we observe that allocations deviate from the equal split in disfavor of the less productive recipient U, who correctly positioned only 27 out of 32 sliders ($x_U = 6.75$ and $x_U = 7.75$ in the two groups, respectively). Furthermore, participants' answers to the debriefing questionnaire provide additional evidence supporting the idea that spectators are concerned with treating U and C in a just way (see Appendix D).

Allocation behavior changes drastically in allocation problems with uncertainty. Figure 2 shows the distributions of allocations to recipient U in allocation problems 2-Risk to 5-Risk. The distributions clearly indicate that just allocations differ across spectators *within* each allocation problem as well as *across* allocation problems.

Table 3 reports descriptive statistics and statistical tests regarding allocations to recipients U.[15] Wilcoxon signed rank (WSR) tests reject the null hypothesis that the median allocation to U is significantly different from 8 only in allocation problem 5-Risk, where less is allocated to U (Table 3, third column). However, WSR tests do not pick up all information contained in the data. Specifically, they do not capture the large variety of allocations clearly visible in Figure 2. Therefore, for

Figure 2. Allocations to Recipient U in Allocation Problems with Uncertainty



each allocation problem, we also employ Kolmogorov–Smirnov (K-S) tests to compare actual distributions to the hypothetical distribution where an equal split is uniformly chosen. We find that in all allocation problems with uncertainty, the K-S tests detect significant differences at least at the 5% significance level, except for 2-Risk, where $p = 0.07$ (Table 3, fourth column).

Result 2. *In each allocation problem characterized by uncertainty, just allocations are widely dispersed and differ significantly from the equal split.*

The distributions depicted in Figure 2 also suggest that spectators allocation decisions are related to the problems' riskiness, which increases from 2-Risk to 5-Risk. To test this, we code each allocation problem with a dummy variable and regress the allocations to U on these dummy variables. Allocation problem 1-Certainty serves as the baseline problem. Table 4 reports the ordinary least squares (OLS) regression results.

The dummy's coefficients show that on average just allocations to recipient U tend to become smaller the higher the riskiness of the allocation problem. Specifically, for the relatively high-risk problems, 4-Risk and 5-Risk, just allocations to U are significantly smaller than in the allocation problem without uncertainty (1-Certainty). Testing for differences between the coefficients of the different allocation problems with uncertainty shows that 5-Risk is significantly smaller than 4-Risk ($F(1, 27) = 18.47$, $p < 0.001$). Further, 4-Risk is smaller, but not significantly, than 3-Risk

Table 3. Allocations to Recipient U

	Allocation to U			
Allocation problem	Mean	Std. dev.	WSR test	K-S test
1-Certainty	8.39	1.59	$p = 0.16$	$p = 1.00$
2-Risk	8.50	1.43	$p = 0.16$	$p = 0.07$
3-Risk	8.13	1.69	$p = 0.90$	$p = 0.01$
4-Risk	7.33	2.10	$p = 0.12$	$p = 0.02$
5-Risk	5.10	2.84	$p = 0.00$	$p = 0.00$

Notes. WSR, Wilcoxon signed-rank; K-S, Kolmogorov–Smirnov. The null hypothesis for both tests is that the true distribution is that all spectators allocate 8 to recipient U.

Table 4. Allocation to U in Dependence of Allocation Problem

Decision situation	Coefficient	Std. err.
1-Certainty (constant)	8.39***	(0.306)
2-Risk	0.11	(0.310)
3-Risk	−0.26	(0.378)
4-Risk	−1.06**	(0.485)
5-Risk	−3.31***	(0.703)
N	140	
R^2	0.296	
$F_{(4, 27)}$	6.593	

Note. OLS regression; standard errors are robust to heteroscedasticity and are clustered on the 28 subjects.
*** and ** indicate significance at the 1% and 5% levels, respectively.

($F(1,27) = 2.23$, $p = 0.15$) and 3-Risk is also smaller, but not significantly, than 2-Risk ($F(1,27) = 1.71$, $p = 0.20$). We summarize these observations in the following result.

Result 3. *Allocations to recipients exposed to uncertainty tend to decrease with increasing riskiness of the allocation problem. Specifically, in comparison to the allocation problem without risk, these allocations are significantly smaller in the allocation problems with highest risks (4-Risk and 5-Risk).*

The result indicates that the average allocation to recipient U is unaffected when moving from 1-Certainty to relatively little uncertainty in 2-Risk and 3-Risk. As noted above already, this only holds for the first moments but not for the spread of allocations (see Figures 1 and 2 and Table 3). Moreover, in view of our theoretical justice views this is not surprising, as different views predict different responses to increasing uncertainty. EV-equality predicts no effect of a change in uncertainty, whereas EU-equality predicts an increase (decrease) in allocations to recipient U with increasing uncertainty, given that recipients are risk averse (risk seeking). Ex post equality predicts a decrease in allocations to recipient U irrespective of risk preferences, and utilitarianism predicts a decrease for risk-averse preferences but no effect for risk-seeking preferences. (cf. the discussion of justice views in Section 2 and the summary of predicted allocations shown in Table 1). These noneffects and offsetting effects, respectively, make it unlikely to detect differences in average allocations, especially when the introduced uncertainty is relatively small, as in 2-Risk and 3-Risk. The result thus is consistent with the idea that different spectators adhere to different views of justice under uncertainty. In the following section, we discuss this idea more thoroughly.

4.2. Views of Justice Under Uncertainty

The large variety in just allocations *within* each allocation problem suggests that spectators have differing views of justice under uncertainty. To further investigate this, we use our discussed theoretical justice views to calculate for each of them the implied allocations (see Section 2). For some of these views, just allocations depend on risk preferences of recipients, which are unknown to the spectators. To deal with this, we use the spectators' elicited beliefs about recipients' risk preferences to predict individual just allocations for each proposed justice view.[16] We then use these predictions to attribute to each spectator the justice view that best fits her actual just allocations.

In a first step, we estimate for each spectator her believed risk preferences of recipients, using the believed certainty equivalents elicited in the lottery tasks in Part 3 of the experiment. In line with the theory section, we assume that recipients' preferences can be represented by a CRRA utility function for money $W(x) = x^{\alpha}$. We then estimate the value of the believed α for each spectator by minimizing the sum of squared distances between predicted and elicited believed certainty equivalents (Wakker 2008, 2010).[17] We find that the average estimated level of risk aversion of recipients as believed by spectators is moderate (mean $\alpha = 0.72$, std. dev. = 0.23, median $\alpha = 0.72$). These values are in keeping with risk aversion reported in the literature (see Holt and Laury 2002, Dohmen et al. 2011).[18]

In a second step, we calculate the theoretical just allocations according to each justice view for each allocation problem and each spectator. Recall that just allocations according to EV-equality are independent of risk preferences and the riskiness of the allocation problem, that just allocations according to ex post equality are independent of risk preferences but affected by the riskiness of the allocation problem, and that just allocations according to EU-equality and utilitarianism are, in opposite ways, influenced by both risk preferences and the riskiness of the allocation problem (see Table 1).

Finally, we use these predictions to estimate for each spectator which justice view best represents her actual just allocations across problems. To this end, for each spectator and each allocation problem under uncertainty, we calculate the squared distance between the observed allocation and each of the four theoretical just allocations. The justice view that minimizes the sum of squared residuals over all risky problems is the one that best represents a spectator's justice type. Formally, for each spectator i we estimate

$$\min_{j} \sum_{m=2}^{5} (y_i^m - x_i^{j,m})^2, \tag{6}$$

where y_i^m is the actual amount allocated by spectator i to recipient U_i in allocation problem m and $x_i^{j,m}$ is the amount recipient U_i should receive in allocation problem m according to justice view $j \in$ {EV-equality, EU-equality, ex post equality, utilitarian} of i.

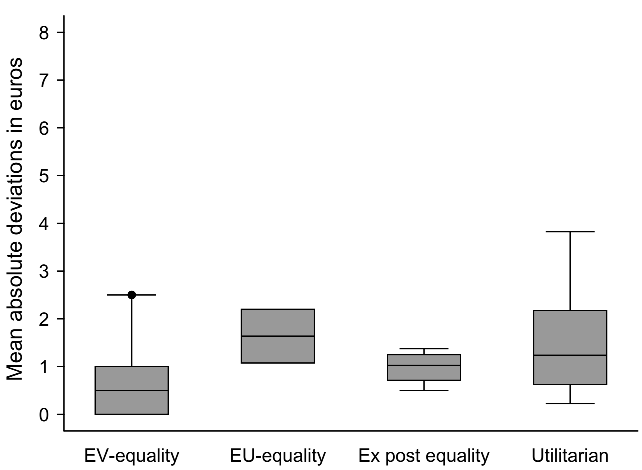
Result 4. *Spectators exhibit fundamentally different views of justice under uncertainty. Specifically, in our sample, 43% are best represented by EV-equality, 36% by utilitarianism, 14% by ex post equality, and 7% by EU-equality.*

The result shows that all justice views are represented, indicating that the observed variation in just allocations is due to fundamentally different views of justice under uncertainty. A relative majority of spectators is best represented by EV-equality that equalizes expected earnings of both recipients. This coincides with the equal split of resources in the allocation problem without uncertainty, indicating that these spectators do not adapt their just allocations to recipients facing uncertainty. However, a majority of 57% of the spectators is best represented by justice views that do respond to uncertainty. Of these, the largest group of 36% can be classified as utilitarians who allocate the less to U the more risk averse they believe U is and the riskier the allocation problem is. A nonnegligible minority of 14% adopts the ex post equality view, which allocates less to U the higher the riskiness of the allocation problem, irrespective of recipients' risk preferences. The smallest group of spectators is the one best represented by EU-equality, who are those who compensate U for facing uncertainty. They give more to recipient U than to recipient C in all allocation problems and the more so the riskier the allocation problem.

We want to emphasize that the estimated percentages should be taken with a pinch of salt, as measurement errors and environmental factors may affect the precise values, especially in a relatively small sample like the one of our experiment. What the result clearly indicates however is that spectators do differ fundamentally in their ideas about just allocations under uncertainty.[19]

One may wonder how well our theory-based classification fits the data. To get a first indication, we looked at the absolute differences between the actual allocations and the predicted allocations. More specifically, for each spectator and each decision situation, we calculated the absolute difference between her actual allocation and the allocation according to the assigned justice view and then calculated the average across decision situations. Figure 3 shows a box plot of this measure for each justice view. As can be seen, the differences (measured in €) are relatively small with not much variation, neither across spectators for a given justice view nor across justice views. In the following, we explore the fit more thoroughly with some additional statistical analysis.

Figure 3. Average Absolute Differences Between Actual and Predicted Allocations by Justice Views



Note. Horizontal lines indicate medians, boxes indicate interquartile ranges.

First, we regress the observed allocations on those predicted by each spectator's justice type, clustering standard errors at the individual level. If the classification would be perfect, the estimated constant should be 0 and the coefficient of predicted allocations should be 1. We find that the constant is close to 0 and insignificant (coeff.: 0.750, $F(1,27) = 1.35$, $p = 0.256$), the coefficient of predicted allocations is close to 1 and insignificantly different from it (coeff: 0.952, $F(1,27) = 0.26$, $p = 0.615$), and $R^2 = 0.53$. Hence, the regression result shows that our classification provides a good fit and that spectators behavior is to a considerable extent guided by (diverging) views of justice under uncertainty.[20]

Second, we test whether our classification is able to capture a larger fraction of the data variability than a random classification procedure. To this end, we uniformly randomly assign a justice type to each spectator and then regress the observed allocations on the ones "predicted" by the random assignment. We conduct 100 regressions, corresponding to 100 random assignments of types, and find that the R^2 is at best 0.20 and on average equal to 0.04. This is much lower than the obtained $R^2 = 0.53$ when using our classification.

Third, we conduct robustness tests where we exclude one of the four justice views at a time. That is, for all four possible permutations, we first use the same classification procedure as described above using only three of the theoretically derived views of justice and then regress the observed allocations on those predicted by each spectator's (possibly new) justice type. If the proposed four theoretical views of justice indeed capture participants justice ideas under uncertainty, we expect (a) that even using only three justice views gives a reasonable good fit that is better than with the random classification procedure but (b) that the fit of the remaining three views is worse than in the full model. To test this, we apply the same regression analysis as above. We find that, depending on which justice view is dropped, the R^2's vary between 0.42 and 0.51 and are thus indeed lower than when using all four justice views but significantly larger than for the random assignment procedure. Interestingly, in some of the alternative specifications, the constant is even significantly different from 0 or the coefficient of the predicted allocation is significantly different from 1, indicating a considerably worse fit.[21] We are therefore confident that our theory-based classification is a good representation of spectators' actual justice types.

We have used spectators' believed risk preferences of recipients to determine their justice type. Alternatively, one could take spectators' own risk preferences. Using the certainty equivalents elicited in Part 3 of the experiment and applying the same estimation techniques as explained above, we find that spectators' own risk preferences are similar to their believed risk preferences (mean $\alpha = 0.77$, std. dev. $= 0.24$, median $\alpha = 0.79$) and statistically not significantly different (WSR test, $p = 0.17$). Still one may ask how robust our results are to a change in used risk preferences.

We run the same procedure as above to calculate the predicted just allocations according to the four theoretical views of justice for spectators' own risk preferences. Unsurprisingly, the estimated percentages of the different justice views differ from those when using believed risk preferences. In particular, we find that 39% of the spectators are best represented by EV-equality, 29% by utilitarianism, 18% by ex post equality, and 14% by EU-equality. Importantly, however, the changes are moderate and ranking of frequencies of justice views is preserved. Moreover, testing the goodness of fit shows that, also when using own preferences, our classification captures actual allocations pretty well. The R^2 is with 0.50 slightly lower than with believed preferences, but both the estimated constant and predicted allocation is not significantly different from 0 ($p = 0.23$) and 1 ($p = 0.45$), respectively.[22] In sum, although the exact estimated frequencies of justice types differ when assuming spectators' own preferences as opposed to using their beliefs about recipients' preferences, we can conclude that the ability of our theoretical approach to describe allocation behavior does not strongly hinge on these assumptions.

So far, we have assumed that spectators endorse one single justice view, which is either utilitarianism, capturing efficiency concerns, or one of the three principles of equality. It is however conceivable that a spectator may care about both equality and efficiency at the same time. In that case, a spectator's allocation decisions would be the result of a convex combination of the allocations predicted by one of the equality ideals and utilitarianism. To explore this idea of combined justice views, we assume that each spectator attributes a weight γ to utilitarianism and $1 - \gamma$ to one equality principle (either EV-equality, EU-equality, or ex post equality). We then use the actual allocations to estimate for each of these three combined justice ideas the best fitting value of γ at the individual level, and determine which of the resulting combined justice ideas fits the allocations best. More specifically, for each combined justice idea, we calculate the best fitting γ by minimizing the sum of squared residuals between predicted and observed allocations. The combined justice idea that yields the smallest residuals is then attributed to the spectator, along with its associated γ. Table 5 summarizes our findings.

The table shows that when combined with utilitarianism, the most frequent equality-based justice idea is EV-equality, which is attributed to 57% of the spectators. It is followed by EU-equality with 29% and ex post equality with 14%. The best-fitting weight γ on utilitarianism varies strongly with the equality-based justice ideas (mean γ: 0.76 for EU-equality, 0.31 for EV-equality, 0.33 for ex post equality). When comparing the distribution of the individual-level residuals, we observe that they are significantly smaller when allocations are predicted by combined justice ideas than when using single justice views (t-test $p < 0.01$). This is not surprising as the former adds a parameter and hence a degree of freedom, which makes it easier to capture the variability in the allocation data. Importantly, this does not necessarily imply that an approach based on combined justice views is closer to the "true" model of individual behavior.[23] Most importantly, the results for combined justice ideas confirm that there is considerable heterogeneity in spectators' views of justice under uncertainty.

Table 5. Best-Fitting Combined Justice Ideas

Equality view	Fraction of spectators (%)	Mean weight on utilitarianism (γ)
EU-equality	29	0.76
EV-equality	57	0.31
Ex post equality	14	0.33

4.3. Inequality Averse Spectators

In our experiment, spectators do not have any material stakes in the group account and we therefore assumed that they make allocation decisions according to their normative views of justice. In Section 3 (Part 2) we have argued that this assumption is justified both on theoretical and empirical grounds. It is also in line with important literature on the topic (see Konow 2000, Cappelen et al. 2013). Nevertheless, as different allocations lead to different (expected) distributions of earnings among the spectator and the two recipients, it may be conceivable that spectators are motivated by inequality aversion instead of normative justice views. In the following, we discuss this possibility.

In our experiment, spectators do not have the power to redistribute money between themselves and the recipients, as their earnings are unrelated to their choices in the allocation problems. They can however influence how recipients' expected earnings are distributed. Originally, models of other-regarding preferences were developed for decisions where the consequences of allocation decisions are known with certainty (see Fehr and Schmidt 1999, Bolton and Ockenfels 2000). Recently, Saito (2013) has developed a model of other-regarding preferences under uncertainty based on Fehr and Schmidt (1999). Importantly, Saito (2013) models a decision maker that cares both about inequality in ex ante expected payoffs and in ex post realized outcomes.

We use this model to derive a spectator's optimal allocations for each decision situation under uncertainty.

Table 6. Optimal Allocations for Inequality Averse Spectators with "Saito Utility"

<table>
<tr><th>Allocation problem</th><th>$\delta = 0$</th><th>$\delta \in [0, 1/17[$</th><th>$\delta \in [1/17, 1/5[$</th><th>$\delta \in [1/5, 1/3[$</th><th>$\delta \in [1/3, 1]$</th></tr>
<tr><td>2-Risk</td><td colspan="2">20/3</td><td colspan="3">8</td></tr>
<tr><td>3-Risk</td><td>[6, 8]</td><td colspan="4">8</td></tr>
<tr><td>4-Risk</td><td>[5, 6]</td><td colspan="3">6</td><td>8</td></tr>
<tr><td>5-Risk</td><td>[12/5, 4]</td><td colspan="2">4</td><td>6</td><td>8</td></tr>
</table>

Note. The weight put on the ex ante payoffs is denoted by δ, and $1 - \delta$ denotes the weight put on ex post payoffs.

Table 6 relates the optimal allocations to U to the relative importance of ex ante inequality aversion, captured by δ in the model.[24]

Our experiment was not designed to estimate individual spectator's values of δ and Fehr and Schmidt (1999) inequality parameters. We therefore will limit our discussion to considerations on how the model performs at the aggregate level.

A first observation is that in all allocation problems the predicted allocation to U is at most 8. Hence, the model does not capture the fact that actual allocations to U are frequently larger than 8, especially in 2-Risk and 3-Risk (32% and 29% of all allocations, respectively), but also in 4-Risk and 5-Risk (18% and 7%, respectively; see Figure 2).

Second, using the actual allocations in one decision situation, we can make inferences on the values of δ and check whether allocations in other decision situations are consistent with the model's predictions. For instance, in 5-Risk, 68% of spectators choose an allocation $x_U < 8$. Assuming that the model is correct, that would imply a $\delta < 1/3$ for this fraction of spectators (see Table 6, first and 5-Risk row). Hence, about the same fraction of spectators should choose to allocate 5 or 6 to U in 4-Risk (see Table 6, first and 4-Risk row). This however happens only for 32% of all spectators, leaving at least 36% of choices inconsistent with the model's predictions. Alternatively, one can start with the observation that in 5-Risk, 36% of spectators allocate to U an amount strictly larger than 6, which implies a $\delta \geq 1/3$. For this value of δ, we should then observe a similar share of spectators choosing allocations above 6 in 4-Risk and allocations exactly equal to 8 in 3-Risk and 2-Risk. We see, however, that in 4-Risk, 64% of spectators choose an allocation above 6, and that in 3-Risk and 2-Risk, respectively, 29% and 50% of spectators choose the equal split. Hence, although allocations patterns in 5-Risk and 3-Risk may be viewed as being consistent with the idea that spectators are inequality averse, the allocation patterns in 2-Risk and 4-Risk can hardly be reconciled with the model's predictions.

Finally, it is noteworthy that spectators characterized by $\delta > 1/3$ are predicted to choose an equal split in all allocation decisions. That is, equal allocations between recipients are optimal in all allocation problems for spectators even if they are not too much concerned about ex ante equality, while only relatively small values of $\delta < 1/3$ can justify allocating less than the equal split to U.

To summarize, the idea that spectators care about how their own earnings compare to those of the recipients is certainly appealing but does not receive strong support by our data. In addition, qualitative evidence from the responses to the debriefing questionnaire shows that spectators never refer to their own earnings when explaining their allocation decisions, but instead use arguments consistent with normative justice ideas (see Appendix D).

5. Concluding Remarks

Our study provides first empirical evidence on justice views of uninvolved decision makers (spectators) when recipients of resources are exposed to different levels of uncertainty. We find that spectators treat equally deserving recipients very differently when one of them is exposed to *uncertainty* and that there is pronounced disagreement on what constitutes a just treatment. This holds even though under *certainty* there is an implicit agreement among spectators to split resources equally between recipients. We also find that just allocations respond to the degree of uncertainty: spectators tend to allocate the less to the recipient exposed to uncertainty the higher this uncertainty is. Our study further offers a theoretical framework to think about normative justice views under uncertainty and we provide evidence that the proposed framework is able to organize spectators' allocation choices well.

Because of our subject pool and experimental design, our results are generated in the absence of large socioeconomic differences or biases due to self-interest. Thus, our results indicate that even in the absence of these potentially important factors influencing justice ideas, there is not necessarily a consensus about what constitutes just policies to tackle societal or economical problems. Therefore, it can be expected that differences in justice views are more pronounced in contexts where people also differ in socioeconomic backgrounds, ideology, or self-interest.

Although one has to be careful in drawing general conclusions from an experiment, our results suggest that heterogeneity in justice views may play an important part in the regular occurrence of controversies surrounding allocation problems with uncertain outcomes. In healthcare, the public debate in Italy regarding the issue of whether or not taking into account health risks in the allocation of health resources is an example at hand (Simoes et al. 2012). Fundamentally different views of justice may also underlie the debates among medical ethics concerning the fairness of organ allocation policies (Childress 2001, Persad et al. 2009) and the discussion on fair compensations for employees in risky jobs, such as police forces and firemen (Moore and Viscusi 1990). More generally, the observed heterogeneity of justice views helps explain how the public support for different policies may differ depending on their perceived expected effects. The results we derive are also relevant for the design of employment contracts in the private sector. In various types of businesses, individuals are assigned to projects that differ in their riskiness. Our results imply that compensations may need to be adjusted to take those different risks into account, and that individuals may disagree on the magnitudes of such compensations.

Notably, seminar and conference audiences regularly failed in correctly predicting spectators' behavior in the experiment. This anecdotal evidence demonstrates that even experts find it difficult to anticipate views of justice under uncertainty. For policy makers, this may be even more difficult. To implement sustainable policies, it seems therefore advisable for policy makers to acquire knowledge on the distribution of justice ideas. Alternatively, policy makers could propose multiple solutions inspired by justice views, and ask the population directly in referendums about their preference. Moreover, our results also show that the possibility to reach a consensus is related to the characteristics of the allocation problem: the higher the uncertainty, the more individuals' opinions may differ from each other. This suggests that reducing (perceived) uncertainty through, for example, information provision, may be a way to bring individuals' opinions on just policies closer to each other.

We consider our study as a first step toward a better understanding of people's views on justice under uncertainty. Naturally, many questions remain open that may provide interesting avenues for future research. To achieve clean comparisons, we have implemented a mean preserving spread when varying the degree of uncertainty. It would be interesting to explore whether our results generalize to other forms of uncertainty. Moreover, to avoid confounds, a special feature of our design is that recipients are equally deserving. In future research it would be interesting to investigate just allocation decisions under uncertainty when people are unequal at the outset. Our results could serve as a basis for predictions in these circumstances and help to understand how it interacts with the pluralism of fairness ideals when people differ in degrees of deservingness (Cappelen et al. 2007). Further, in our study uncertainty is exogenous and it would be interesting to investigate how justice views change when individuals choose their risk exposure (see Cappelen et al. 2013, Cettolin and Tausch 2015). Future empirical research on justice views would also benefit from the use of large representative samples, which allow investigating the individual characteristics and preferences associated to justice views.

There are many other possible extensions of our design that would allow studying other interesting and realistic situations. For example, situations where risk is affecting the outcomes of both recipients or where chances, rather than resources, need to be allocated. Given that our experiment is one of the first on the topic, we have deliberately chosen a relatively simple environment.

We have focused on justice views and, thus, on allocation decisions of uninvolved decision makers. It has been shown that when people have stakes in a distribution problem they tend to interpret fairness in a way that is beneficial for themselves (see, e.g., Babcock et al. 1995, Babcock and Loewenstein 1997, Gächter and Riedl 2005, Rodriguez-Lara and Moreno-Garrido 2012). Such self-serving biases seem to emerge especially when information on the relation between actions and outcomes can be selectively chosen or interpreted (Dana et al. 2006, 2007), which is certainly the case in environments characterized by uncertainty. Furthermore, since it has been reported that subjects strongly dislike uncertain environments (Gneezy et al. 2006), it is perceivable that stakeholders exposed to uncertainty are particularly prone to self-serving biases. Thus, another interesting extension of our study could be to investigate behavior of stakeholders who are exposed to uncertainty (similar to, e.g., in Brock et al. 2013), and relate it to possibly self-serving interpretations of justice. Our results on the prevalence and pluralism of views of justice under uncertainty provide a necessary first step for such investigations.

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Appendix A. Just Allocations Under Uncertainty: Analytical Derivations

Here, we formally derive the just allocations according to the justice views EU-equality, ex post equality, and utilitarianism, respectively, discussed in Section 2.

A.1. EU-Equality

EU-equality requires equalization of expected utilities, that is

$$E[W(x_U)] = E[W(x_C)] \quad \text{s.t. } x_U + x_C = X.$$

Assuming $W(x) = x^\alpha$, using the definition of our allocation problems (see Equation (1)) and substituting the constraint, we can rewrite the previous equations as

$$p(x_U k^H)^\alpha + (1-p)(x_U\, k^l)^\alpha = (X - x_U)^\alpha$$
$$\Leftrightarrow \; \ln x_U^\alpha + \ln(p(k^H)^\alpha + (1-p)(k^l)^\alpha) = \ln(X - x_U)^\alpha.$$

Define $Z := \ln[p(k^H)^\alpha + (1-p)(k^l)^\alpha]$ and rewrite the previous equation to

$$\alpha \ln x_U + Z = \alpha \ln(X - x_U) \;\Leftrightarrow\; \frac{X}{x_U} - 1 = \exp(Z\alpha^{-1}),$$

which after some more rearrangements gives the just allocations to U and C as

$$x_U^{\text{EU-eq}} = \frac{1}{\exp(Z\alpha^{-1}) + 1} X, \quad x_C^{\text{EU-eq}} = \frac{\exp(Z\alpha^{-1})}{\exp(Z\alpha^{-1}) + 1} X. \quad \square$$

A.2. Ex Post Equality

Ex post equality requires the minimization of inequality after uncertainty has been resolved, that is, using the definition of our allocation problems (see Equation (1)),

$$\min_{x_U, x_C} p|k^H x_U - x_C| + (1-p)|k^l x_U - x_C| \quad \text{s.t. } x_U + x_C = X.$$

Substituting the constraint, the minimization problem becomes

$$\min_{x_U} p|x_U(k^H + 1) - X| + (1-p)|x_U(k^l + 1) - X|.$$

To find the minimizing x_U, we have to distinguish three cases.

Case 1. $x_U \geq X/(k^l + 1)$ $(\Rightarrow x_U \geq X/(k^H + 1))$:

That is, $\min_{x_U} p[x_U(k^H + 1) - X] + (1-p)[x_U(k^l + 1) - X]$:

$$\frac{\partial}{\partial x_U} = p(k^H + 1) + (1-p)(k^l + 1) > 0 \;\Rightarrow$$
$$x_U = \frac{X}{k^l + 1} \text{minimizes the function.}$$

Case 2. $x_U \leq X/(k^H + 1) (\Rightarrow x_U \leq X/(k^l + 1))$:

That is, $\min_{x_U} p[X - x_U(k^H + 1)] + (1-p)[X - x_U(k^l + 1)]$:

$$\frac{\partial}{\partial x_U} = -p(k^H + 1) - (1-p)(k^l + 1) < 0 \;\Rightarrow$$
$$x_U = \frac{X}{k^H + 1} \text{minimizes the function.}$$

Case 3. $X/(k^H + 1) \leq x_U \leq X/(k^l + 1)$:

That is, $\min_{x_U} p[x_U(k^H + 1) - X] + (1-p)[X - x_U(k^l + 1)]$:

$$\frac{\partial}{\partial x_U} = p(k^H + 1) - (1-p)(k^l + 1),$$
$$\frac{\partial}{\partial x_U} > (<) 0 \quad \text{iff } \frac{k^H + 1}{k^L + 1} > (<) \frac{1-p}{p},$$

using $pk^H + (1-p)k^l = 1$(Equation (1)) this reduces to

$$\frac{\partial}{\partial x_U} > (<) 0 \quad \text{iff } k^H > (<) \frac{1-p}{p}.$$

Hence, for this case the function is minimized at

$$x_U = \frac{X}{k^H + 1} \quad \text{if } k^H > \frac{1-p}{p} \quad \text{and at}$$
$$x_U = \frac{X}{k^l + 1} \quad \text{if } k^H < \frac{1-p}{p}.$$

Combining Case 3 with Case 1 (function is increasing for $x_U \geq X/(k^H + 1)$) and Case 2 (function is decreasing for $x_U \leq X/(k^H + 1)$) and continuity of the min function in x_U it follows that the global minimum is obtained at $x_U^* = X/(k^H + 1)$ if $k^H > (1-p)/p$ and at $x_U^* = X/(k^l + 1)$ if $k^H < (1-p)/p$. Therefore, the just allocations under ex post equality are given by

$$x_U^{\text{ex post-eq}} = \frac{1}{k^H + 1} X, \; x_C^{\text{ex post-eq}} = \frac{k^H}{k^H + 1} X \qquad \text{if } k^H > \frac{1-p}{p},$$
$$x_U^{\text{ex post-eq}} = \frac{1}{k^l + 1} X, \; x_C^{\text{ex post-eq}} = \frac{k^l}{k^l + 1} X \qquad \text{if } k^H < \frac{1-p}{p}. \quad \square$$

A.3. Utilitarianism

Utilitarianism requires the maximization of the expected sum of utilities, that is

$$\max_{x_U, x_C} E[W(x_U) + W(x_C)] \quad \text{s.t. } x_U + x_C = X.$$

Again, assuming $W(x) = x^\alpha$, using the definition of our allocation problems (see Equation (1)) and substituting the constraint we can rewrite the maximization problem as

$$\max_{x_U} p(x_U k^H)^\alpha + (1-p)(x_U k^l)^\alpha + (X - x_U)^\alpha.$$

For $0 < \alpha < 1$ the function is concave and the first-order condition is given by

$$\frac{\partial}{\partial x_U} = \alpha p k^H (x_U k^H)^{\alpha-1} + (1-p)\alpha k^l (x_U k^l)^{\alpha-1}$$
$$- \alpha(X - x_U)^{\alpha-1} = 0$$
$$\Leftrightarrow \; \ln x_U^{\alpha-1} + \ln(p(k^H)^\alpha + (1-p)(k^l)^\alpha) = \ln(X - x_U)^{\alpha-1}.$$

Define $Z := \ln[p(k^H)^\alpha + (1-p)(k^H)^\alpha]$ and rewrite the previous equation to

$$\ln x_U^{\alpha-1} + Z = \ln(X - x_U)^{\alpha-1} \;\Leftrightarrow\; \frac{X}{x_U} - 1 = \exp(-Z(1-\alpha)^{-1}),$$

which after some more rearrangements gives the just allocations for risk-averse recipients as

$$x_U^{util} = \frac{1}{\exp(-Z(1-\alpha)^{-1}) + 1} X,$$
$$x_C^{util} = \frac{\exp(-Z(1-\alpha)^{-1})}{\exp(-Z(1-\alpha)^{-1}) + 1} X.$$

When considering risk-seeking recipients ($\alpha > 1$) the function to maximize is convex and, thus, the solution to the maximization problem is

$$x_U^{util} = X, \quad x_C^{util} = 0. \quad \square$$

Appendix B. Optimal Allocations of Inequality Averse Spectators

Saito (2013) introduced a model of inequality aversion under uncertainty. We use this model to derive predictions of the optimal choices of an inequality averse spectator who takes her own (expected) earnings into account when making resource allocation decisions between U and C. The "Saito utility" of the spectator is given by the value function

$$V(X) = \delta W(E_p(X)) + (1-\delta)E_p(W(X)),$$

where W corresponds to the inequity aversion model of Fehr and Schmidt (1999). In particular,

$$W(X) = x_S - \alpha\Sigma_{i=U,C}\max\{x_i - x_S, 0\} - \beta\Sigma_{i=U,C}\max\{x_S - x_i, 0\},$$

where x_S is the material payoff of the spectator, and x_U and x_C the amounts the spectator allocates to recipient U and recipient C, respectively. The term $W(E_p(X))$ captures the utility of expected payoffs and is referred to as ex ante utility. The term $E_p(W(X))$ captures the expected utility of ex post payoffs and is referred to as ex post utility. The parameter δ measures the weight the spectator puts on the ex ante utility. Following Saito (2013) we assume $\delta \in [0,1]$ and for simplicity $x_U \in [0,16]$.[25]

Proposition B.1 (Spectator's Optimal Allocation to U When Assuming Saito Utility). (1) *Assume $\alpha > 0$ and $\beta \in]0,1]$. The spectator's Saito utility maximizing allocation x_U^* to recipient U is in*

1-*Certainty*:

$$x_U^* = 8 \quad \forall\, \delta \in [0,1];$$

2-*Risk*:

$$x_U^* \in \begin{cases} \{20/3\} & \text{if } \delta \in [0, 1/17[, \\ [20/3, 8] & \text{if } \delta = 1/17, \\ \{8\} & \text{if } \delta \in\ ]1/17, 1]; \end{cases}$$

3-*Risk*:

$$x_U^* \in \begin{cases} [6,8] & \text{if } \delta = 0, \\ \{8\} & \text{if } \delta \in]0,1]; \end{cases}$$

4-*Risk*:

$$x_U^* \in \begin{cases} [5,6] & \text{if } \delta = 0, \\ \{6\} & \text{if } \delta \in]0, 1/3[, \\ [6,8] & \text{if } \delta = 1/3, \\ \{8\} & \text{if } \delta \in\ ]1/3, 1]; \end{cases}$$

5-*Risk*:

$$x_U^* \in \begin{cases} [12/5, 4] & \text{if } \delta = 0, \\ \{4\} & \text{if } \delta \in]0, 1/5[, \\ [4,6] & \text{if } \delta = 1/5, \\ \{6\} & \text{if } \delta \in]1/5, 1/3[, \\ [6,8] & \text{if } \delta = 1/3, \\ \{8\} & \text{if } \delta \in]1/3, 1]. \end{cases}$$

(2) *Assume $\alpha = \beta = 0$. In each allocation problem, the spectator's Saito utility maximizing allocation x_U^* to recipient U is any value in* $[0,16]$.

Proof. (1) The spectator's ex ante utility is given by

$$\begin{aligned} W(E_p(X)) &= E_p(x_S) - \alpha \sum_{i=U,C} \max\{E_p(x_i) - E_p(x_S), 0\} \\ &\quad - \beta \sum_{i=U,C} \max\{E_p(x_S) - E_p(x_i), 0\} \\ &= \begin{cases} 8 - \beta(8 - x_U) - \alpha(x_C - 8) & \text{if } 0 \le x_U \le 8, \\ 8 - \alpha(8 - x_U) - \beta(x_C - 8) & \text{if } 8 \le x_U \le 16, \end{cases} \end{aligned}$$

which, with $x_U + x_C = 16$, is equivalent to

$$W(E_p(X)) = \begin{cases} 8 - (\alpha+\beta)(8 - x_U) & \text{if } 0 \le x_U \le 8, \\ 8 - (\alpha+\beta)(x_U - 8) & \text{if } 8 \le x_U \le 16. \end{cases}$$

The ex post payoffs of the spectator, recipient U, and recipient C are, respectively, x_S, $k^j x_U$ ($j = H, l$), and x_C.

The payoff of the spectator is randomly determined and can take any value $x_S \in \{4, 6, 10, 12\}$ with probability 1/4 each. Hence, if $k^j = 0$ the payoff of the spectator is always larger than the payoff of recipient U and if $k^j > 0$ is equal to the payoff of recipient U if $x_S = k^j x_U$ ($\Leftrightarrow x_U = x_S/k^j$). The payoff of the spectator is equal to the payoff of recipient C if $x_S = x_C = 16 - x_U$ ($\Leftrightarrow x_U = 16 - x_S$). The terms x_S/k^j and $16 - x_S$ thus represent the *equality benchmarks* of the spectator's payoff compared to the payoffs of recipients U and C. Together with the values of k^j, these benchmarks distinguish the three following cases.

Case 1. $k^j > 0$ and $x_S/k^j \le 16 - x_S$:

$$W(X) = \begin{cases} x_S - \beta(x_S - k^j x_U) - \alpha(16 - x_S - x_U) \\ \quad \text{if } x_U \le x_S/k^j, \\ x_S - \alpha(k^j x_U - x_S) - \alpha(16 - x_S - x_U) \\ \quad \text{if } x_S/k^j \le x_U \le 16 - x_S, \\ x_S - \alpha(k^j x_U - x_S) - \beta(x_S - 16 + x_U) \\ \quad \text{if } x_U \ge 16 - x_S. \end{cases}$$

Case 2. $k^j > 0$ and $16 - x_S \le x_S/k^j$:

$$W(X) = \begin{cases} x_S - \beta(x_S - k^j x_U) - \alpha(16 - x_S - x_U) \\ \quad \text{if } x_U \le 16 - x_S, \\ x_S - \beta(x_S - k^j x_U) - \beta(x_S - 16 + x_U) \\ \quad \text{if } 16 - x_S \le x_U \le x_S/k^j, \\ x_S - \alpha(k^j x_U - x_S) - \beta(x_S - 16 + x_U) \\ \quad \text{if } x_U \ge x_S/k^j. \end{cases}$$

Case 3. $k^j = 0$:

$$W(X) = \begin{cases} x_S - \beta x_S - \alpha(16 - x_S - x_U) & \text{if } x_U \le 16 - x_S, \\ x_S - \beta x_S - \beta(x_S - 16 + x_U) & \text{if } x_U \ge 16 - x_S. \end{cases}$$

The equality benchmark for the ex ante utility is independent of the riskiness of the allocation problem and is always equal to the expected payoff of the spectator, i.e., 8. In contrast, for ex post utility, the equality benchmarks are different in each allocation problem. Based on these general results, we now explore the optimal allocation of the spectator for each allocation problem.

For each problem, the first step is to obtain all the intervals defined by the equality benchmarks. The second step is to derive the function $W(X)$ corresponding to the values of x_U in different intervals. The third step is to calculate the ex post utility. Finally, we calculate the first derivative of $V(X)$ with respect to (w.r.t.) x_U and determine the optimal allocation to U.

1-*Certainty.* In this allocation problem, ex ante and ex post utility are identical and the Saito utility is given by

$$V(X) = W(E_p(X)) = E_p(W(X)) = \begin{cases} 8-(\alpha+\beta)(8-x_U) & \text{if } 0 \le x_U \le 8, \\ 8-(\alpha+\beta)(x_U-8) & \text{if } 8 \le x_U \le 16. \end{cases}$$

Taking the first derivative of $V(X)$ w.r.t. x_U, we obtain

$$\frac{dV(X)}{dx_U} = \begin{cases} \alpha+\beta & \text{if } 0 \le x_U \le 8, \\ -(\alpha+\beta) & \text{if } 8 \le x_U \le 16. \end{cases} \tag{B.1}$$

The optimal allocation is thus 8 for all $\delta \in [0,1]$.

2-*Risk.* This problem is characterized by $p = 0.5$, $k^H = 1.5$, and $k^l = 0.5$. The values of k^H and k^l together with the distribution of x_S, yield the equality benchmarks 8/3, 4, 6, 20/3, 8, 10, and 12. Using these benchmarks, we can derive the function $W(X)$ for the different intervals for x_U.

As an example, the results for the lowest range, $0 \le x_U \le 8/3$, are shown in Table B.1. The probability in each row is derived from the probabilities of ex post payoffs of the spectator and recipient U. For example, the probability in the first row is 1/8 because the spectator receives 4 with probability 1/4 and recipient U receives $1.5x_U$ with probability 1/2.

In a similar way, values of $W(X)$, $V(X)$ and the derivatives $dV(X)/dx_U$ are computed for all other possible intervals for x_U. The derivatives are summarized in Table B.2. From the table it is clear that $V(X)$ is strictly increasing in x_U for $x_U \le 20/3$ and strictly decreasing in x_U for $x_U \ge 8$. For $20/3 \le x_U \le 8$ it holds that the first derivative is zero if $\delta = 1/17$. In that case any x_U in this interval constitutes an optimal allocation. In contrast, if $\delta < 1/17$ the optimal allocation is 20/3 and it is 8 if $\delta > 1/17$.

Table B.1. 2-Risk—$W(X)$, $V(X)$ and $dV(X)/dx_U$ for $0 \le x_U \le \frac{8}{3}$

Probability	$W(X)$
$\frac{1}{4} \times \frac{1}{2} = \frac{1}{8}$	$4-\beta(4-1.5x_U)-\alpha(12-x_U)$
$\frac{1}{4} \times \frac{1}{2} = \frac{1}{8}$	$6-\beta(6-1.5x_U)-\alpha(10-x_U)$
$\frac{1}{4} \times \frac{1}{2} = \frac{1}{8}$	$10-\beta(10-1.5x_U)-\alpha(6-x_U)$
$\frac{1}{4} \times \frac{1}{2} = \frac{1}{8}$	$12-\beta(12-1.5x_U)-\alpha(4-x_U)$
$\frac{1}{4} \times \frac{1}{2} = \frac{1}{8}$	$4-\beta(4-0.5x_U)-\alpha(12-x_U)$
$\frac{1}{4} \times \frac{1}{2} = \frac{1}{8}$	$6-\beta(6-0.5x_U)-\alpha(10-x_U)$
$\frac{1}{4} \times \frac{1}{2} = \frac{1}{8}$	$10-\beta(10-0.5x_U)-\alpha(6-x_U)$
$\frac{1}{4} \times \frac{1}{2} = \frac{1}{8}$	$12-\beta(12-0.5x_U)-\alpha(4-x_U)$
$E_p(W(X))$	$8-(\alpha+\beta)(8-x_U)$
$W(E_p(X))$	$8-(\alpha+\beta)(8-x_U)$
$V(X)$	$8-(\alpha+\beta)(8-x_U)$
$\frac{dV(X)}{dx_U}$	$\alpha+\beta$

Table B.2. 2-Risk—Derivatives $dV(X)/dx_U$ for All Intervals for x_U

Interval	$dV(X)/dx_U$
$0 \le x_U \le \frac{8}{3}$	$(\alpha+\beta)$
$\frac{8}{3} \le x_U \le 4$	$\frac{1}{16}(\alpha+\beta)(3\delta+13)$
$4 \le x_U \le 6$	$\frac{1}{8}(\alpha+\beta)(5\delta+3)$
$6 \le x_U \le \frac{20}{3}$	$\frac{1}{8}(\alpha+\beta)(7\delta+1)$
$\frac{20}{3} \le x_U \le 8$	$\frac{1}{16}(\alpha+\beta)(17\delta-1)$
$8 \le x_U \le 10$	$-\frac{1}{6}(\alpha+\beta)(11\delta+5)$
$10 \le x_U \le 12$	$-\frac{1}{16}(\alpha+\beta)(7\delta+9)$
$12 \le x_U \le 16$	$-\frac{1}{8}(\alpha+\beta)(\delta+7)$

3-*Risk.* This problem is characterized by $p = 0.8$, $k^H = 1.25$, and $k^l = 0$. Using the values of k^H and k^l together with the distribution of x_S gives thus 16/5, 4, 24/5, 6, 8, 48/5, 10, and 12 as equality benchmarks. From these benchmarks, we can again derive the function $W(X)$ in different intervals for x_U.

As an example, Table B.3 shows the results for the interval $4 \le x_U \le 24/5$. The probability in each row is derived from the probabilities of the ex post payoffs of the spectator and recipient U. For example, the probability in the first row is 1/5 because the spectator receives 4 with probability 1/4 and recipient U receives $1.25x_U$ with probability 4/5.

Similarly, we obtain values of $W(X)$, $V(X)$ and the derivatives $dV(X)/dx_U$ for all intervals of x_U. The derivatives are summarized in Table B.4. It is easily seen from the table, that if $\delta > 0$, $V(X)$ is strictly increasing in x_U for $x_U \le 8$ and strictly decreasing in x_U when $x_U \ge 8$. Hence, the optimal allocation in this case is 8. In contrast, if $\delta = 0$ the first derivative is strictly positive (negative) for $x_U < 6$ ($x_U > 8$) and zero for $6 \le x_U \le 8$. Therefore, any value in the latter interval constitutes an optimal allocation.

4-*Risk.* This problem is characterized by $p = 0.5$, $k^H = 2$, and $k^l = 0$ and the equality benchmarks are given by 2, 3, 4, 5, 6, 8, 10, and 12. As in the former problems, using these

Table B.3. 3-Risk—$W(x)$, $V(X)$ and $dV(X)/dx_U$ for $4 \le x_U \le 24/5$

Probability	$W(X)$
$\frac{1}{4} \times \frac{4}{5} = \frac{1}{5}$	$4-\alpha(1.25x_U-4)-\alpha(12-x_U)$
$\frac{1}{4} \times \frac{4}{5} = \frac{1}{5}$	$6-\beta(6-1.25x_U)-\alpha(10-x_U)$
$\frac{1}{4} \times \frac{4}{5} = \frac{1}{5}$	$10-\beta(10-1.25x_U)-\alpha(6-x_U)$
$\frac{1}{4} \times \frac{4}{5} = \frac{1}{5}$	$12-\beta(12-1.25x_U)-\beta(x_U-4)$
$\frac{1}{4} \times \frac{1}{5} = \frac{1}{20}$	$4-4\beta-\alpha(12-x_U)$
$\frac{1}{4} \times \frac{1}{5} = \frac{1}{20}$	$6-6\beta-\alpha(10-x_U)$
$\frac{1}{4} \times \frac{1}{5} = \frac{1}{20}$	$10-10\beta-\alpha(6-x_U)$
$\frac{1}{4} \times \frac{1}{5} = \frac{1}{20}$	$12-12\beta-\beta(x_U-4)$
$E_p(W(X))$	$8-(\alpha+\beta)\left(\frac{31}{5}-\frac{1}{2}x_U\right)$
$W(E_p(X))$	$8-(\alpha+\beta)(8-x_U)$
$V(X)$	$8-(\alpha+\beta)\left[(1-\delta)\left(\frac{31}{5}-\frac{1}{2}x_U\right)+\delta(8-x_U)\right]$
$\frac{dV(X)}{dx_U}$	$\frac{1}{2}(\alpha+\beta)(\delta+1)$

Table B.4. 3-Risk—Derivatives $dV(X)/dx_U$ for All Intervals for x_U

Interval	$dV(X)/dx_U$
$0 \le x_U \le \frac{16}{5}$	$(\alpha+\beta)$
$\frac{16}{5} \le x_U \le 4$	$\frac{1}{4}(\alpha+\beta)(\delta+3)$
$4 \le x_U \le \frac{24}{5}$	$\frac{1}{2}(\alpha+\beta)(\delta+1)$
$\frac{24}{5} \le x_U \le 6$	$\frac{1}{4}(\alpha+\beta)(3\delta+1)$
$6 \le x_U \le 8$	$(\alpha+\beta)\delta$
$8 \le x_U \le \frac{48}{5}$	$-\frac{1}{4}(\alpha+\beta)(3\delta+1)$
$\frac{48}{5} \le x_U \le 10$	$-\frac{1}{2}(\alpha+\beta)(\delta+1)$
$10 \le x_U \le 12$	$-\frac{1}{4}(\alpha+\beta)(\delta+3)$
$12 \le x_U \le 16$	$-(\alpha+\beta)$

benchmarks we can derive the function $W(X)$ for the different intervals for x_U.

As an example, Table B.5 shows the results for the interval $5 \le x_U \le 6$. The probability in each row is derived from the probabilities of the ex post payoffs of the spectator and recipient U. For example, the probability in the first row is 1/8 because the spectator receives 4 with probability 1/4 and recipient U receives $2x_U$ with probability 1/2.

Similarly, we obtain values of $W(X)$, $V(X)$ and the derivatives $dV(X)/dx_U$ for all intervals of x_U. The derivatives are summarized in Table B.6. Using the results from the table it is easily shown that if $\delta = 0$, the optimal allocation to recipient U is any value in the interval $[5, 6]$. If $0 < \delta < 1/3$, the optimal value is 6. If $\delta = 1/3$, any value in the interval $[6, 8]$ is optimal. Finally, with $\delta > 1/3$, the optimal amount given to recipient U is 8.

5-*Risk.* This problem is characterized by $p = 0.2$, $k^H = 5$, $k^l = 0$ and the equality benchmarks are given by 4/5, 6/5, 2, 12/5, 4, 6, 8, 10, and 12. As in the former problems, using these benchmarks we can derive the function $W(X)$ for the different intervals for x_U.

As an example, Table B.7 shows the results for the interval $6 \le x_U \le 8$. The probability in each row is derived from the probabilities of the ex post payoffs of the spectator and recipient U. For example, the probability in the first row is 1/20 because the spectator receives 4 with probability 1/4 and recipient U receives $5x_U$ with probability 1/5.

Similarly, we obtain values of $W(X)$, $V(X)$ and the derivatives $dV(X)/dx_U$ for all intervals of x_U. The derivatives are summarized in Table B.8. From the table the optimal allocations are easily obtained. If $\delta = 0$ any value in the interval $12/5 \le x_U \le 4$ is optimal, if $\delta = 1/5$ any value in the interval $4 \le x_U \le 6$ is optimal, and if $\delta = 1/3$ any value in the interval

Table B.5. 4-Risk—$W(x)$, $V(X)$ and $dV(X)/dx_U$ for $5 \le x_U \le 6$

Probability	$W(X)$
$\frac{1}{4}\times\frac{1}{2}=\frac{1}{8}$	$4-\alpha(2x_U-4)-\alpha(12-x_U)$
$\frac{1}{4}\times\frac{1}{2}=\frac{1}{8}$	$6-\alpha(2x_U-6)-\alpha(10-x_U)$
$\frac{1}{4}\times\frac{1}{2}=\frac{1}{8}$	$10-\alpha(2x_U-10)-\alpha(6-x_U)$
$\frac{1}{4}\times\frac{1}{2}=\frac{1}{8}$	$12-\beta(12-2x_U)-\beta(x_U-4)$
$\frac{1}{4}\times\frac{1}{2}=\frac{1}{8}$	$4-4\beta-\alpha(12-x_U)$
$\frac{1}{4}\times\frac{1}{2}=\frac{1}{8}$	$6-6\beta-\alpha(10-x_U)$
$\frac{1}{4}\times\frac{1}{2}=\frac{1}{8}$	$10-10\beta-\alpha(6-x_U)$
$\frac{1}{4}\times\frac{1}{2}=\frac{1}{8}$	$12-12\beta-\beta(x_U-4)$
$E_p(W(X))$	$8-\frac{9}{2}(\alpha+\beta)$
$W(E_p(X))$	$8-(\alpha+\beta)(8-x_U)$
$V(X)$	$8-(\alpha+\beta)\left[\frac{9}{2}(1-\delta)+\delta(8-x_U)\right]$
$\frac{dV(X)}{dx_U}$	$(\alpha+\beta)\delta$

Table B.6. 4-Risk—Derivatives $dV(X)/dx_U$ for All Intervals for x_U

Interval	$dV(X)/dx_U$
$0 \le x_U \le 2$	$(\alpha+\beta)$
$2 \le x_U \le 3$	$\frac{1}{4}(\alpha+\beta)(\delta+3)$
$3 \le x_U \le 4$	$\frac{1}{2}(\alpha+\beta)(\delta+1)$
$4 \le x_U \le 5$	$\frac{1}{4}(\alpha+\beta)(3\delta+1)$
$5 \le x_U \le 6$	$(\alpha+\beta)\delta$
$6 \le x_U \le 8$	$\frac{1}{2}(\alpha+\beta)(3\delta-1)$
$8 \le x_U \le 10$	$-\frac{1}{2}(\alpha+\beta)(\delta+1)$
$10 \le x_U \le 12$	$-\frac{1}{4}(\alpha+\beta)(\delta+3)$
$12 \le x_U \le 16$	$-(\alpha+\beta)$

Table B.7. 5-Risk—$W(x)$, $V(X)$ and $dV(X)/dx_U$ for $6 \le x_U \le 8$

Probability	$U(X)$
$\frac{1}{4}\times\frac{1}{5}=\frac{1}{20}$	$4-\alpha(5x_U-4)-\alpha(12-x_U)$
$\frac{1}{4}\times\frac{1}{5}=\frac{1}{20}$	$6-\alpha(5x_U-6)-\alpha(10-x_U)$
$\frac{1}{4}\times\frac{1}{5}=\frac{1}{20}$	$10-\alpha(5x_U-10)-\beta(x_U-6)$
$\frac{1}{4}\times\frac{1}{5}=\frac{1}{20}$	$12-\alpha(5x_U-12)-\beta(x_U-4)$
$\frac{1}{4}\times\frac{4}{5}=\frac{1}{5}$	$4-4\beta-\alpha(12-x_U)$
$\frac{1}{4}\times\frac{4}{5}=\frac{1}{5}$	$6-6\beta-\alpha(10-x_U)$
$\frac{1}{4}\times\frac{4}{5}=\frac{1}{5}$	$10-10\beta-\beta(x_U-6)$
$\frac{1}{4}\times\frac{4}{5}=\frac{1}{5}$	$12-12\beta-\beta(x_U-4)$
$E_p(U(X))$	$8-(\alpha+\beta)\left(\frac{39}{10}+\frac{1}{2}x_U\right)$
$U(E_p(X))$	$8-(\alpha+\beta)(8-x_U)$
$V(X)$	$8-(\alpha+\beta)\left[(1-\delta)\left(\frac{39}{10}+\frac{1}{2}x_U\right)+\delta(8-x_U)\right]$
$\frac{dV(X)}{dx_U}$	$(\alpha+\beta)\left(\frac{3}{2}\delta-\frac{1}{2}\right)$

Table B.8. 5-Risk—Derivatives $dV(X)/dx_U$ for All Intervals for x_U

Interval	$dV(X)/dx_U$
$0 \le x_U \le \frac{4}{5}$	$(\alpha+\beta)$
$\frac{4}{5} \le x_U \le \frac{6}{5}$	$\frac{1}{4}(\alpha+\beta)(\delta+3)$
$\frac{6}{5} \le x_U \le 2$	$\frac{1}{2}(\alpha+\beta)(\delta+1)$
$2 \le x_U \le \frac{12}{5}$	$\frac{1}{4}(\alpha+\beta)(3\delta+1)$
$\frac{12}{5} \le x_U \le 4$	$(\alpha+\beta)\delta$
$4 \le x_U \le 6$	$\frac{1}{4}(\alpha+\beta)(5\delta-1)$
$6 \le x_U \le 8$	$\frac{1}{2}(\alpha+\beta)(3\delta-1)$
$8 \le x_U \le 10$	$-\frac{1}{2}(\alpha+\beta)(\delta+1)$
$10 \le x_U \le 12$	$-\frac{1}{4}(\alpha+\beta)(\delta+3)$
$12 \le x_U \le 16$	$-(\alpha+\beta)$

$6 \le x_U \le 8$ is optimal. Moreover, if $0 < \delta < 1/5$ allocation 4 is optimal, if $1/5 < \delta < 1/3$ allocation 6 is optimal, and finally if $1/3 < \delta < 1$ allocation 8 is optimal.

(2) The statement follows straightforwardly from setting $\alpha = \beta = 0$ in Equation (B.1) and Tables B.2, B.4, B.6, and B.8, respectively. □

Appendix C. Goodness of Fit of Estimated Justice Types

Table C.1 shows regression results where observed allocations are regressed on predicted allocations using the classification method discussed in the main text with all four justice views and assuming spectators' believed risk preferences of recipients.

Tables C.2–C.5 show regression results where observed allocations are regressed on predicted allocations using the classification method discussed in the main text with only three justice views and assuming spectators' believed risk preferences of recipients.

Table C.1. Goodness of Fit (Using All Four Justice Views)

	Dep. var.: *Observed allocation to U*	
Predicted allocation	0.952***	(0.094)
Constant	0.750	(0.646)
N	112	
R^2	0.528	
$F_{(1,27)}$	101.69	
Constant = 0	$F_{(1,27)} = 1.35$ $p = 0.2563$	
Predicted allocation = 1	$F_{(1,27)} = 0.26$ $p = 0.6149$	

Note. OLS regression; standard errors (in parentheses) are robust to heteroscedasticity and are clustered on the 28 subjects.
***Indicates significance at the 1% level.

Table C.2. Goodness of Fit ("Utilitarian" View Dropped)

	Dep. var.: *Observed allocation to U*	
Predicted allocation	0.901***	(0.084)
Constant	1.197**	(0.556)
N	112	
R^2	0.466	
$F_{(1,27)}$	115.82	
Constant = 0	$F_{(1,27)} = 4.64$ $p = 0.0402$	
Predicted allocation = 1	$F_{(1,27)} = 1.40$ $p = 0.2466$	

Note. OLS regression; standard errors (in parentheses) are robust to heteroscedasticity and are clustered on the 28 subjects.
*** and ** indicate significance at the 1% and 5% levels, respectively.

Table C.3. Goodness of Fit ("EV-Equality" View Dropped)

	Dep. var.: *Observed allocation to U*	
Predicted allocation	0.745***	(0.115)
Constant	2.465***	(0.766)
N	112	
R^2	0.424	
$F_{(1,27)}$	41.86	
Constant = 0	$F_{(1,27)} = 10.37$ $p = 0.0033$	
Predicted allocation = 1	$F_{(1,27)} = 4.93$ $p = 0.0350$	

Note. OLS regression; standard errors (in parentheses) are robust to heteroscedasticity and are clustered on the 28 subjects.
***Indicates significance at the 1% level.

Table C.4. Goodness of Fit ("Ex Post Equality" View Dropped)

	Dep. var.: *Observed allocation to U*	
Predicted allocation	0.943***	(0.097)
Constant	0.699	(0.678)
N	112	
R^2	0.496	
$F_{(1,27)}$	94.89	
Constant = 0	$F_{(1,27)} = 1.06$ $p = 0.3112$	
Predicted allocation = 1	$F_{(1,27)} = 0.35$ $p = 0.5605$	

Note. OLS regression; standard errors (in parentheses) are robust to heteroscedasticity and are clustered on the 28 subjects.
***Indicates significance at the 1% level.

Table C.5. Goodness of Fit ("EU-Equality" View Dropped)

	Dep. var.: *Observed allocation to U*	
Predicted allocation	0.981***	(0.102)
Constant	0.595	(0.684)
N	112	
R^2	0.514	
$F_{(1,27)}$	92.76	
Constant = 0	$F_{(1,27)} = 0.76$ $p = 0.3918$	
Predicted allocation = 1	$F_{(1,27)} = 0.04$ $p = 0.8518$	

Note. OLS regression; standard errors (in parentheses) are robust to heteroscedasticity and are clustered on the 28 subjects.
***Indicates significance at the 1% level.

Table C.6. Goodness of Fit (Using All Four Justice Views and Spectators' Own Risk Preferences)

	Dep. var.: *Observed allocation to U*	
Predicted allocation	0.923***	(0.100)
Constant	0.859	(0.696)
N	112	
R^2	0.503	
$F_{(1,27)}$	84.788	
Constant = 0	$F_{(1,27)} = 1.52$ $p = 0.23$	
Predicted allocation = 1	$F_{(1,27)} = 0.60$ $p = 0.45$	

Note. OLS regression; standard errors are robust to heteroscedasticity and are clustered on the 28 subjects.
***Indicates significance at the 1% level.

Table C.6 shows regression results, where observed allocations are regressed on predicted allocations using the classification method discussed in the main text, assuming spectators' own risk preferences.

Appendix D. Answers to Debriefing Questionnaire

In the following we provide some examples of answers provided by spectators in the debriefing questionnaire, where they were asked to shortly explain their allocation decisions.

Answers are grouped into categories that correspond to the theoretically identified justice views.

Examples of answers related to EV-equality:

"I wanted to give B and C what they earned in their assignment, so 8 per person. 50% chance of 16 euros and 50% chance of 0 euro will also lead to a average earning of 8 (when repeating it very often)"

"Both scored the same amount of money. I did not want to punish C for being selected as C"

"I always allocated 8 because I thought this was most fair for C who always got the amount allocated. C earned 8 so I thought it was good to always grant him that amount. B had some random events that also influenced his earnings but since I could not influence those, I didn't take it into account"

Examples of answers related to EU-equality:

"tried to give B a bit more as he has the risk."

"compensate B with a higher amount to compensate the risk of him getting 0"

"Since B takes a higher risk, he/she deserves a higher payout to remedy the risk he/she takes"

Examples of answers related to ex post equality:

"Since it would be either five times the amount or nothing I wanted to let the amount that B could earn be equal that of C. So I gave 3 points to B (so that this person could earn 15 euros) and the remaining 13 to C. This way the least amount of points was "wasted" and could lead to an equal distribution."

"in case B is rewarded with money, the amount will be multiplied by 5. I chose this distribution in order for everyone to have almost the same outcome"

"My aim was that if B wins, B won't earn much more than C."

Examples of answers related to utilitarianism:

"Since B has greater possibilities to get 0. I allocate more to C."

"The chance was low for B to win, therefore more money to C."

Endnotes

[1] In the economic literature the terms justice and fairness are often treated synonymously. However, in moral philosophy and social choice theory these terms can conceptually differ. For instance, Pareto efficiency can be viewed as a principle (or axiom) of justice but its distributive consequences can be perceived as unfair. Similar arguments can be made for desert-based principles of justice (see, e.g., Varian 1975, Lamont and Favor 2014). The term fairness is also often invoked when referring to other-regarding behavior and/or preferences (e.g., Rabin 1993, Fehr and Schmidt 1999). To avoid confusion, in this paper we use the term justice when referring to views and decisions of *uninvolved* agents who have no stakes in the decision situation and to the term fairness when referring to views and decisions of *involved* agents.

[2] The extensive normative theoretical literature on how to assess social situations involving risk differ from the problem we consider. Nevertheless, the justice concepts discussed in this literature, utilitarianism (e.g., Harsanyi 1955), ex ante egalitarianism (e.g., Diamond 1967, Larry G. Epstein 1992), and ex post egalitarianism (e.g., Adler and Sanchirico 2006), provide important guidance in how to think about just allocations under uncertainty (see also Ben-Porath et al. 1997, Gajdos and Maurin 2004, Fleurbaey 2010).

[3] Importantly, this third-party impartiality procedure is not equivalent to the Rawlsian "veil of ignorance" (Rawls 1971), because spectators' earnings in the experiment are completely unrelated to their allocation decisions. We deliberately did not choose a "behind the veil of ignorance" approach because it has been shown that the type of uncertainty entailed by the veil of ignorance influences individuals' allocation behavior by introducing insurance purposes (Aguiar et al. 2010, Schildberg-Hörisch 2010) and strategic considerations (Gerber et al. 2014).

[4] For the importance of material efficiency concerns in resource allocations, see Engelmann and Strobel (2004). We do no want to imply that expected material efficiency may not be interesting when investigating justice under uncertainty. However, as this is the first experimental study on justice under uncertainty, we chose a setup that minimizes the potential influences of other motives.

[5] Details about parameter values chosen in the experiment are presented in Section 3. The theoretical results derived below do not dependent on these specific parameter values.

[6] We also investigated two allocation problems characterized by ambiguity. For brevity, we do not discuss them in the main text. However, we present their characteristics and the corresponding results in Online Appendix S2.

[7] In his Difference Principle, John Rawls argues, "(...) that social and economic inequalities (...) are just only if they result in compensating benefits (...) for the least advantaged members of society" (Rawls 1971, pp. 14–15). In our experiment, under risk aversion, recipient U is in the least advantaged and thus deserves to be compensated.

[8] From the spectator's viewpoint recipients do not differ in any other aspect than their exposure to uncertainty. It is therefore natural to assume that they are characterized by the same utility function.

[9] In the empirical results section we analyze our data also under the assumption of CARA and show that our results do not change substantially.

[10] The formal proofs of these and the subsequently presented theoretical results are presented in Appendix A.

[11] In our context, the related concept of Pareto efficiency does not have any discriminatory power, as any allocation satisfying $x_U + x_C = X$ is Pareto efficient.

[12] Figure S1.1 in Online Appendix S1 shows examples of the slider task.

[13] For the discussion on allocation problems characterized by ambiguity, we refer the reader to Online Appendix S2.

[14] The interval scoring rule has two advantages compared to other belief elicitation procedures. First, it is less time consuming and less cognitively demanding then eliciting the probabilities over all possible events. Second, the interval scoring rule allows inferences that are valid under any degree of subjects' risk aversion and not only when subjects are risk neutral (Schlag and van der Weele 2015).

[15] All reported statistical tests are two-sided.

[16] Further, below we also discuss the implications when using spectators' elicited own risk preferences.

[17] Formally, α is chosen such that $\min_\alpha \sum_{i=1}^{6}[(p_i y_i^\alpha + (1-p_i)z_i^\alpha)^{1/\alpha} - ce_i]^2$, where the first term in brackets indicates the theoretically predicted certainty equivalent for lottery i and ce_i is the elicited believed certainty equivalent of lottery i. To correct for heteroscedasticity, lotteries are normalized to uniform length.

[18] We find that men and women do not differ in their believed risk preferences (male $\alpha = 0.73$, female $\alpha = 0.72$; Mann–Whitney test, $p = 0.75$).

[19] In line with the literature (Eckel and Grossman 2008), female participants have more risk-averse own risk preferences than male participants, although not statistically significantly so (male $\alpha = 0.82$, female $\alpha = 0.74$; Mann–Whitney test, $p = 0.46$).

[20] The regression Table C.1 can be found in Appendix C. We have also estimated the frequency of different justice views assuming that spectators' believed risk preferences are represented by a CARA utility function for money. We find that the distribution of types slightly differ from using the CRRA specification. Importantly, we still find that spectators seem to have fundamentally different views of justice under uncertainty. However, we also find that goodness of fit under the CARA assumption is much worse (coeff. of constant: 3.897, $F(1,27) = 5.14$, $p = 0.032$; coeff. of predicted allocation: 0.467, $F(1,27) = 4.24$, $p = 0.049$; $R^2 = 0.21$). Therefore, we consider the CRRA specification as a better representation of spectators believed risk preferences.

[21] Tables C.2–C.5 in Appendix C report the regression and test results. We have also explored classifications using only two or one of the theoretical justice views. In all cases, these categorizations perform worse (regression and test results are available from the authors upon request).

[22] Table C.6 in Appendix C reports the regression and test results.

[23] In fact, when we regress the observed allocations on the ones predicted by each spectator's combined justice view (like we did above when assuming single justice views), we find that the intercept is marginally significantly different from 0 (coeff.: −1.216, $F(1,27) = 3.77$, $p = 0.063$) and the coefficient of the predicted allocations is significantly different from 1 (coeff: 1.21, $F(1,27) = 4.84$, $p = 0.036$). Due to the increased degree of freedom, the R^2 is with 0.62 somewhat higher than for single justice views. These results suggest that combining justice views allows capturing a larger fraction of the variability in the data, but provides a worse fit than achieved when using single justice views.

[24] We focus on strictly inequality averse spectators and on allocation problems with uncertainty. For narrowly selfish spectators any allocation $x_U \in [0,16]$ is optimal in each allocation problem. In 1-Certainty inequity averse spectators' optimal allocation to U is 8. In Appendix B the model of Saito (2013) is described in more detail, and we provide the proof of the results shown in Table 6.

[25] The results can be easily adapted for integer values of x_U.

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