



Are risks over multiple attributes traded off? A case study of aid[☆]

Lata Gangadharan^a, Glenn W. Harrison^{b,1,*}, Anke D. Leroux^a

^a Department of Economics, Monash University, Australia

^b Department of Risk Management & Insurance and Center for the Economic Analysis of Risk, Robinson College of Business, Georgia State University, USA

ARTICLE INFO

Article history:

Received 21 August 2018

Revised 17 May 2019

Accepted 18 May 2019

Available online 13 June 2019

JEL classification:

D01

C91

D91

Keywords:

Multi-attribute risk preferences

Non-monetary risks

Correlation aversion

Experiment

ABSTRACT

Understanding decisions in situations involving multiple risks is vital in many contexts, including the provision of aid to developing countries. Aid typically involves trade-offs over multiple, desirable, but risky outcomes. We partner with an aid organisation and design a laboratory experiment to investigate multi-attribute risk preferences in the context of donations to risky aid projects. We find significant differences between attitudes over single risk outcomes in monetary and non-monetary domains. Our results show that individuals are generally multi-attribute risk averse and view aid outcomes as substitutes rather than complements. These preferences of donors contrast sharply with the views of experts and aid agencies, who tend to emphasise the complementary nature of aid outcomes. Finally, when individuals make risky donation decisions with their own money rather than someone else's money, the degree of risk aversion decreases markedly.

© 2019 Elsevier B.V. All rights reserved.

1. Introduction

How do we make decisions when outcomes are subject to risk? Economists have produced a rich theoretical and empirical literature on attitudes towards single risks. To date comparatively little empirical attention has been given to situations that involve multiple, risky outcomes. Yet such situations are commonplace. For example, physicians decide about health care, which consists of multiple outcomes, all of which are associated with inherently different levels of clinical risk. Similarly, development interventions are frequently designed to achieve the dual objectives of poverty reduction and natural resource protection, both of which are subject to risk. We examine decision making in the important context of aid where individuals face risks on single and multiple outcomes and in different domains.

Global spending on foreign aid is substantial and amounts to around USD 500 billion annually. The vast majority of foreign aid targets specific sectors, projects or outcomes, with only a tiny fraction spent on non-specific objectives (OECD, 2015). In addition to aid given by foreign governments to improve developmental outcomes in poor countries, private

[☆] The authors thank the editor and two anonymous reviewers, Paul Raschky and Tim Cason for helpful comments and suggestions. Funding from the Cooperative Research Centre for Water Sensitive Cities (CRC grant number 20110044) is acknowledged.

* Corresponding author.

E-mail addresses: lata.gangadharan@monash.edu (L. Gangadharan), gharrison@gsu.edu (G.W. Harrison), anke.leroux@monash.edu (A.D. Leroux).

¹ Harrison is also affiliated with the School of Economics, University of Cape Town.

donors also contribute significantly towards these outcomes. Individual preferences matter not only for the donation decisions of individuals but also because they are reflected in the allocation of aid provided by the public sector. Importantly, an individual's preferences over aid projects may differ depending on whether private or public funds are used. This issue remains largely unexplored and is a potential reason for why we may observe preference heterogeneity amongst individuals when we study the use of public versus private funds for aid provision.

Preference heterogeneity may arise due to the risky and multidimensional nature of aid. Aid is inherently risky, in the sense that the final outcomes of aid projects depend on many factors that are outside the control of donors. Risk may or may not be explicitly acknowledged to donors, and can have a variety of causes ranging from corruption and geographical or technological challenges to adverse weather and natural disasters. Brock et al. (2013) investigate the preferences of individuals for giving in risky settings where perceptions of fairness behavior are related to *ex ante* comparisons of opportunities or, as in our study, *ex post* comparisons of outcomes. Similarly, Exley (2016) investigates the effect on contributions when the charitable outcome is subject to risk and finds significant reductions in donations even when the risk is small. In addition to investigating risk attitudes over single outcomes, we investigate preferences and behavior when more than one outcome is subject to risk.²

Aid projects commonly target many outcomes simultaneously. For example, the distribution of solar lamps in developing countries aims at improving educational outcomes by enabling children to study after dark as well as reducing emissions by replacing kerosene lamps with a solar-powered lamp (SolarAid, 2018; Stojanovski et al., 2018). In the health domain, aid agencies often promote the multipronged approach of improving water, sanitation and hygiene (WASH) jointly to combat waterborne diseases.

It is not clear, however, how individual donors trade-off different aid outcomes. The charitable giving literature has investigated the relationship of an individual's giving to multiple organizations. For example, de Oliveira et al. (2011) find that there are “giving types:” people who give in many instances and across many charities (such as charities targeted towards education, health and job training) as opposed to people who seldom or never give. In contrast, we keep the aid organization the same but have multiple outcomes that serve the purpose of improving the health and well-being of disadvantaged people. Also, in our setting these outcomes are subject to risk.

Moreover, while aid outcomes in the solar lamp example are substitutes since improvements in educational outcomes are not necessary to achieve emission reductions, aid agencies clearly promote the complementarity across WASH initiatives. It is an open question as to whether individual donors perceive aid outcome substitutability or complementarity in accordance with expert opinion and how these perceptions affect donation behaviour. To answer these questions, we design a unique experiment that allows us to disentangle multi-attribute risk attitudes from perceived outcome complementarity.

We partner with a well-established aid organisation to accurately describe individual preferences with respect to risky aid. In particular, the problem of insufficient control in the field, needed to allow one to investigate these subtle conceptual issues, is circumvented by conducting laboratory experiments that use simple treatments over well-defined risks and aid outcomes. The partner organisation has the added advantage of allowing donors to target specific aid outcomes, making it the ideal conduit to bring together our research investigation on risk and multiple outcomes.

We implement a three-part experimental, within-subject design, where in Part 1 participants decide over binary lotteries with monetary outcomes. In Parts 2 and 3 the decisions involve respectively experimenter donation and own donation decisions over binary aid lotteries where single and multiple outcomes for the beneficiaries of the aid project are subject to risk.

This design allows us to first analyze the extent to which risk preferences differ across monetary outcomes in Part 1 and non-monetary outcomes in subsequent parts. This part of the design builds on the risk elicitation method developed by Holt and Laury (2002) and contributes to the extensive analysis of single attribute risk. Second, we investigate attitudes towards the presence of multiple risks. Is the type of aid project chosen one that is likely to achieve one good outcome with near certainty at the cost of almost surely failing all others, one that might achieve just passable outcomes across all objectives, or one that either succeeds or fails in all domains? Are these risks traded off in an additive manner? Our novel experimental design in Parts 2 and 3 involves participants choosing amongst different kinds of aid projects, all of which have risk associated with them. In some cases participants choose amongst projects, targeting a single risky outcome, while other choices are over aid projects that target multiple risky outcomes. In the case of aid projects with multiple outcomes, we vary the extent to which outcome risks are correlated.

Third, the effect of using private versus public funds to administer aid on observed preferences is examined by comparing donation decisions made by the participants when using their own money in Part 3 with decisions that the same participants make in Part 2, knowing that the donation is taken out of the experimenter's fund.

In terms of preference ranking our results indicate that individuals have a clear preference for *monetary outcomes* to themselves over *non-monetary outcomes* for aid recipients. Within this latter category we find that one aid outcome is also preferred over the other. We are able to identify this aspect of preferences over different attributes of risk because we avoid reducing all attributes to their monetary equivalent. Doing so would mimic the workings of a complete market between these attributes, a convenient modelling assumption but one that we find unattractive for the applications that interest us.

² Our treatment of multi-attribute risk allows for utility dependence and is therefore distinct from multi-attribute risk assessment decision models that typically assume additive utility across outcomes (Ananda and Herath, 2005; Brito and de Almeida, 2009).

Similarly, in terms of single attribute risk attitudes, we find significant differences in attitudes towards risks in *monetary* versus *non-monetary* (aid) outcomes. Across the different *non-monetary outcomes*, average risk attitudes are indistinguishable. We also find that individuals are on average averse to *multi-attribute risk* in non-monetary settings, implying that donors faced with multiple risky aid outcomes will apply an overall risk premium comprising the risk premia for each singular outcome risk as well as a premium for the joint risk. Our result that multi-attribute risk aversion is less pronounced when subjects make risky donation decisions with their own money rather than someone else's money suggests that the joint risk premium is highest when evaluating contributions to aid projects made by a third party, such as Government Aid.

These insights contribute to the growing application of models of tradeoffs over risky attributes. For example, [Bommier \(2006, 2010, 2013\)](#) applies multi-attribute risk aversion to the idea that agents know that they have finite lives, but do not know when they will die. This is a naturally-occurring and pervasive time-dated risk, and concepts of correlation aversion then have sharp implications for the characterization of discounting, portfolio choice, and life-cycle behavior. One could easily imagine extensions of our application to consider risk management choices, in the form of investments in health or location to improve one's chances of living longer. Or extensions to consider another attribute, the quality of life, as well as longevity *per se*.

[Section 2](#) provides a brief exposition of the theoretical framework tested. The experimental design and procedures are described in [Section 3](#). The results of the data analysis are presented in [Section 4](#), followed by a discussion of limitations and extensions of our research in [Section 5](#). [Section 6](#) concludes.

2. Theoretical framework

Modelling an individual's choices over risky aid projects requires a theoretical framework that is able to handle multiple outcomes that are subject to potentially correlated risks. A utility function that is non-additively separable in its multiple attributes has been shown to be sufficiently rich to allow for context-dependent risk preferences over single risks as well as aversion to multiple risks ([Richard, 1975](#); [Keeney and Raiffa, 1976](#); [Bommier, 2007](#); [Andersen et al., 2018](#)). By assuming Expected Utility Theory (EUT) with constant relative risk aversion we have opted for a familiar functional form that allows us to demonstrate simply and clearly the behavioral insights that can be gained by allowing interactions amongst multiple risky attributes. There is also evidence that EUT characterizes well the behavior of roughly 50% of subjects in traditional lab settings, when risk preferences are estimated at the level of the individual (e.g., [Harrison and Ng, 2016](#)). Relaxing the special case of EUT to estimate a more general utility functional form is feasible but comes at the cost of added complexity.

In our setting we have both monetary and non-monetary outcomes that are subject to risk. The risk to the monetary outcome is borne by the individual. The same individual then makes donation decisions over aid projects where the non-monetary outcomes for the recipients are subject to risk. We focus on two kinds of non-monetary outcomes, access to safe water and sanitation.

We define a multi-attribute utility function over the utilities derived from the aid outcomes in terms of water access, x , and sanitation, y , as well as experimental income, m :³

$$U(X, Y, M) = (1 - \beta) \left(\frac{((1 - \alpha)u(x) + \alpha u(y))^{(1-\eta)}}{1 - \eta} \right) + \beta u(m), \quad (1)$$

where $x \in X$, $y \in Y$ and $m \in M$. The expressions $u(x) = x^{(1-r_w)}/(1 - r_w)$ and $u(y) = y^{(1-r_s)}/(1 - r_s)$ are, respectively, the utilities derived from the uncertain water access and sanitation outcomes as a result of donations to aid projects. The utility derived from the subject's earnings in the experiment is given by $u(m) = m^{(1-r_m)}/(1 - r_m)$. The parameters r_w , r_s and r_m may be interpreted as attribute-specific or good-specific risk aversion parameters. Given the distinctive nature of the outcomes we consider, we allow for $r_w \neq r_s \neq r_m$. We assume that the non-monetary outcomes, water access and sanitation, enter the utility function in a separable but non-additive manner, whereas experimental income is a purely additive term. The weights α and β describe, respectively, the relative preferences across non-monetary attributes and between monetary and non-monetary attributes. For example, $\beta > 0.5$ implies that participants attach more importance to their own monetary outcomes than to the non-monetary outcomes to aid recipients. Similarly, if $\alpha > 0.5$ then improving sanitation is considered more important than providing access to safe water.

Following [Kihlstrom and Mirman \(1974\)](#) (KM), and extending the definition of single attribute risk aversion to the multi-variate case, gives rise to the most general description of multi-attribute risk preferences: an agent, preferring the expected value vector of outcomes over the utility of the corresponding random outcome vector is said to be multi-attribute risk averse.⁴ In our utility specification (1), the curvature of the multi-attribute utility function over x and y is given by the parameter η , so that $\eta < 0$, $\eta = 0$ and $\eta > 0$ represent, respectively, multi-attribute risk loving, multi-attribute risk neutrality and multi-attribute risk aversion.

Multi-attribute risk aversion, $\eta > 0$, incorporates the special case of correlation aversion, a term coined by [Epstein and Tanny \(1980\)](#). Correlation aversion describes the case where agents prefer outcome risks to be negatively correlated, thus

³ Experimental income is defined as total experimental earnings minus total donations.

⁴ This definition has the advantage of spanning n attributes, but its validity in terms of comparing risk aversion across multi-attribute utility functions is restricted to those utility functions that maintain the same preference ordering over non-stochastic outcomes. This restriction is appropriate for comparisons defined over a single decision-maker or, as in our case, a "representative agent."

effectively allowing them to hedge risks across attributes rather than having to face the possibility of complete failure across all attributes. A necessary condition for aversion to correlated outcome risks is that attributes are seen as substitutes rather than complements. This implies for our specific application to aid that finding our participants to be correlation averse would be at odds with the expert view that water access and sanitation are complementary in the fight against water-borne diseases. In effect, donors would prefer that aid agencies trade off risks across aid attributes, rather than opting for extreme outcomes that allow the risk of complete failure across attributes. Aid agencies never present aid packages this way, but it is an implication of stressing the complementarity of water access and sanitation.

Borrowing from the formal literature on the complementarity of goods, reviewed by Samuelson (1974), allows us to identify the link between multi-attribute risk aversion and the complementarity of consumption goods. Formally, the Edgeworth-Pareto condition of substitutability between x and y requires that $\frac{\partial^2 u}{\partial x \partial y} < 0$, which holds in our utility specification (1) when $\eta > 0$ and is consistent with correlation aversion. On the other hand, if the results of our experiment indicate that $\eta < 0$, the interpretation becomes ambiguous since this could arise due to multi-attribute risk loving preferences or from the complementarity between x and y , defined as $\frac{\partial^2 u}{\partial x \partial y} > 0$ and requiring $\eta < 0$. Setting $\eta = 0$ implies additively separable preferences in x and y , which is appropriate if one assumes multi-attribute risk neutrality. Informally, evidence for (greater) correlation aversion with respect to aid attributes is consistent with evidence for (greater) substitutability between attributes.

We leverage the complementarity interpretation of η to design a unique experiment that allows us to disentangle empirically multi-attribute risk aversion from complementarity in consumption. In doing so, we combine the two broad strands of the theoretical literature on multi-attribute risk aversion and correlation aversion in our experimental design.⁵ Building on early works by de Finetti (1952) and Richard (1975) [FR], we define multi-attribute risk aversion in the sense of correlation aversion over decisions between binary lotteries with identical, but arbitrary, marginal probabilities. Let $x_0, x_1 \in X$ denote, respectively, low and high water security outcomes, $x_0 < x_1$. Similarly, $y_0, y_1 \in Y$ are low and high sanitation outcomes, $y_0 < y_1$.⁶ Given the two lottery options

$$\text{Option A} = \begin{cases} x_1, y_0 & \text{w.p. } p \\ x_0, y_1 & \text{w.p. } 1-p \end{cases} \quad \text{and} \quad \text{Option B} = \begin{cases} x_1, y_1 & \text{w.p. } p \\ x_0, y_0 & \text{w.p. } 1-p \end{cases}$$

an agent is averse to correlated outcome risk if Option A is preferred to Option B for $p = 0.5$. Our experiment extends the probability space to $0 \leq p \leq 1$ so as to provide a richer experimental test of the extent of correlation aversion. The ambiguity arises in this setting if Option B is preferred, since this could imply correlated risk loving preferences or that x and y are seen as complements, therefore resulting in any Option that yields asymmetric payoff across the two attributes being rejected.

To parse out this distinction, we also present subjects with a modified set of bivariate KM lotteries, which exemplify multi-attribute risk aversion in its most general form: given a vector of random outcomes (X, Y, \dots, Z) , a multi-attribute risk averse agent is said to prefer the expected value vector over the utility of the corresponding random outcome vector, for any (X, Y, \dots, Z)

$$U[E(X), E(Y), \dots, E(Z)] \geq U(X, Y, \dots, Z).$$

We adapt this notion of multi-attribute risk aversion to our experimental setting by modifying the “safe” lottery Option A from FR to yield medium level outcomes, $0.5(x_0 + x_1)$ and $0.5(y_0 + y_1)$, for each attribute with probability p as well as $(1-p)$, such that

$$\text{Option A} = \begin{cases} 0.5(x_0 + x_1), 0.5(y_0 + y_1) & \text{w.p. } p \\ 0.5(x_0 + x_1), 0.5(y_0 + y_1) & \text{w.p. } 1-p \end{cases} \quad \text{and} \quad \text{Option B} = \begin{cases} x_1, y_1 & \text{w.p. } p \\ x_0, y_0 & \text{w.p. } 1-p \end{cases}$$

Hence, both lottery options are equally acceptable if the complementarity between x and y is considered to be a sufficiently important characteristic. However, a clear choice prediction can be made on the grounds of risk: a multi-attribute risk loving individual prefers Option B over Option A. In contrast, someone who prefers Option A over Option B exhibits multi-attribute risk aversion in the sense of KM: it is better to donate to a project that achieves medium level outcomes in both attributes for sure over one that may achieve good outcomes in both attributes or in neither.

The structural framework outlined above enables the investigation of the following three research questions. Do individuals exhibit different levels of risk aversion when choosing over risky monetary versus risky aid outcomes? Is there evidence of multi-attribute risk aversion when multiple attributes are subject to risk? And finally, do individuals exhibit different (risk) preferences when making decisions about aid using public funds instead of their own money?

3. Experimental design

3.1. Overview

The experiment involves donations to WaterAid, an international aid organisation that provides water, sanitation and hygiene (WASH) related services to combat waterborne diseases in developing countries. According to WaterAid's philosophy

⁵ See Finkelshtain et al. (1999) and Dorfleitner and Krapp (2007) for helpful discussions of this literature.

⁶ Assuming non-satiation in each attribute, we assume $U(x_0) < U(x_1)$ and $U(y_0) < U(y_1)$.

Table 1
Main design features of the experiment.

Features	Part 1	Part 2	Part 3
Lotteries	Monetary lotteries	Aid lotteries	Aid lotteries
Attributes	Single	Single and joint	Single and joint
Number of decisions	10	30	30
Risk borne by	Subject	Aid recipients	Aid recipients
Payoff consequences for	Subject	Aid recipients and experimenter	Aid recipients, experimenter and subject

WASH services are highly complementary as each service targets a distinct root cause of waterborne diseases in developing countries. Donations to WaterAid can be made easily and verifiably online, and it is possible to specify whether the donor is an individual or a group. The contribution is designated to the overall cause or to a specific objective, such as improving water security, sanitation or hygiene education. For the purpose of the experiment we focus on two outcomes of WASH projects: water security and sanitation.

In accordance with WaterAid's definition, water security is explained to our subjects as the reliable access to water of sufficient quantity and quality for basic human needs, small-scale livelihoods and local ecosystem services, coupled with a well-managed risk of water-related disasters. In the experiment, water security outcomes are measured in terms of the number of people gaining water security.

As distinct from water security, sanitation is the provision of services for the safe disposal of human faeces and urine and the maintenance of hygiene. The sanitation outcome is explained to our subjects as the provision of hygiene education and sanitation. WaterAid estimates that providing 1000 people with improved sanitation will prevent on average one death that is attributable to the lack of hygiene and sanitation. In the experiment, sanitation outcomes are quantified in terms of disability-adjusted life months (DALMS) gained for each member of a poor family of four.⁷

The outcomes from any aid project are subject to risks. In the case of WASH services the risks are often technology, weather and location specific. With respect to providing water security a number of different technology options exist to provide clean water to individuals and communities in rural areas of developing countries. Examples of technologies are hand-dug wells, boreholes and gravity flow schemes. These technologies not only differ in their costs and the level of water security they offer, but some technologies may not be feasible in some settings. Similarly for sanitation outcomes, the cost/benefactor ratio is determined by the type and durability of the sanitation equipment installed and by how many people have convenient access to the sanitation services and are exposed to the hygiene education provided.⁸

Thus, from a donor's perspective, both the water security and sanitation outcomes that result from a given donation to water security or sanitation and hygiene are subject to risk. This risk was described to the subjects and a draw from the bingo cage mimics this randomness for subjects in the experiment.⁹

Table 1 gives an overview of the experimental design, comprising three parts. As shown in the experimental timeline in Fig. 1, the three parts are presented in sequential order for half the sessions while, for the remainder, Parts 2 and 3 are reversed.¹⁰

Throughout the experiment, subjects make 70 consecutive choices over pairwise lotteries. In Part 1 ten of these choices yield monetary payoffs to the participants, while the remaining choices in Parts 2 and 3 yield water security or sanitation outcomes for the aid recipients, or a combination of these. The important difference between Parts 2 and 3 is that the

⁷ The units of measurements are based on information that WaterAid publishes on its website about the costs of providing particular services and the number of benefactors of these services in different countries (<http://www.wateraid.org/au>, 2012). The cost and outcome information from ten developing countries in Africa and South East Asia where WaterAid is currently operating indicates that giving access to safe water costs on average \$2.50 (AUD) per person. A unit of the sanitation outcome is scaled to match the average cost of providing a unit of the water security outcome: the average cost of providing one DALM to each member of a poor family of four is also \$2.50. At the time of the experiment the exchange rate was approximately 1 Australian Dollar (AUD) = 1.02 U.S. Dollars (USD).

⁸ Technologies that are used to provide water security in developing countries range in cost from AUD 250 to AUD 17,000 and in terms of benefit from providing water from 100 to 1,000 people. Similarly, the statistics on sanitation and hygiene education services show a large variation in costs from AUD 10 to AUD 14,000 and number of benefactors ranging from one family to 50,000 people.

⁹ Our use of random draws to mimic the risk of the final aid contribution is one 'artefactual' approach to evaluating attitudes to these risks. It has the advantage of inducing control over the specific risks, so that we could confront subjects with a battery that allowed us to infer multi-attribute risk aversion in a manner consistent with our theoretical framework in Section 2. It has the disadvantage that, in the end, a deterministic aid contribution is made on behalf of the subjects, and that aid contribution is subject to risk that might differ from those we induced. An alternative, 'natural' approach would have been to elicit subjective beliefs about these risks from individual subjects, using procedures such as those developed by Harrison et al. (2017), and then infer the 'aid lottery' perceived by the subject using those beliefs. This approach is closer to how the subject would naturally perceive the aid contribution decision, given the motivation provided in our instructions, but would have made it harder to draw clear inferences about multi-attribute risk aversion, since we would have to construct the appropriate battery in 'real time' rather than prior to the experiment. In principle this more elaborate design could be implemented, particularly over several sessions for the same subject. We thank a referee for stressing this distinction between our 'artefactual' approach and the more natural approach.

¹⁰ In the Appendix (Appendix B) we describe in detail the sequence in numerical order. Altering the sequencing in the experiment allows us to control for order effects. It is possible that after making decisions that lead to donations made from the funds of the experimenter, the subject may want to free ride on the experimenter's donation and not donate in Part 3. Changing the order of these two parts allows us to test for this effect. We do not find any order effects.

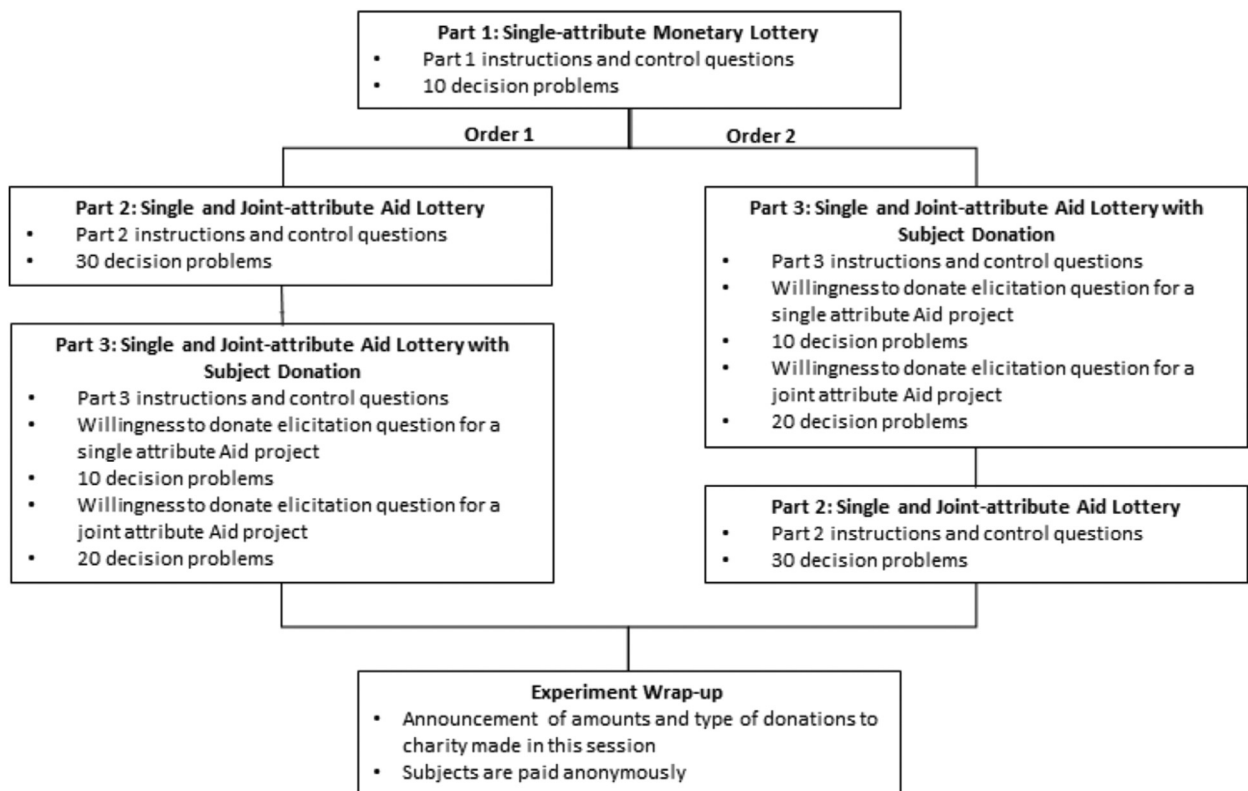


Fig. 1. Timeline of the experiment.

donation is made from the experimenter's funds in Part 2, while subjects donate their own money in Part 3. Over the course of the experiment the pairwise lottery choices are sequentially built up to the type of decision tasks shown in Fig. 2. These tasks, presented in Part 3 of the experiment, involve pairwise lotteries that are specified over multiple non-monetary attributes, whereby a price is connected to each lottery. We describe the experiment by starting from Part 3 for ease of explanation, even though as the instructions indicate subjects participated sequentially from Part 1 to Part 3.¹¹

3.2. Joint outcome lotteries with subject donation

The choice task shown in Fig. 2 embeds all arguments of Eq. (1) in the sense that subjects are asked to choose over two aid projects with multiple, risky outcomes, each associated with a unique donation amount to be made by the subject. The aid projects are described as Options A and B and yield different water security and sanitation outcomes to recipients in developing countries. Subjects are also given an opt-out Option C that carries no donation and no water security or sanitation benefits.¹²

The water security and sanitation outcomes for each Option are subject to risk. The subject specific example shown in Fig. 2 corresponds to line 5 in payoff Table 2. In this example, there is a 50–50 chance that donating AUD 10.36 to Option A provides either 4 people with access to safe water and prolongs the life of each member of a family of four by 3 healthy life month or provides 3 people with access to water and prolongs the life of each member of a family of four by 4 healthy life months. In contrast, donating AUD 11.20 to Option B yields a 50–50 chance that either seven people are given access to safe water and the life of each member of a family of four is prolonged by seven healthy life months or provides only 1 person with access to safe water and prolongs the life of each member of a family of four by one healthy life month. Hence, Option A may be considered the safer choice since it guarantees at least a medium level of water security and sanitation provision. In this decision block, subjects were shown 10 pairwise lotteries with identical payoffs and an opt-out option and only the payoff probabilities and donation amounts varied as shown in Table 2.

¹¹ We provide a condensed description of the experiment here. Additional detail and a full set of experimental instructions can be found in Appendices A and B.

¹² The opt-out Option C was added to ensure that no one would be forced to donate if they did not want to. There is some evidence from stated-choice experiments, reviewed by Harrison (2014), that providing this “opt-out” Option mitigates hypothetical bias (e.g. List et al., 2006). Of course, our experiments were not hypothetical.

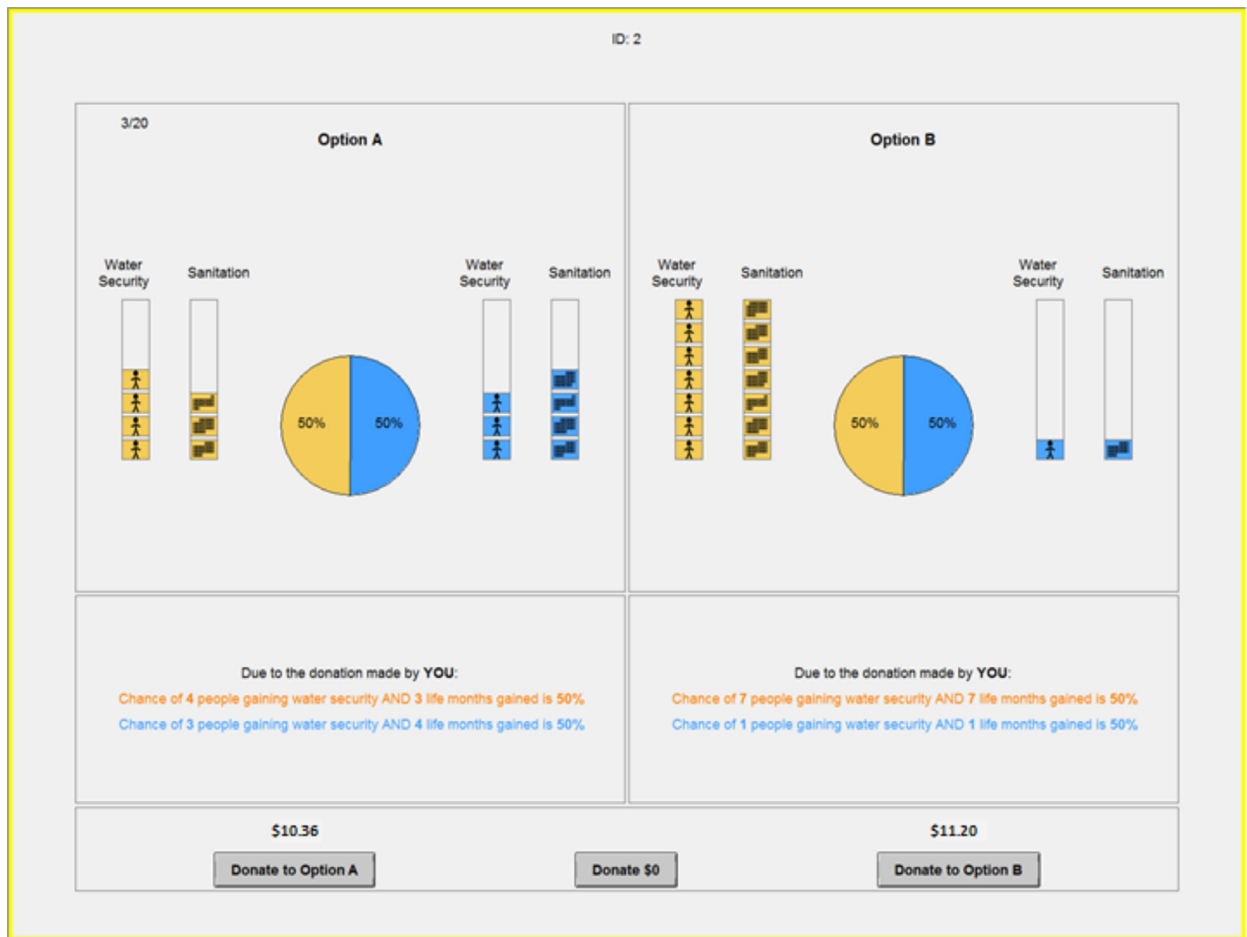


Fig. 2. Example of a joint-attribute KM (Kihlstrom and Mirman) decision problem from Part 3 with subject specific donations.

Notes: donation amounts are based on elicited willingness to donate \$12.60 for a project achieving a single aid outcome and \$19.60 for a project achieving both aid outcomes. This decision task corresponds to line 5 in Table 2.

Table 2

Illustrative payoffs for a KM lottery game over joint risky outcomes, water security (x , outcome in number of people gaining access to safe water) and sanitation (y , outcome in number of life months saved per family), with donations based on an elicited willingness to pay of \$19.60.

Payoff (x, y)	Option A		Option B		Donation (\$) ^a		EP(A) – EP(B) (\$)
	Left (4,3)	Right (3,4)	Left (7,7)	Right (1,1)	Option A	Option B	
Probabilities	0.1	0.9	0.1	0.9	9.80	6.61	2.13
	0.2	0.8	0.2	0.8	9.80	7.62	1.46
	0.3	0.7	0.3	0.7	9.80	8.62	0.78
	0.4	0.6	0.4	0.6	9.80	9.63	0.11
	0.5	0.5	0.5	0.5	10.36	11.20	–0.56
	0.6	0.4	0.6	0.4	11.03	12.88	–1.23
	0.7	0.3	0.7	0.3	11.70	14.56	–1.90
	0.8	0.2	0.8	0.2	12.38	16.24	–2.58
	0.9	0.1	0.9	0.1	13.05	17.92	–3.25
	1.0	0.0	1.0	0.0	13.72	19.60	–3.92

^a The donation amounts for Options A and B are calculated based on the participants stated willingness to donate to a charitable single attribute project (\$12.60 for this example) as well as the stated amount for a project resulting in water and sanitation benefits (\$19.60 in this example). Opting for the risk neutral choice pattern (Option A for lines 1–4 and Option B for lines 5–10) will result in paying the expected value of the choice, whereas deviations from this choice pattern come at a cost premium equal to the absolute value of entries in last column.

ID: 2

Part 3

Your total earnings are:

Initial endowment	\$20.00
Part 1 earnings	\$0.60
Total earnings	\$20.60

To give you some idea of how the money donated would be spent:

A \$5 dollar water donation would give 2 poor people access to safe water
 A \$10 dollar water donation would give 4 poor people access to safe water
 A \$20 dollar water donation would give 8 poor people access to safe water

How much of your experimental earnings are you willing to donate to a **water project** (you can donate any amount between zero and your total earnings)?

Your donation: \$

Fig. 3. Example of elicitation of willingness to donate to a charitable project with water security benefits (Part 3).

The donation amounts presented are calculated for each participant and lottery, using two willingness-to-donate elicitation questions pertaining to projects with single and multiple attributes (an example of the first type is shown in Fig. 3).¹³ This ensures that subjects are presented with decision tasks that offer donation amounts within the range of their own stated willingness to donate. Moreover, eliciting donations amounts to single and multiple outcome projects circumvents the need to exogenously impose a (restrictive) functional form on the relationship between the number of outcomes targeted and the amount subjects might be willing to donate.

Joint lotteries such as the one described above are necessary to determine the curvature of the joint utility function $U(X,Y)$ and hence help infer the value for η . In order to distinguish Option B choices that are due to a multi-attribute risk loving preferences from Option B choices that are motivated by aid outcomes being seen as complements, each subject is presented with two different versions of lotteries over joint outcomes in water security and sanitation. Only the aid outcomes from Option A differs between the KM and FR versions, as explained earlier. The FR version of Option A yields one high and one low payoff with probability p and one low and one high payoff with probability $(1-p)$. In contrast, and as shown in Fig. 2, the KM version of Option A guarantees medium payoffs for both attributes.

Subjects made a total of 20 decisions in the context of these joint lotteries.

3.3. Three-part experimental design

The remaining 50 decisions in the experiment are variants of the lotteries shown in Fig. 2 and are designed to help with the identification of all parameters in Eq. (1). In addition to the joint lotteries described above, Part 3 comprised a set of 10 decisions over single attribute lottery pairs involving either water security or sanitation outcomes. The purpose of having choices over single-attribute lotteries is to determine the curvature of the single-attribute utility function with respect to water security or sanitation, i.e. r_w and r_s in $u(x)$ and $u(y)$, respectively, in Eq. (1). Fig. 4 gives an example screenshot of such a single-attribute lottery decision task over water security. This example corresponds to line 8 of the payoffs presented in Table 3.

Part 2 closely replicates Part 3 in the sense that it comprises decisions over single and joint lottery pairs. In Part 2 however subjects make decisions over risky aid projects on behalf of the experimenter: it is the experimenter and not the

¹³ The stated willingness to pay for a project with both aid outcomes has monetary consequences as it represents the donation amount that is presented to the participant for Option B under certainty. In the example above this amount is \$19.60 and corresponds to line 10 in Table 2. Both stated willingness to donate are required to infer the amount that a subject would be willing to donate per unit of each aid outcome. Each lottery choice that corresponds to the risk-neutral choice pattern of choosing Option A in the first four lines and Option B in lines 5–10 in Table 2 requires a donation that represents the subject-specific expected value of the lottery. Any choices that deviate from this risk-neutral pattern involve donations amounts comprising the expected value of the lottery plus a premium. The added premium ensures that single and multi-attribute risk neutral individuals are not indifferent between lottery Options A and B. Appendix A provides a detailed explanation and some examples.

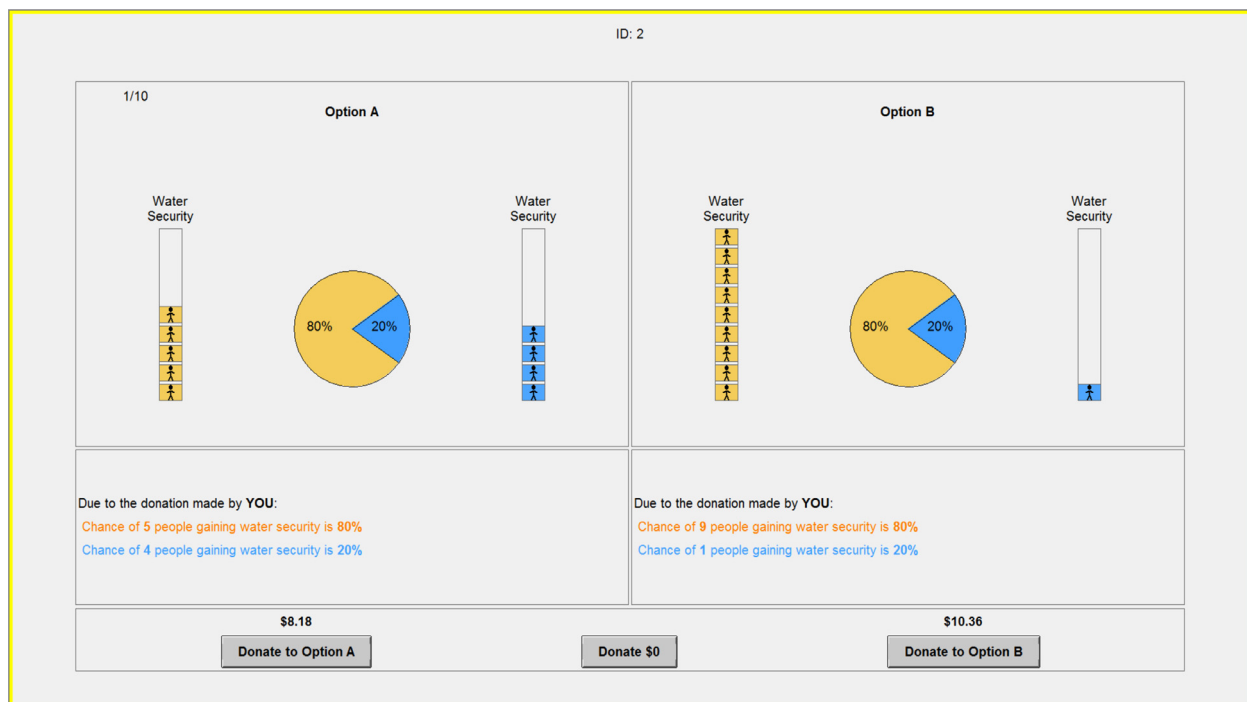


Fig. 4. Example of a single-attribute decision problem from Part 3.

Table 3

Illustrative payoffs for a charitable lottery game over a single risky outcome (water security outcomes as measured in the number of people gaining access to safe water) with donations based on an elicited willingness to pay of \$12.60.

Outcome (x)	Option A		Option B		Donation (\$) ^a		EP(A) – EP(B) (\$)
	Left (5)	Right (4)	Left (9)	Right (1)	Option A	Option B	
Probabilities	0.1	0.9	0.1	0.9	5.74	3.81	1.29
	0.2	0.8	0.2	0.8	5.88	4.54	0.90
	0.3	0.7	0.3	0.7	6.06	5.26	0.50
	0.4	0.6	0.4	0.6	6.16	5.99	0.11
	0.5	0.5	0.5	0.5	6.58	7.00	–0.28
	0.6	0.4	0.6	0.4	7.11	8.12	–0.67
	0.7	0.3	0.7	0.3	7.64	9.24	–1.06
	0.8	0.2	0.8	0.2	8.18	10.36	–1.46
	0.9	0.1	0.9	0.1	8.71	11.48	–1.85
	1.0	0.0	1.0	0.0	9.24	12.60	–2.24

^a The donation amounts for Options A and B are calculated based on the participants stated willingness to donate to a charitable water security project, assumed to be \$12.60 in this example. Opting for the risk neutral choice pattern (Option A for lines 1–4 and Option B for lines 5–10) will result in paying the expected value of the choice, whereas deviations from this choice pattern come at a cost premium equal to the absolute value of entries in last column.

subject who makes the donation that corresponds to the subject's choice. This design feature allows us to test whether risk attitudes vary when aid projects are being supported by the subject's rather than the experimenter's money. Table 4 shows the outcomes, probabilities and inferred risk aversion ranges for the single attribute lotteries over water security used in Part 2. Fig. 5 gives an example of a joint outcome lottery of the FR type from Part 2.

Part 1 consists of one set of 10 binary monetary lotteries using the payoffs of Holt and Laury (2002). Fig. 6 presents an example screenshot that subjects saw in this part. The objective of this part is to determine the curvature of $u(\tilde{m})$, the degree of risk aversion with respect to money, r_m .

3.4. Common design features

Several experimental design features are common throughout the experiment. Each lottery type is presented in a series of 10 decisions in which payoffs remain the same, while payoff probabilities vary in increments of 0.1. This risk experiment therefore builds on the multiple price list approach of Holt and Laury (2002).

Table 4

Payoffs and implied risk attitudes for a charitable lottery game over a single risky outcome: water security outcomes as measured in the number of people gaining access to safe water.

Outcome (x)	Option A		Option b		EV(A) – EV(B) ^a (\$)	Risk aversion (r_w)		
	Left (5)	Right (4)	Left (9)	Right (1)				
Probabilities	0.1	0.9	0.1	0.9	5.75	–1.94	$< r_w \leq$	–1.08
	0.2	0.8	0.2	0.8	4.00	–1.08	$< r_w \leq$	–0.54
	0.3	0.7	0.3	0.7	2.25	–0.54	$< r_w \leq$	–0.11
	0.4	0.6	0.4	0.6	0.50	–0.11	$< r_w \leq$	0.26
	0.5	0.5	0.5	0.5	–1.25	0.26	$< r_w \leq$	0.61
	0.6	0.4	0.6	0.4	–3.00	0.61	$< r_w \leq$	0.99
	0.7	0.3	0.7	0.3	–4.75	0.99	$< r_w \leq$	1.42
	0.8	0.2	0.8	0.2	–6.50	1.42	$< r_w \leq$	2.04
	0.9	0.1	0.9	0.1	–8.25	2.04	$< r_w \leq$	460.16
	1.0	0.0	1.0	0.0	–10.00	460.16	$< r_w$	

^a The expected values for options A and B are based on an exchange rate of \$2.50 per person being given access to safe water.



Fig. 5. Example of a multi-attribute (de Finetti and Richard: FR) decision problem from Part 2.

The payoffs for all pairwise lotteries (single and joint outcomes and with and without donation by the subject) are constructed such that an individual with a neutral attitude towards all single and multiple risks is expected to choose the safe Option A for payoff probabilities $p = 0.1, 0.2, 0.3$ and 0.4 and the riskier lottery in the remaining six cases. This choice pattern corresponds to a Constant Relative Risk Aversion (CRRA) parameter range $-0.15 < r_m < 0.14$ for the monetary attribute. The payoffs in the single non-monetary lotteries of either 5 or 4 persons or DALMS in Option A, and either 9 or 1 persons or DALMS in Option B, yields the CRRA range $-0.11 < r_w, r_s < 0.26$ for the risk neutral choice pattern (see 4th line in Table 4).¹⁴ Similarly, for all other lotteries the payoffs are constructed such that four choices of Option A are optimal for a single and multi-attribute risk neutral subject (see Tables 2 and 3 as examples of the single and joint lottery games with subject donation).

To ensure that our results are not affected by the specific sequence in which the lotteries are presented (Harrison et al., 2005), subjects are shown the lottery pairs in a random order and each on a separate screen. To reduce the cognitive burden

¹⁴ These minor differences in CRRA ranges arise because of the constraint to use integer payoff values for the number of people being given access to water or number of life months saved.



Fig. 6. Example of monetary lottery decision problem from Part 1.

on the subjects, the payoffs and probabilities are presented visually, using color coded bar charts and pie charts, as well as explained in words, as shown in Figs. 2, 4, 5 and 6.¹⁵

3.5. Procedure

All sessions were conducted at the Monash Laboratory for Experimental Economics (MonLEE), using Z-tree (Fischbacher, 2007). Subjects were drawn from the undergraduate student population, broadly recruited across the university by email using ORSEE (Greiner, 2015). Although some had participated in other economics experiments, all were inexperienced in the sense that they had never participated in a similar experiment which had features of decision making relating to risk or charitable giving. Each session had about 20 subjects and we collected data from 154 subjects.

At the beginning of each session an experimenter read the instructions aloud while subjects followed along on their own copy. The instructions and computer decision screens used context specific terminology. In particular, the instructions provide information about WaterAid and about the attributes: water security and sanitation. The instructions for the experiment are given in Appendix B.¹⁶

We used a within-subject design where all subjects made decisions in all three parts, allowing for control over individual-specific effects. Participants were given explanations on each part just prior to starting it. We asked for a volunteer to come forward to be the monitor in each of the sessions. The monitor took part in the experiment just like everyone else, and in addition helped pick out balls from the bingo cage for random number determination and verified that the money was donated online to the aid organization at the end of the experiment. The procedure of using a monitor who verifies the amount donated helped ensure credibility of the decision tasks.

Each of the three parts in the experiment was incentivized by selecting one of the choices made in that part using a bingo cage. A second draw from the bingo cage determined the outcome of the randomly selected lottery. The outcomes of these draws were told to all participants. In Part 1 this process, conducted at the beginning of Part 3, determined each subject's earnings from the monetary lottery game to be added to the AUD 20 showup fee. In Part 2 the same process was used to determine which lottery outcome was converted into a donation made by the experimenter to WaterAid. Part 3 was incentivized in the same manner as Part 2, except that the donation amount associated with the subject's choice of Option

¹⁵ Further, we used intentionally impartial visualizations of the two non-monetary attributes (viz., a stylized stick figure per person getting access to safe water, and a calendar month of life prolonged per DALM for a family of four) and additional explanatory text of each Option's outcomes to reduce concerns over varying saliency or ease of visualization across the two attributes. We aimed to keep the ease of visualization similar across the two attributes, but cannot fully exclude the possibility that some subjects may relate to, or be influenced by, the visualization of one attribute more than the other.

¹⁶ Ethics clearance for this experiment was obtained from the Monash University Human Research Ethics Committee (CF12/2511 – 2012001358), which requires that informed consent is obtained from the participants and that their privacy rights are observed.

Table 5Proportion of safe (Option A) and risky (Option B) choices by participants in Parts 1–3.^a

Part	Option A	Option B	Option C ^b
Part 1	0.59	0.41	n/a
Part 2	0.56	0.44	n/a
Part 3	0.25	0.19	0.56

^a The reported proportions are out of 10 choices in Part 1, 30 choices in Part 2 and 30 choices in Part 3.^b Option C is the no donation option in Part 3.**Table 6**Proportion of participants with risk averse, risk neutral or risk loving attitudes towards single risks.^a

Lottery	Risk averse	Risk neutral	Risk loving
Monetary	0.74	0.17	0.09
Water security	0.67	0.17	0.16
Sanitation	0.73	0.14	0.13

^a For this table, only subjects who switch from A to B once are considered.

was deducted from the subject's earning balance. The random draws for Parts 2 and 3 were implemented at the end of Part 3. At the end of the experiment subjects were paid in cash and were shown the total amount of donations that were made in the session towards water, sanitation and the joint projects.

The average payout to subjects was approximately AUD 32. The total amount donated by participants was AUD 198.36 (an average of 2.54 per subject) and the total amount donated by the experimenters was AUD 1187.50 (an average of 15.22 per subject). Including the instruction and payment distribution time, sessions usually lasted between 90 and 120 min.

4. Data

We present results in two, complementary ways. The first, in this section, is to examine the observed behavior using descriptive statistical tools, which allow us to remain agnostic about the latent structure. The second, in the next section, is to assume some latent structure consistent with our theoretical model, along with some parametric structure, to allow us to identify parameters characterizing the extent and nature of any tradeoff between risky attributes.

Table 5 shows the proportion of safe and risky choices by subjects in each part of the experiment. On average the safe option (Option A) was chosen more often than the risky option (Option B) in all parts of the experiment, pointing to some degree of risk aversion. In Part 3, Option C (no donation) was chosen with the highest frequency.

Using the information on when subjects switch from the safe option (Option A) to the risky option (Option B), we can define whether they are risk lovers, risk neutral or risk averse. Subjects who switch before the 5th lottery are classified as risk lovers. Subjects who switch at the 5th lottery are risk neutral and subjects who switch after the 5th lottery are risk averse.

As shown in Table 6 we find that for the monetary lottery nearly three quarters of the participants are risk averse and only 9% were risk lovers. The remaining 17% were risk neutral. For the charitable lottery games, while the general pattern is similar, with most subjects being risk averse, we observe slightly more risk loving behavior. In the water security and sanitation lotteries, respectively 16% and 13% are risk lovers.¹⁷

Fig. 7 presents the proportion of safe choices made by participants for each of the ten decisions in the first and second parts of the experiment. We estimate the predicted probability using an ordered probit model of safe choices, i.e. Option A, for each individual and decision and then sum over the sample so as to obtain the cumulative probabilities. The blue line displays the decisions in the monetary lottery, while the red line shows the individuals' decisions in the non-monetary water lottery. The red line is lower than the blue line, indicating a more risk-averse behavior by the subjects in the monetary lottery compared to the water lottery.

Fig. 8 compares the proportion of safe choices between the monetary lottery and the sanitation lottery. Again, subjects display on average more risk averse behavior in the monetary lottery compared to the sanitation lottery, although this difference in risk attitude is not as important as between the monetary and water lotteries. To illustrate the differences between choices across the two charitable goods, Fig. 9 displays the proportion of safe choices between the water and the sanitation lottery. The line presenting individual choices in the water lottery is lower than the line presenting the choices in the sanitation lottery. However, the water and sanitation choices do not appear to be systematically different.

¹⁷ For each of these cases, we only consider subjects who switch from A to B once. In the estimations we examine the robustness of results including the subjects with inconsistent responses.

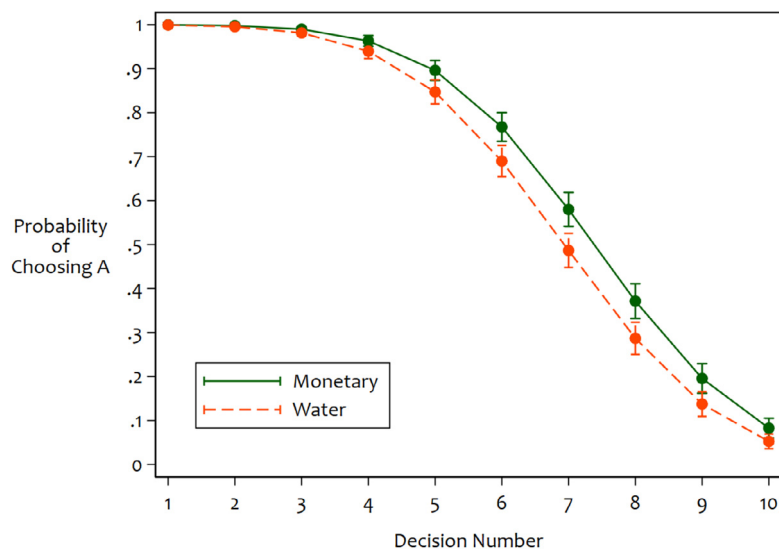


Fig. 7. Proportion of safe choices by decision number: money and water security lotteries.

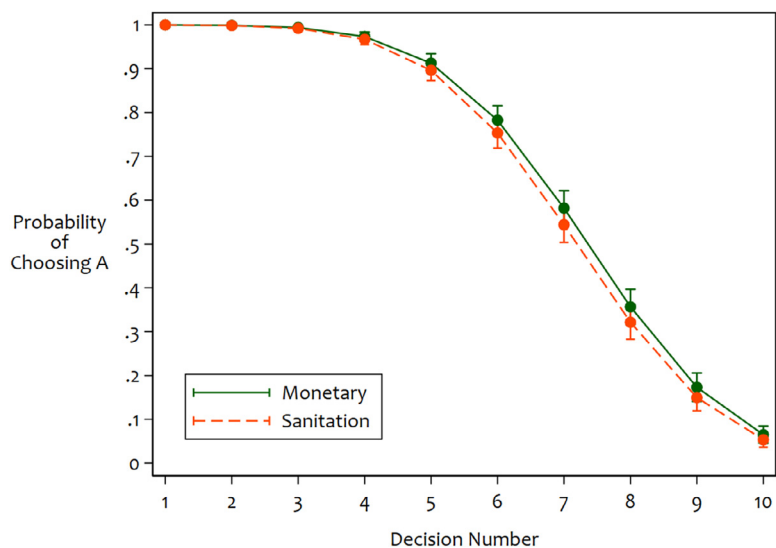


Fig. 8. Proportion of safe choices by decision number: money and sanitation lotteries.

Table 7

Proportion of incidents where a donation was made and the average donation amount by lottery type.^a

Donation	Water security	Sanitation	Joint ^b
Donation incidence	0.44	0.43	0.43
Average donation amount (\$)	5.55	5.54	5.54

^a 4620 observations 154 subjects.

^b Donation incidence and amounts pooled across KM and FR lotteries.

For decisions involving multiple attributes, one's attitude towards both single and multi-attribute risk matters. Therefore, a simple summary statistic of the choices made by participants in lotteries involving multiple attributes is not very informative. Structural estimation is required to properly account for the interaction between single and multi-attribute risk. The results of this structural analysis are discussed in the following section.

A summary of the donation decisions by participants in Part 3 is provided in Fig. 10, showing a high correlation of 0.91 for the subjects' stated maximum willingness to donate to single and multiple outcomes. The donation decisions in subsequent lotteries are described in Table 7, which shows that when participants were given the option to donate they did

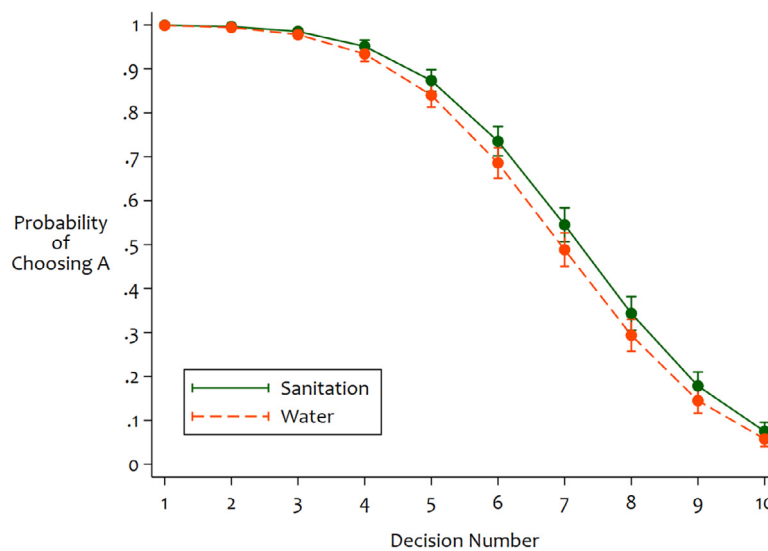


Fig. 9. Proportion of safe choices by decision number: water security and sanitation lotteries.

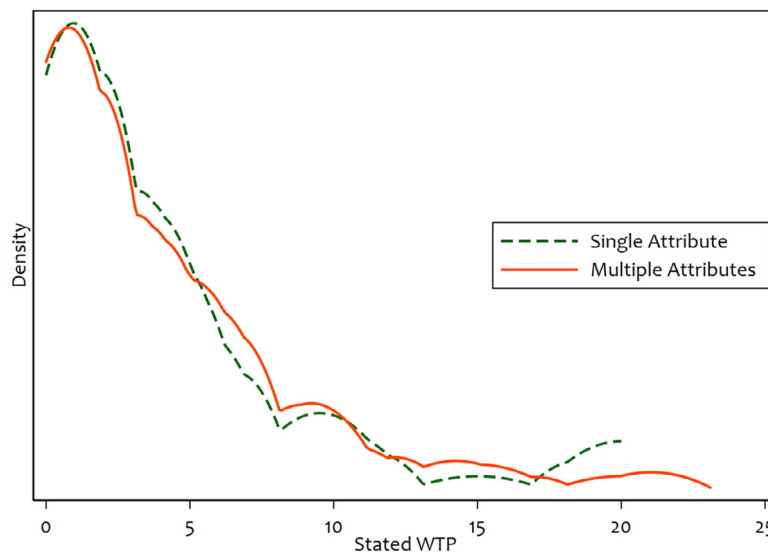


Fig. 10. Maximum willingness to donate to WaterAid in AUD.

so over 40% of the time across all types of aid lotteries.¹⁸ Conditional on donating a positive amount, participants donated on average \$5.55 to aid projects yielding only water security benefits, \$5.54 to projects yielding only sanitation benefits and \$5.54 to projects yielding both benefits. Further, conditional on stating a positive willingness to donate the probability of donating to either Option A or Option B was 82% across all types of aid lotteries. Overall 98% of participants donated at least once in the subsequent lotteries and 56% made a donation at every opportunity provided.

5. Results

We now turn to the econometric results, which are organised around the three research questions outlined earlier. All risk parameters are estimated jointly for the theoretical model described by Eq. (1), which allows for the two aid outcomes to interact in a non-additive manner, while these two then interact with money in an additive manner. In effect, this is assuming a nested multi-attribute utility function, which is the natural choice, given that the amount that the subjects donate in Part 3 is not subject to risk.

¹⁸ Participants chose not to donate in the majority of cases, instead preferring to keep all their earnings from Part 1, which suggests that participants felt a high degree of entitlement to this money, similar to lottery winners in the field (Cheng et al., 2018).

Table 8

Joint estimation of the non-additive EUT specification for all single and joint lotteries.

Variable	Description	Estimate	Standard error ^a	p-value	Lower 95% confidence interval	Upper 95% confidence interval
r_m	CRRA (money)	0.9201	0.0782	<0.001	0.7669	1.0734
r_w	CRRA (water security)	0.4967	0.0203	<0.001	0.4568	0.5365
r_s	CRRA (sanitation)	0.5155	0.0252	<0.001	0.4661	0.5649
η	MARA (FR&KM)	0.3121	0.0302	<0.001	0.2529	0.3713
α	Weight on sanitation	0.1000	(Constrained)			
β	Weight on money	0.8500	(Constrained)			
γ	$P(\text{contribution} > 0)$	0.5281	0.1508	<0.001	0.2326	0.8237
μ	Behavioral error	0.4612	0.0653	<0.001	0.3333	0.5891
Pseudo loglikelihood				Observations	Subjects	
–8752.7091				10,780	154	

^a Standard errors are clustered by subject.

The structural econometric model mimics the theoretical specification explained earlier. It is estimated using full-information maximum likelihood, following the general procedures outlined in [Appendix C](#) and [Harrison and Rutström \(2008\)](#) and the specific procedures for estimating correlation aversion from [Andersen et al. \(2018\)](#). The only novelty is the use of a “hurdle” specification for the decision to contribute in Part 3: we separate the data-generating process explaining the decision to contribute a positive amount from the data-generating process explaining the decision on how much to contribute.¹⁹ It is well-known that hurdle specifications can be estimated using methods that are limited-information (one equation at a time) or full-information (all equations jointly) and be consistent ([McDowell, 2003](#)). We exploit the recursive nature of the experimental design, following [Andersen et al. \(2008, 2018\)](#), to allow identification of all parameters. From Part 1 we identify and estimate univariate risk attitudes towards money, from Part 2 we use those estimates to identify and estimate univariate and multivariate risk attitudes towards the two aid outcomes, the two attributes, for donations made by the experimenter, and from Part 3 we undertake comparable estimates of risk attitudes towards own-contributions of aid versus donations made by the experimenter.

Profile likelihood estimation is used to trace out the effects of certain parameters that are difficult to identify separately from parameters that must be controlled for, but are not of direct interest.²⁰ We find that subjects on average strongly prefer the monetary outcome to themselves ($\beta = 0.85$) over the two non-monetary outcomes to the aid recipients. Preference weighting is also highly asymmetrical across the two non-monetary attributes, with subjects preferring water security to sanitation outcomes ($\alpha = 0.10$). To aid the identification of the risk parameters of interest, we constrain $\alpha = 0.10$ and $\beta = 0.85$ in the results presented below.

5.1. Main results on univariate risk versus multivariate risk

With respect to univariate risk we find that the coefficients for all three attributes reflect statistically significant single-attribute risk aversion. [Table 8](#) shows that risk aversion is greatest with respect to money ($r_m = 0.920$), followed by water ($r_w = 0.497$) and sanitation ($r_s = 0.516$). While we cannot reject the hypothesis that the two non-monetary attributes have the same degree of risk aversion ($r_w = r_s$; $p\text{-value} = 0.320$), they are significantly different from the monetary attribute ($r_m = (r_w = r_s)$; $p\text{-value} < 0.001$).²¹

Pooling the FR and KM lotteries in the multi-variate case, we find significant evidence of multi-attribute risk aversion shown in [Table 7](#), where $\eta = 0.312$ ($p\text{-value} < 0.001$). This result suggests that in addition to being averse to single-outcome risk the public also worries about the types of risk that affect the success of development projects as a whole. Projects that can ensure at least some progress, as measured by achieving medium progress in both attributes or high-level success in just one, are on average preferred to projects that carry a risk of universal failure.²²

¹⁹ Hurdle specifications are widely used in health economics and other fields, and find natural application in many experiments in which there is a clear “spike” at some specific value. [Botelho et al. \(2009\)](#) illustrate the application to experimental behavior, in the context of contributions to public goods, where there is typically a spike at zero due to free-riders.

²⁰ Profile likelihood estimation is a technique used to “concentrate” the likelihood and reduce the number of independent parameters that have to be estimated. It most often arises in the presence of “nuisance parameters” that are not the main focus of interest, and that might confound identification of the parameters of interest. In effect one assumes values for those parameters, and then optimizes the likelihood conditional on those assumed values. By tracing out these conditional likelihoods, one can identify the values of the nuisance parameters that maximize conditional likelihood of the overall structural model. In parametric settings, such as ours, it is possible to infer asymptotically valid confidence intervals for the non-nuisance parameters, conditional on these parameter values (e.g., [Barndorff-Nielsen and Cox, 1994](#), p.90ff.).

²¹ As pointed out to the participants in the experimental instructions, aid provision is subject to risk in its natural setting. Our estimates of risk aversion over the non-monetary attributes likely overestimate true risk aversion to the extent that subjects have taken this background risk into account when making decisions in Parts 2 and 3 (see [Harrison et al., 2007](#)). An important extension of our approach would be to incorporate these background risks into the multi-attribute analysis.

²² The result of overall multi-attribute risk aversion yields practical insights for the management of development project risks (including those related to WASH) that are made possible by explicitly allowing for $\eta \neq 0$ in our modelling framework.

Table 9

Joint estimation of the non-additive EUT specification with separate FR and KM effects.

Variable	Description	Estimate	Standard error ^(a)	p-value	Lower 95% confidence interval	Upper 95% confidence interval
r_m	CRRA (money)	0.9200	0.0777	<0.001	0.7677	1.0723
r_w	CRRA (water security)	0.4960	0.0204	<0.001	0.4560	0.5360
r_s	CRRA (sanitation)	0.5183	0.0249	<0.001	0.4694	0.5672
$\eta_{FR}^{(b)}$	MARA (FR)	0.1223	0.0540	0.023	0.0166	0.2281
η_{KM}	MARA (KM)	0.2338	0.0444	<0.001	0.1468	0.3208
Γ	P (contribution > 0)	0.5281	0.1508	<0.001	0.2326	0.8237
M	Behavioral error	0.4540	0.0647	<0.001	0.3271	0.5808
Pseudo loglikelihood				Observations	Subjects	
−8748.015				10,780	154	

^a Standard errors are clustered by subject.^b η_{FR} is the marginal effect on multi-attribute risk aversion when presented with a de Finetti and Richard (FR) lottery.**Table 10**

Comparison of risk preferences over all lotteries (Parts 1–3) compared with lotteries with donations by the subject (Parts 1 and 3).

Variable	Description	Parts 1 & 2 & 3		Parts 1&3	
		Estimate	p-value	Estimate	p-value
r_m	CRRA (money)	0.9201 (0.0782)	<0.001	0.9350(0.0834)	<0.001
r_w	CRRA (water security)	0.4967 (0.0203)	<0.001	0.4583(0.0130)	<0.001
r_s	CRRA (sanitation)	0.5155 (0.0252)	<0.001	0.5130(0.0192)	<0.001
η	MARA (FR&KM)	0.3121 (0.0302)	<0.001	0.1707(0.0255)	<0.001
μ	Behavioral error	0.4612 (0.0653)	<0.001	0.5650(0.0562)	<0.001
Pseudo loglikelihood		−8752.7091		−5907.0793	
Subjects		154		154	
Observations		10,780		6160	

When allowing for the different ways to test for multi-attribute risk aversion an intriguing result emerges. Table 9 shows that η is economically and statistically significantly greater with the FR lotteries than the KM lotteries: the multi-attribute risk aversion parameter increases by 0.122 (p -value = 0.023) from $\eta_{KM} = 0.234$ (p -value < 0.001) (the multi-attribute risk aversion when subjects are presented with KM lotteries).²³

This difference in observed behavior under multi-variate risk is not explained by behavioral errors, which are very similar at $\mu = 0.461$ when FR and KM are not separately accounted for, as compared to $\mu = 0.454$ when they are distinguished separately.²⁴ The large and significant increase in η , when presented with an FR lottery, indicates strong aversion to correlated risk, which in turn suggests that the subjects viewed the two non-monetary attributes as substitutes. This is an important behavioral distinction between private donors and experts in the provision of aid services to developing countries, since the latter frequently emphasise the complementarity of WASH services. This may explain why some development aid agencies allow donors to give to individual WASH outcomes, despite emphasising their complementarity in their multipronged approach. It also points to the value of having possible menus of alternative aid programs that might be offered to potential donors, so that donors can find a program that matches their preferences over attribute risk across several attributes.

5.2. Additional results on private aid versus public aid

Finally, we investigate whether attitudes to single or multiple risks vary when subjects make risky aid decisions on behalf of the experimenter in Part 2 or with their own money in Part 3. We compare the results in the 3rd and 4th column of Table 10 with the estimation results that exclude observations from Part 2, which are shown in the 5th and 6th column. Reassuringly, we find no statistically significant difference in monetary risk aversion ($r_{m(all\ parts)} = r_{m(parts\ 1+3)}$, p -value = 0.86). We also find almost no difference in aversion to sanitation risk ($r_{s(all\ parts)} = r_{s(parts\ 1+3)}$, p -value = 0.90). However, we find that aversion to water security risk decreases significantly when subjects make donations with their own money ($r_w = 0.46$, $r_{w(all\ parts)} = r_{w(parts\ 1+3)}$, p -value = 0.003). We also find subjects exhibit significantly less multi-attribute risk aversion ($\eta_{(all\ parts)} = \eta_{(parts\ 1+3)}$, p -value < 0.001) when they are making donation decisions to risky aid projects using their own earnings.

²³ The total effects for the multi-attribute risk aversion parameters from FR and KM lotteries are, respectively, $\eta_{FR} = 0.234 + 0.122 = 0.356$ (p -value < 0.001) and $\eta_{KM} = 0.234$ (p -value < 0.001).

²⁴ The estimation includes all individuals, even those that might have switched multiple times from one Option to the other. See Wilcox (2008) for an examination of stochastic models of choices under risk.

Our findings indicate that on average subjects are also multi-attribute risk averse when making donations with their own money. This finding provides a potential explanation for why some donation-dependent aid agencies elicit donations for distinct, single objectives: ‘buy a goat,’ ‘buy a mosquito net,’ ‘vaccinate a child’ or ‘buy a toilet.’ These donation campaigns are uni-dimensional in terms of outcome and perceived risk. In contrast, eliciting donations for more holistic objectives, such as ‘to eradicate child poverty’ or ‘eradicate water borne diseases,’ comprise multiple dimensions and objectives, and donations may be subject to risk premia for individual and joint risks.

We also find that risk attitudes are jointly significantly different when subjects make risky aid decisions on behalf of the experimenter as compared to with their own money (p -value < 0.001). This indicates, for example, that the risk premium for joint risks is highest when evaluating contributions to aid projects made by a third party, such as Government Aid. A possible explanation for this result is that subjects focus primarily on the donation amount when giving with their own money, which involves a premium for risk averse choices. Given the estimated value for the preference weight on money income, $\beta = 0.85$, it is perhaps not surprising that the premium on the donation amount is given greater consideration than are the outcomes for aid recipients and the riskiness of outcomes. This conjecture is also supported by the high correlation of the subjects’ stated maximum willingness to donate to single and multiple outcomes as discussed previously.

Our findings in this aspect are consistent with results from other researchers, who show that subjects are influenced by the fixed total sacrifice effect. One conjecture is that subjects use a two stage reasoning in which they first determine the amount they want to keep for themselves and then distribute the remaining amount (if any) among needy causes. [Selten and Ockenfels \(1998\)](#) for example, show that in their solidarity game the total amount of gift given by subjects is independent of the number of recipients: it is the same for one or two recipients.²⁵

6. Extensions

This research contributes to our understanding of how preferences over multiple monetary and non-monetary risks may be characterised. Given the additional complexity required to model multi-attribute risk attitudes, we deliberately kept other aspects of the utility framework simple by assuming EUT. Our analysis suggests that EUT is indeed suitable to model behavior subject to multiple risks. However, this does not rule out other models of decision-making under risk, such as Rank Dependent Utility, which may reveal a richer behavioural picture in these settings.

Our experimental investigation has important implications for understanding behavior that is subject to multiple risks in the field. In particular, we find that the presence of multiple risks matters beyond the existence of individual risks. Two immediate opportunities to extend this research arise. The first relates to the nature of the risky goods under investigation. While our focus is on the provision of risky aid outcomes, similar issues arise with respect to private goods. Examples include choosing between competing job offers, when several aspects such as promotion opportunities and future salary increases are subject to risk, or choosing between different schools where learning outcomes and fees are subject to risk. There are only a few examples in the literature that investigate behavior with respect to multiple risky private goods (see for example, [von Winterfeldt, 1980](#)).

The second research avenue relates to the nature of risky aid. Our experimental design applies the same background risk to water security and sanitation lotteries. Investigating these in a less parsimonious model of risk would be interesting, especially in light of the diversity of risks that influence aid outcomes, ranging from poor administration, to corruption, poor implementation and to adverse environments.

Finally, our research has direct links to the vast and emerging literature on multi-dimensional poverty. When aid is given to reduce poverty, which dimensions do donors care most about? How are these influenced by the existence of risk, including the risk of poverty spells?

7. Conclusion

Questions about how people behave when facing decisions involving single and multiple risks are important in many public and private good contexts that involve trade-offs over multiple risky outcomes. We designed a laboratory experiment to investigate whether individuals exhibit different levels of risk aversion when choosing over risky monetary or aid outcomes; if there is evidence of multi-attribute risk aversion when several outcomes are subject to risk; and whether individuals perceive risk differently if they make decisions with others’ money versus their own.

The experiment comprised three parts, and for each part participants were presented with choice pairs over single or joint payoff lotteries involving either monetary or non-monetary outcomes from a contribution to an aid organisation. Contributions had either water access or sanitation implications for disadvantaged people in developing countries, and subjects made donation decisions with the experimenter’s money as well as their own money.

Our results show that risk attitudes are significantly different across single monetary and non-monetary risks. Individuals showed greater risk aversion when presented with lottery pairs over monetary outcomes compared with equivalent lottery

²⁵ The fixed total sacrifice effect is also similar to ‘warm glow’ behaviour. Pure warm glow givers do not care about the well-being of the recipient, only about how the act of giving makes them feel about themselves ([Andreoni, 1989; 1990](#)). The total amount given, particularly when giving with their own money, could make the giver feel virtuous or good about themselves.

pairs over aid outcomes. Moreover, while the average risk attitudes towards different aid outcomes are indistinguishable, individuals preferred to donate to projects that yielded access to safe water rather than sanitation outcomes.

The experiment was designed to test for multi-attribute risk aversion according to two popular definitions used in the literature. We find that individuals behave in accordance with being multi-attribute risk averse according to both definitions, and that choices between binary lottery pairs that are consistent with testing for correlation aversion induce significantly greater multi-attribute risk averse behavior than binary lottery pairs that differ in the riskiness of the lotteries but not in the correlation of the risk. We take this as being indicative of participants viewing water access and sanitation outcomes as being substitutes rather than complements. Hence individuals in our study are trading off risks over multiple attributes. In contrast, aid agencies tend to emphasise the complementarity of different aid outcomes, which would find greatest appeal among donors that exhibit correlation loving preferences. This finding is significant as it can help in the design of fundraising campaigns that result in better matches between philanthropic donors and aid providers.

We also found that subjects were less risk averse when making risky donation decisions with their own money compared with the experimenter's money. In line with previous findings in the literature, we conjecture that subjects who make donation decisions with their own money are primarily concerned with the donation amount, while giving less consideration to higher-order effects such as the riskiness of the outcome.

Our findings suggest that decision making in the presence of one kind of risk is different to decision making when multiple risks are involved. Our research is a first step in understanding behavior in situations involving multiple risks, which are commonly observed in the field.

Appendix A. Calculation of subject and option specific donation amounts (Part 3)

The experiment is divided into 3 Parts. Part 1 is a monetary lottery. Part 2 consists of 20 pairwise single and 10 pairwise joint lottery decisions, where the subject chooses amongst risky aid projects on the experimenter's behalf. Part 3 involves 10 single outcome lottery decisions and 20 joint outcome lottery decisions. Each of these Part 3 lottery decision is associated with an option and subject specific donation amount to be made by the subject.

Single outcome

These option specific donation amounts are calculated for each participant, using two elicitation questions. The first elicitation at the beginning of Part 3 asks subjects to nominate an amount that they would be willing to donate to a single type of outcome (water security for half the subjects and sanitation for the other half of the subjects) by entering their willingness to donate in a decision box as shown for an illustrative amount of AUD 12.60 in Fig. 2. We do not present any explicit risk associated with this outcome. This stated willingness to donate is followed by 10 single attribute lottery choices. Each of the lottery Options has a monetary donation associated with it that is constructed such that it never exceeds the subject's initial nominated donation amount and such that a univariate risk neutral choice pattern is given by 4 Options A and 6 Options B.

Table 2 shows the subject-specific donation amounts for the case of water security for a stated willingness to donate (AUD 12.60 in this example). The subject's nominated amount is taken as the maximum willingness to donate and is set equal to the required donation of selecting Option B when probabilities are 1/0, i.e. the high payoff of 9 people being given access to safe water is achieved with certainty. Accordingly, the largest donation amount shown in Table 3 is AUD 12.60, which corresponds to Option B in the last line of the Table and allows the calculation of an individual specific exchange rate for water security of $ER_w = \text{AUD } 12.60/9 = \text{AUD } 1.40$ per person being given access to safe water. This exchange rate is used to calculate the expected value of each Option A and B. The donation amounts associated with each of the lottery choices within the risk neutral choice pattern of 4 Option A and 6 Option B represent their expected value to the participant, while deviations from the risk neutral choice pattern incur a donation premium.²⁶ Hence, selecting Option B for probabilities, $p = 0.1, 0.2, 0.3$ and 0.4 requires a donation amount in excess of the expected value, whereas selecting Option A attracts a donation premium in the remaining lottery pairs. In the experiment, the subjects were not presented with information about expected values of lotteries, nor about differences in expected payoffs.

Using the subjects' initial willingness to pay for charitable outcomes to calculate their donation amounts in different lotteries helps isolate differences in risk attitudes from differences in valuations of charitable outcomes that exist regardless of the riskiness of outcomes. The initial elicitation is not affected by risk and that can help guide the true valuation of individuals for these charitable outcomes.

²⁶ This was done for two reasons. First we wanted to avoid indifferent choices for the risk neutral decision maker. Secondly, by adding the donation premium to the options consistent with risk averse or risk loving attitudes, we made these relatively less attractive as compared with the risk neutral choice and therefore avoided introducing a bias. For example, the donation amount for Option A for probabilities 0.1/0.9 in the first line of Table 2 is equal to its expected outcome value, $EV(A) = (0.1 \times 5 + 0.9 \times 4) \times \text{AUD } 1.40 = \text{AUD } 5.74$ and a risk neutral person would be indifferent between donating AUD 5.74 or not to Option A. The expected outcome value of Option B for probabilities 0.1–0.9 is $EV(B) = (0.1 \times 9 + 0.9 \times 1) \times \text{AUD } 1.40 = \text{AUD } 2.52$. Being classified as a risk loving choice, Option B attracts a donation premium, which is based on the expected values for Options A and B and equal to $[(EV(A) - EV(B))/2.5] = [(\text{AUD } 5.74 - \text{AUD } 2.52)/2.5] = \text{AUD } 1.29$. The donation amount associated with Option B is then $\text{Donation}(B) = \text{AUD } 2.52 + \text{AUD } 1.29 = \text{AUD } 3.81$ and the expected payoff for Option B is $EP(B) = \text{AUD } 2.52 - \text{AUD } 3.81 = -\text{AUD } 1.29$. The difference in expected payoffs is $EP(A) - EP(B) = \text{AUD } 1.29$, which is reported in the last column of Table 2.

Joint outcomes

Subjects are then asked to nominate an amount they would like to donate to a risky aid project that has *both* sanitation and water security benefits. Again, this amount is not paid directly to WaterAid. Instead, this stated willingness to pay is used to calculate donation amounts associated with lotteries in subsequent decision problems. Using their single attribute donation in addition to the multiple attribute donation, an exchange rate for the remaining attribute, for example, the exchange rate per life month saved for a family of 4, is calculated as follows:

$$ER_s = \frac{D_j - ER_w W_{Bh}}{S_{Bh}},$$

where D_j is the subject's nominated donation amount for a project with sanitation and water security benefits, ER_w is the exchange rate for water security based on the single attribute donation, W_{Bh} is the high water security payoff, and S_{Bh} is the high sanitation payoff in Option B. Based on this exchange rate, and using the same adjustment mechanism described above for the single attribute lotteries, donation amounts were calculated for each option in the joint outcome lotteries that generated the 4–6 choice pattern for single-attribute and multiple-attribute risk neutral individuals and never exceeded the nominated donation amount. This was done for the elicited donation amount, which in the example shown in Table 4 is AUD 19.60 for a project that has both water security and sanitation benefits. Fig. 5 shows how the second-last line of Table 4 was presented to subjects.

Appendix B. Instructions to the participant

Original formatting has been preserved

Instructions

General information. Thank you for participating in this experiment. This is a study of decision-making. You will receive compensation for your participation, which will be paid to you in cash at the end of the experiment. How you will be compensated is explained below.

The instructions that we have distributed to you are for your private information. Please do not communicate with the other participants during the experiment. Should you have any questions please raise your hand.

To ensure the anonymity of all participants' choices, the computer will assign you a random ID.

We will ask for a volunteer to come forward to be the monitor for today's study. The monitor will verify that the instructions, as they appear, have been followed, but will otherwise take part in the experiments as everybody else.

The experiment is divided into three parts. Once the first part is finished you will receive detailed information about the next part of the experiment.

Instructions for part 1. In this part of the experiment you will be asked to make a series of choices in decision problems. How much you receive will depend partly on chance and partly on the choices you make. The decision problems are not designed to test you. What we want to know is what choices you would make in them. The only right answer is what you really would choose.

Each of the decision problems would be numbered 1 to 10 and would appear on a separate screen of the computer. In each, please state whether you prefer option A or option B. Though you will make choices in many decision problems, one of the 10 will be randomly selected for payment. As any of the decisions can be chosen for payment, you should pay attention to the choice you make in every decision screen.

Here is an example of the choice that you will see on the screen.

Example: Option A yields a 60–40 chance of a payoff of either \$12.00 or \$9.60. Option B yields a 60–40 chance of either \$23.10 or of \$0.60. You have to state whether you prefer option A or B.



How will you be paid?

At the end of this part of the experiment, the monitor will randomly draw a ball out of the bingo cage containing balls numbered from 1 to 10. The number on the ball determines which decision is going to be paid.

The outcome in each decision problem will be determined by another random draw of a ball out of the bingo cage containing balls numbered from 1 to 10. The monitor will draw the ball.

If in the above example, you had chosen Option A, and the ball randomly drawn from the bingo cage was numbered between 1 and 6, then you earn \$12.00. If the ball drawn was numbered 7–10, then you earn \$9.60. Notice that the pie slice in the figure above is yellow for 60% of the pie and blue for 40% of the pie, (you will see the colours clearly on the screen). So the size of the pie slices show you chances of each possible outcome. The bars adjacent to the pie, show the outcome, i.e.: payoffs in dollars.

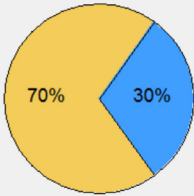
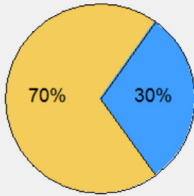
If in the above example, you had chosen Option B. Then if the ball drawn was between 1 and 6, your earnings would be \$23.10 and if the ball was numbered 7–10, then your earnings would be \$0.60. As with option A, the pie slices represent the fraction of the possible numbers that yield each payoff.

All earnings are in cash and are in addition to the \$20.00 initial endowment that you receive as compensation for your time and effort in this and the following parts of the experiment.

Control question

(This example aims to help you better understand the experiment and should not be used as a guide for decisions in the experiment)

1. Assume that in Part 1, the following decision was randomly picked for payment purposes:

<div style="text-align: center;">1/10</div> <div style="text-align: center;">Option A</div> <div style="display: flex; justify-content: space-around; align-items: center; margin-top: 20px;"> <div style="text-align: center;"> <p>\$</p> <div style="width: 40px; height: 100px; border: 1px solid black; position: relative;"> <div style="position: absolute; bottom: 0; left: 0; width: 100%; height: 80%; background-color: yellow;"></div> </div> <p>\$12.00</p> </div> <div style="text-align: center;">  <p>70% 30%</p> </div> <div style="text-align: center;"> <p>\$</p> <div style="width: 40px; height: 100px; border: 1px solid black; position: relative;"> <div style="position: absolute; bottom: 0; left: 0; width: 100%; height: 20%; background-color: blue;"></div> </div> <p>\$9.60</p> </div> </div> <div style="margin-top: 20px; text-align: center;"> <p>Chance of earning \$12.00 is 70%</p> <p>Chance of earning \$9.60 is 30%</p> </div> <div style="text-align: center; margin-top: 10px;"> <input type="button" value="Select Option A"/> </div>	<div style="text-align: center;">Option B</div> <div style="display: flex; justify-content: space-around; align-items: center; margin-top: 20px;"> <div style="text-align: center;"> <p>\$</p> <div style="width: 40px; height: 100px; border: 1px solid black; position: relative;"> <div style="position: absolute; bottom: 0; left: 0; width: 100%; height: 100%; background-color: yellow;"></div> </div> <p>\$23.10</p> </div> <div style="text-align: center;">  <p>70% 30%</p> </div> <div style="text-align: center;"> <p>\$</p> <div style="width: 40px; height: 100px; border: 1px solid black; position: relative;"> <div style="position: absolute; bottom: 0; left: 0; width: 100%; height: 0%; background-color: blue;"></div> </div> <p>\$0.60</p> </div> </div> <div style="margin-top: 20px; text-align: center;"> <p>Chance of earning \$23.10 is 70%</p> <p>Chance of earning \$0.60 is 30%</p> </div> <div style="text-align: center; margin-top: 10px;"> <input type="button" value="Select Option B"/> </div>
---	--

You have chosen Option A in this decision. The ball drawn randomly from the bingo cage is numbered 4. What would your earnings be from this task?

Do you have any questions?

Instructions for part 2. In this part of the experiment you will be asked to make a series of choices in decision problems. These decisions relate to water security and health in poor countries. One of the decisions will be randomly picked and the choice you made in that decision will have real implications for water security and health and sanitation in these countries. For this reason please think very carefully about each choice you are making.

Background information

A number of international charities focus on the provision of water, sanitation and hygiene in poor countries. One of these is WaterAid, an international non- government organization charity that partners with local organisations to work with individuals and families in their communities. WaterAid is a fiscally responsible and financially reliable charity (<http://www.wateraid.org>). They help communities build and maintain water and sanitation projects.

Each project that they fund is unique, but all have the following in common:

- Technologies are low-cost and suited to local conditions
- Water, sanitation and hygiene education are combined to ensure people gain the maximum health benefits
- WaterAid works with local partner organisations, which are best placed to understand the communities' needs
- Local people are supported to plan, construct, manage and maintain their own projects

We will focus on two outcomes of this charity: providing Water Security and Improving Sanitation.

Water security is defined by WaterAid as the reliable access to water of sufficient quantity and quality for basic human needs, small-scale livelihoods and local ecosystem services, coupled with a well-managed risk of water related disasters.

Sanitation and health education can improve the quality of life in poor communities. Researchers have quantified the equivalent months of healthy life lost due to being in states of poor health or disability or due to premature death.

A mix of technologies, for example hand-dug wells versus boreholes versus gravity flow schemes, is used to deliver water to people living in these communities. Some of these technologies are more efficient or reliable than others, but not every technology is suitable in every situation. Similarly, education programs to improve hygiene and health standards may have more or less impact due to local geography or demographic characteristics. Hence the outcomes (water security and health and sanitation benefits) from a donation are affected by chance.

How will you be paid?

The initial endowment of \$20.00 that you received at the beginning of the experiment is intended to compensate you for your effort and careful consideration of each choice in this part of the experiment.

Description of the decision problem

These decision problems are not designed to test you. What we want to know is what choices you would make in them. The only right answer is what you really would choose. Though you will make choices in 30 decision problems, one out of 30 will be randomly selected and the money associated with it will be donated by us to WaterAid. How much the charity receives will depend partly on chance and partly on the choices you make.

The donation amount is calculated on the basis of exchange rates that reflect the average outcomes to poor people in Africa and South East Asia from donations made to WaterAid. To give you some idea of how the money donated would be spent:

- A \$5 dollar water donation would give 2 poor people access to safe water.
- A \$10 dollar water donation would give 4 poor people access to safe water.
- A \$20 dollar water donation would give 8 poor people access to safe water.
- A \$5 sanitation donation would prolong the life of each member of a poor family of four by 2 months.
- A \$10 sanitation donation would prolong the life of each member of a poor family of four by 4 months.
- A \$20 sanitation donation would prolong the life of each member of a poor family of four by 8 months.
- A \$5 dollar donation to water and sanitation would give 1 poor person access to safe water and would prolong the life of each member of a poor family of four by 1 month.
- A \$10 dollar donation to water and sanitation would give 2 poor people access to safe water and would prolong the life of each member of a poor family of four by 2 months.
- A \$20 dollar donation to water and sanitation would give 4 poor people access to safe water and would prolong the life of each member of a poor family of four by 4 months.

Donation amount	Water security (number of people)	Sanitation (number of months)	Water security (number of people) and sanitation (number of months)
\$5	2	2	1,1
\$10	4	4	2,2
\$20	8	8	4,4

Here are some examples of the choice that you may see on the screen.

Example 1:



Option A yields a 60–40 chance that 5 or 4 people gain access to safe water due to the money donated. Option B yields a 60–40 chance that either 9 people or 1 person gains access to safe water as a result of the donation. Note that in these choices the outcomes (i.e., the number of people who gain access to safe water) remain the same in 10 decision problems. Only the chance changes in increments of 10%.

Example 2:



Here the outcomes are shown in terms of life months gained for each member of a family of four. Option A yields a 60–40 chance that either 5 or 4 life months would be gained for each member as a result of the donation. Option B has a 60–40 chance of either 9 or 1 life months gained for each member. Again, note that in these choices the outcomes (i.e., the number of months gained for each member of a family of four) remain the same in 10 decision problems. Only the chance changes in increments of 10%.

Example 3:

1/10	
<p style="text-align: center;">Option A</p> <div style="display: flex; justify-content: space-around; align-items: flex-start;"> <div style="text-align: center;"> <p>Water Security Sanitation</p> </div> <div style="text-align: center;"> </div> <div style="text-align: center;"> <p>Water Security Sanitation</p> </div> </div>	<p style="text-align: center;">Option B</p> <div style="display: flex; justify-content: space-around; align-items: flex-start;"> <div style="text-align: center;"> <p>Water Security Sanitation</p> </div> <div style="text-align: center;"> </div> <div style="text-align: center;"> <p>Water Security Sanitation</p> </div> </div>
<p style="text-align: center;">Due to the donation made by the Experimenter:</p> <p style="color: orange;">Chance of 4 people gaining water security AND 3 life months gained is 60%</p> <p style="color: blue;">Chance of 3 people gaining water security AND 4 life months gained is 40%</p>	<p style="text-align: center;">Due to the donation made by the Experimenter:</p> <p style="color: orange;">Chance of 7 people gaining water security AND 7 life months gained is 60%</p> <p style="color: blue;">Chance of 1 people gaining water security AND 1 life months gained is 40%</p>
<input type="button" value="Select Option A"/>	<input type="button" value="Select Option B"/>

In this example, you see the outcomes in terms of both: access to safe water and the number of months by which the life of each member of a family of four will be prolonged. Option A gives a 60–40 chance: a 60 percent chance that 4 people will gain water security and 3 life months will be gained, and a 40 percent chance that 3 people gain water security and 4 life months are gained. In comparison, Option B yields a 60–40 chance: a 60 percent chance that 7 people gain water security and 7 life months are gained and a 40 percent chance that only 1 person gains water security and only 1 life month is gained as a result of the money donated. As before, in these choices the outcomes (i.e., the number of people who gain access to safe water and the number of months by which the life of a family of four is prolonged) remain the same in 10 decision problems. Only the chance changes in increments of 10%.

How much money would be donated by the Experimenter to the charity?

This depends on your decision and on chance

At the end of the experiment, after you have completed all your choices the monitor will randomly draw a ball out of the bingo cage containing balls numbered from 1 to 30. The number on the ball determines which decision is going to be chosen for a donation from the experimenter.

The outcome of the decision will be determined by a randomly drawn ball numbered between 1 and 10 from the bingo cage. The monitor will draw a ball. The number on this ball will determine which of the outcomes occur and the donations will be based on that.

As the table below shows, if you had chosen Option A in Example 1, and the ball randomly drawn from the bingo cage was numbered between 1 and 6, then 5 times \$2.50 = \$12.50 would be donated by the experimenter to WaterAid so that 5 people gain access to safe water due to the donation. If the ball drawn was numbered 7–10, then 4 people would have access to safe water as 4 times \$2.50 = \$10.00 would have been donated by the experimenter. If you had chosen Option B in this example, and the ball drawn was numbered between 1 and 6, then 9 people would gain access to safe water due to the donation (9 times \$2.50 = \$22.50) made by the experimenter. If the ball drawn was numbered between 7 and 10, then 1 person would gain access to safe water (due to 1 times \$2.50 = \$2.50 donated). The exchange rate of \$2.50 being used in

these calculations arises from the information from WaterAid that: a \$5 donation would give 2 poor people access to safe water ($\$5/2 = \2.50).

Number on the ball drawn	Donation to charity
If you had chosen Option A	
1–6	\$12.50
7–10	\$10.00
If you had chosen Option B	
1–6	\$22.50
7–10	\$2.50

The method of calculating how the charity would be paid in situations where the decision is relating to the number of life months gained for a family of four is similar to the example shown above. The exchange rate of \$2.50 is also used here: as a \$5 donation would prolong the life of each member of a poor family of four by two months. ($\$5/2 = \2.50).

The table below shows how much would be donated by the experimenter to WaterAid in Example 3, in which both the outcomes are present. If you had chosen Option A, and the ball randomly drawn from the bingo cage was numbered between 1 and 6, then 4 times \$2.50 + 3 times \$2.50 = \$17.50 would be donated by us to WaterAid. This donation would ensure that 4 people would gain access to safe water and 3 months would be gained for each member. If the ball drawn was numbered 7–10, then 3 people would have access to safe water and 4 life months would be gained, as 3 times \$2.50 + 4 times \$2.50 = \$17.50 would have been donated by the experimenter. If you had chosen Option B in this example, and the ball drawn was numbered between 1 and 6, then 7 people would gain access to safe water and 7 months would be gained due to the donation (7 times \$2.50 + 7 times \$2.50 = \$35.00) made by the experimenter. If the ball drawn was between 7 and 10, then 1 person would gain access to safe water and 1 life month would be gained (due to 1 times \$2.50 + 1 times \$2.50 = \$5.00 donated).

Number on the ball drawn	Donation to charity
If you had chosen Option A	
1–6	\$17.50
7–10	\$17.50
If you had chosen Option B	
1–6	\$35.00
7–10	\$5.00

At the end of the entire experiment, the monitor and the experimenter will calculate the total amount collected from the randomly chosen choice of all the participants and donate this amount to WaterAid. The experimenter will make the donation directly on their website as verified by the monitor. You will be informed of the total amounts then.

Control question

(This example aims to help you better understand the experiment and should not be used as a guide for decisions in the experiment)

1. Assume that in Part 2, the following decision was randomly picked for donation purposes:

3/10

Option A

Water Security

Sanitation

Water Security

Sanitation

Option B

Water Security

Sanitation

Water Security

Sanitation

Due to the donation made by the **Experimenter**:

Chance of 4 people gaining water security **AND** 3 life months gained is 20%

Chance of 3 people gaining water security **AND** 4 life months gained is 80%

Due to the donation made by the **Experimenter**:

Chance of 7 people gaining water security **AND** 7 life months gained is 20%

Chance of 1 people gaining water security **AND** 1 life months gained is 80%

Select Option A

Select Option B

You have chosen Option A in this decision. The ball drawn randomly from the bingo cage is numbered 4. How much money will be donated to the charity by the experimenter due to the decision made by you?

Do you have any questions?

Instructions for part 3. At the beginning of this part of the experiment, you will be reminded of your earnings from Part 1 of the experiment. You may use your combined earnings from your \$20.00 endowment and your earnings in Part 1 in your decision making in this part. In each decision you will be given the opportunity to make a donation to the charity WaterAid. As before, one of these decisions will be picked at random and the corresponding donation amount deducted from your total earnings.

You will be asked to make a series of choices in decision problems. Your choices will be made privately. As before, these decision problems are not designed to test you in any way. What we want to know is what choices you would make in them. The only right answer is what you really would choose. Though you will make choices in many decision problems, one out of 30 will be randomly selected and the money associated with it will be donated. How much of your earnings the charity receives will depend partly on chance and partly on the choices you make.

In this part, you will be choosing between options that have a monetary amount associated with it. In the 1st decision problem you see, you will be asked to provide the amount that you would like to donate to a water or sanitation project that will benefit the recipients of WaterAid. The next decisions problems numbered 1–10 will give you 3 options, two of them would have a positive donation amount associated with it and the third option carries no donation. You need to choose one of the options. The next decision problem you see, will again ask for a donation towards a project that yields water and sanitation benefits. Another 20 decision problems follow. They are numbered 1–20 and provide specific donation amounts in 3 options that you can choose from.

Here are examples of choices that you may see on the screen after having made your initial donation decisions:

Example 1:



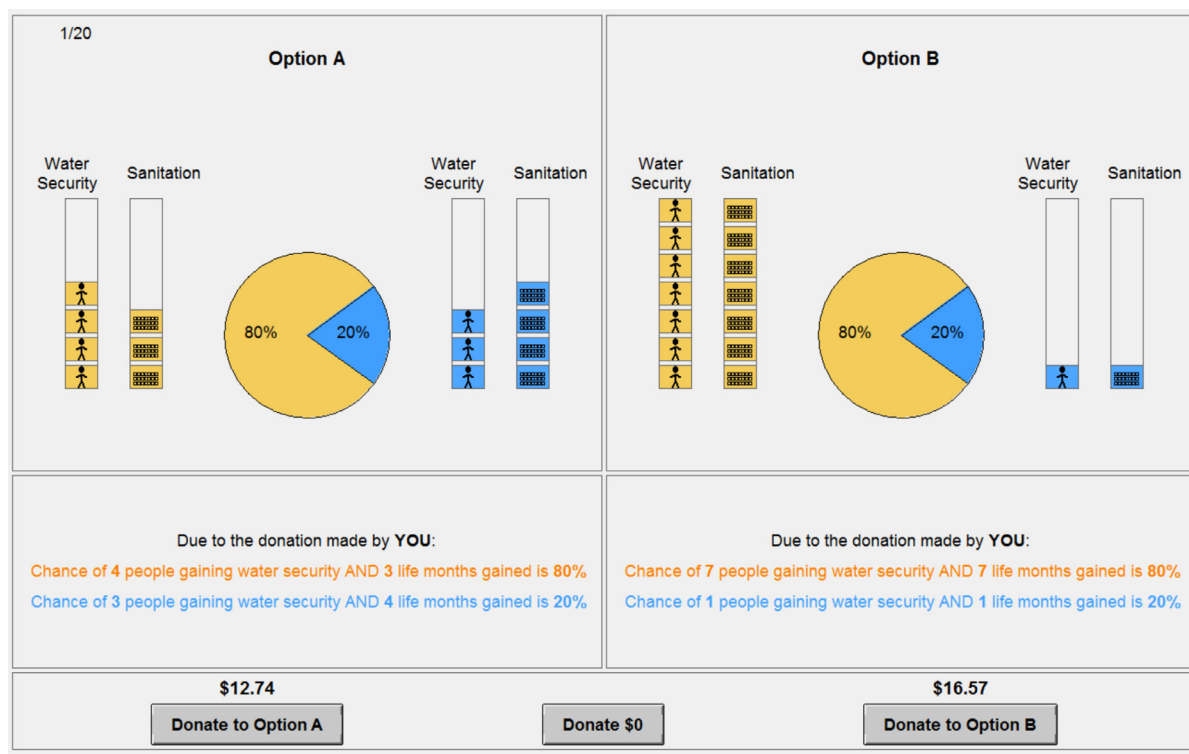
You can choose between 3 options: Option A requires a donation of \$12.98 for an 80–20 chance that 5 or 4 people gain water security. Option B requires a donation of \$16.44 for an 80–20 chance that 9 or 1 person gains water security. The third option requires no donation and carries no aid benefits. In these choices the outcomes (i.e., the number of people who gain access to safe water) remain the same in 10 decision problems. Only the chance and the donation amounts for Options A and B change.

Example 2:



You can choose between 3 options or a Sanitation project: Option A requires a donation of \$5.22 for a 50–50 chance that 5 or 4 life months are gained for each member of a family of four. Option B requires a donation of \$5.56 for a 50–50 chance that 9 or 1 life month are gained. The third option requires no donation and carries no aid benefits. In these choices the outcomes (i.e., the number of disability adjusted life months saved) remain the same in 10 decision problems. Only the chance and the donation amounts for Options A and B change.

Example 3:



In this example, you see the outcomes in terms of both: access to safe water and life months gained. You can choose between 3 options: Option A requires a donation of \$12.74 for an 80–20 chance. An 80 per cent chance that 4 people gain water security and 3 life months are gained; and a 20 per cent chance that 3 people gain water security and 4 disability adjusted life-months are saved. Option B requires a donation of \$16.57 for an 80–20 chance: 80 per cent chance that 7 people gain water security and 7 life months are saved and a 20 percent chance that only 1 person gains water security and only one life months is saved. The third option requires no donation and carries no aid benefits. In these choices the outcomes (i.e., the number of people who gain access to safe water and the number of life months saved) remain the same in 10 decision problems. Only the chance and the donation amounts for Options A and B change.

What does your earnings balance look like?

At the end of the experiment, after you have completed all your choices the monitor will randomly draw a ball out of the bingo cage containing balls numbered from 1 to 30. The number on the ball determines which decision will be played out of the 30 numbered decision problems.

Your earnings balance (ie, the amount after deducting your donation from your total earnings) would be determined by the choice you have made in that decision. If you had chosen option A in Example 3, your earnings would be equal to the following:

Your earnings balance = your initial endowment + your earnings from Part 1 – \$12.74.

If you had chosen option B in Example 3, your earnings would be equal to the following:

Your earnings balance = your initial endowment + your earnings from Part 1 – \$16.57.

If you had chosen the third option in this example, your earnings would be equal to the following:

Your earnings balance = your initial endowment + your earnings from Part 1.

How much money would the charity receive as a result of the donation made by YOU?

This depends on your decision and on chance

The outcome of your choice in the randomly drawn decision will be determined by a random number between 1 and 10. The monitor will draw one ball. The number on this ball will determine which of the outcomes occur with respect to water security and the number of life months saved. The donation paid to the charity will be based on these two outcomes, while also taking into account the amount you donated.

If in Example 3 you had chosen Option A, the donation to WaterAid would be determined as follows:

If the ball randomly drawn from the bingo cage was numbered from 1 to 8, then the donation made to WaterAid would ensure that 4 people would gain access to safe water and 3 life months are gained.

If the ball randomly drawn from the bingo cage was numbered 9 or 10, then the donation to WaterAid would ensure that 3 people would gain access to safe water and 4 life months would be gained.

If in Example 3 you had chosen Option B, the donation to WaterAid would be determined as follows:

If the ball randomly drawn from the bingo cage was numbered from 1 to 8, then the donation to WaterAid would ensure that 7 people would gain access to safe water and 7 life months would be gained.

If the ball randomly drawn from the bingo cage was numbered 9 or 10, then the donation to WaterAid would ensure that 1 person would gain access to safe water and 1 life month would be gained.

If in Example 3 you had chosen the third option, no donation would be made to WaterAid

At the end of the entire experiment, the experimenter will calculate the total amount collected from the choices of all the participants and donate this amount to WaterAid. The monitor will verify that the experimenter has made the donation directly on the WaterAid website. Any differences between the calculated donation amounts to the charity and the amount you have contributed from your earnings in Part 3 will be taken from or returned to the experimental money pool.

Control question

(This example aims to help you better understand the experiment and should not be used as a guide for decisions in the experiment)

1. Assume that in Part 3, the following decision was randomly picked for payment purposes:



You have chosen Option A in this decision. The ball drawn randomly from the bingo cage is numbered 3. What donation amount will be deducted from your total earnings?

Do you have any questions?

Appendix C. Structural estimation

Consider the identification of risk preferences in the simplest possible model of decision-making under risk. We initially assume that EUT holds for the choices over risky alternatives, and that the utility function is the constant relative risk aversion (CRRA) specification

$$U(M) = M^{(1-r)} / (1-r) \quad (1)$$

for $r \neq 1$, where r is the CRRA coefficient. With this functional form for utility, and under EUT, $r=0$ denotes risk neutral behavior, $r > 0$ denotes risk aversion, and $r < 0$ denotes risk loving behavior. We write M as the argument, to suggest that

utility for risk aversion is normally defined over money. But of course our focus here is on three attributes, of which money is but one. We generalize the notation below when needed for the non-additive specification.

We can write out the likelihood function for the choices that our subjects made and estimate the risk parameter r . Probabilities for each outcome M_j , $p(M_j)$, are those that are induced by the experimenter, so expected utility is simply the probability weighted utility of each outcome in each lottery. Since there were two outcomes in each lottery, the EU for lottery i is

$$EU_i = \sum_{j=1,2} [p(M_j) \times U(M_j)]. \quad (2)$$

The EU for each lottery pair is calculated for candidate estimates of r and μ , and the difference

$$\nabla EU = (EU_B - EU_A)/\mu \quad (3)$$

calculated, where EU_A refers to Option A and EU_B refers to Option B, and μ is a structural “noise parameter” used to allow some errors from the perspective of the deterministic EUT model. The latent index ∇EU is in the form of a cumulative probability distribution function defined over differences in the EU of the two lotteries and the noise parameter μ . Thus, as $\mu \rightarrow 0$ this specification collapses to the deterministic choice EUT model, where the choice is strictly determined by the EU of the two lotteries; but as μ gets larger and larger the choice essentially becomes random. This is one of several different types of error story that could be used (Wilcox, 2008).

Thus the likelihood of the risk aversion responses, conditional on the EUT and CRRA specifications being true, depends on the estimates of r and μ , and the observed choices. The conditional log-likelihood is

$$\ln L(r, \mu; y, \mathbf{X}) = \sum_i [(\ln \Phi(\nabla EU) \times \mathbf{I}(y_i = 1)) + (\ln \Phi(1 - \nabla EU) \times \mathbf{I}(y_i = -1))] \quad (4)$$

where $\mathbf{I}(\cdot)$ is the indicator function, $y_i = 1(-1)$ denotes the choice of the Option B (A) lottery in risk aversion task i , and \mathbf{X} is a vector of individual or treatment characteristics reflecting sex or task order, for example. The parameter r is defined as a linear function of the characteristics in vector \mathbf{X} .

The extension to consider the joint estimation of all parameters from all tasks follows the logic developed by Andersen et al. (2008), explained further in Harrison and Rutström (2008).

References

- Ananda, J., Herath, G., 2005. Evaluating public risk preferences in forest land-use choices using multi-attribute utility theory. *Ecol. Econ.* 55 (3), 408–419.
- Andersen, S., Harrison, G.W., Lau, M., Rutström, E., 2008. Eliciting risk and time preferences. *Econometrica* 76 (3), 583–618.
- Andersen, S., Harrison, G.W., Lau, M., Rutström, E., 2018. Multiattribute utility theory, intertemporal utility and correlation aversion. *Int. Econ. Rev.* 59 (2), 537–555.
- Andreoni, J., 1989. Giving with impure altruism: applications to charity and Ricardian equivalence. *J. Polit. Econ.* 97, 1447–1458.
- Andreoni, J., 1990. Impure altruism and donations to public goods: a theory of warm-glow giving. *Econ. J.* 100, 464–477.
- Barndorff-Nielsen, O.E., Cox, D.R., 1994. *Inference and Asymptotics*. Chapman and Hall, London Monographs on Statistics and Applied Probability 52.
- Bommier, A., 2006. Uncertain lifetime and intertemporal choice: risk aversion as a rationale for time discounting. *Int. Econ. Rev.* 47, 1223–1246.
- Bommier, A., 2007. Risk aversion, intertemporal elasticity of substitution and correlation aversion. *Econ. Bull.* 4 (29), 1–8.
- Bommier, A., 2010. Portfolio choice under uncertain lifetime. *J. Public Econ. Theory* 12 (1), 57–73.
- Bommier, A., 2013. Life-cycle preferences revisited. *J. Eur. Econ. Assoc.* 11 (6), 1290–1319.
- Botelho, A., Costa, P.L.M., Harrison, G.W., Rutström, E.E., 2009. Testing static game theory with dynamic experiments: a case study of public goods. *Games Econ. Behav.* 67, 253–265.
- Brito, A.J., de Almeida, A.T., 2009. Multi-attribute risk assessment for risk ranking of natural gas pipelines. *Reliab. Eng. Syst. Saf.* 94 (2), 187–198.
- Brock, J.M., Lange, A., Ozbay, E.Y., 2013. Dictating the risk: experimental evidence on giving in risky environments. *Am. Econ. Rev.* 103 (1), 415–437.
- Cheng, T.C., Costa-Font, J., Powdthavee, N., 2018. Do you have to win it to fix it? A longitudinal study of lottery winners and their health-care demand. *Am. J. Health Econ.* 4 (1), 26–50.
- De Finetti, B., 1952. Sulla preferibilità. *Giornale degli Economisti e Annali di Economia* 11, 685–709.
- de Oliveira, A.C.M., Croson, R.T.A., Eckel, C., 2011. The giving type: identifying donors. *J. Public Econ.* 95, 428–435.
- Dorfleitner, G., Krapp, M., 2007. On multiattributive risk aversion: some clarifying results. *Rev. Manag. Sci.* 1 (1), 47–63.
- Epstein, L.G., Tanny, S.M., 1980. Increasing generalized correlation: a definition and some economic consequences. *Can. J. Econ.* 13, 16–34.
- Exley, C.L., 2016. Excusing selfishness in charitable giving: the role of risk. *Rev. Econ. Stud.* 83 (2), 587–628.
- Finkelshtain, I., Kella, O., Scarsini, M., 1999. On risk aversion with two risks. *J. Math. Econ.* 31 (2), 239–250.
- Fischbacher, U., 2007. z-Tree: zürich toolbox for ready-made economic experiments. *Exp. Econ.* 10, 171–178.
- Greiner, B., 2015. Subject pool recruitment procedures: organizing experiments with ORSEE. *J. Econ. Sci. Assoc.* 1 (1), 114–125.
- Harrison, G.W., 2014. Real choices and hypothetical choices. In: Hess, S., Daly, A. (Eds.), *Handbook of Choice Modelling*. Edward Elgar Publishing.
- Harrison, G.W., Johnson, E., McInnes, M.M., Rutström, E.E., 2005. Risk aversion and incentive effects: comment. *Am. Econ. Rev.* 95 (3), 897–901.
- Harrison, G.W., List, J.A., Towe, C., 2007. Naturally occurring preferences and exogenous laboratory experiments: a case study of risk aversion. *Econometrica* 75 (2), 433–458.
- Harrison, G.W., Martinez-Correa, J., Swarthout, J.T., 2017. Reduction of compound lotteries with objective probabilities: theory and evidence. *J. Econ. Behav. Org.* 134, 430–448.
- Harrison, G.W., Ng, J.M., 2016. Evaluating the expected welfare gain from insurance. *J. Risk Insur.* 83 (1), 91–120.
- Harrison, G.W., Rutström, E.E., 2008. Risk aversion in the laboratory. In: Harrison, G.W., Cox, J.C. (Eds.), *In: Risk Aversion in Experiments, Research in Experimental Economics*, 12. Emerald, Bingley, UK, pp. 41–196.
- Holt, C.A., Laury, S.K., 2002. Risk aversion and incentive effects. *Am. Econ. Rev.* 92 (5), 1644–1655.
- Keeney, R.L., Raiffa, H., 1976. *Decisions With Multiple Objectives: Preferences and Value Trade-Offs*. Wiley, New York.
- Kihlstrom, R.E., Mirman, L.J., 1974. Risk aversion with many commodities. *J. Econ. Theory* 8 (3), 361–388.
- List, J.A., Sinha, P., Taylor, M.H., 2006. Using choice experiments to value non-market goods and services: evidence from field experiments. *B.E. J. Econ. Anal. Policy* 6 (2), 1–37.
- McDowell, A., 2003. From the help desk: hurdle models. *Stata J.* 3 (2), 178–184.

- OECD, 2015. OECD.Stat. Development Theme. <http://stats.oecd.org/Index.aspx?DataSetCode=DACGEO#>, accessed (07/2015).
- Richard, S.F., 1975. Multivariate risk aversion, utility independence and separable utility functions. *Manag. Sci.* 22 (1), 12–21.
- Samuelson, P.A., 1974. Complementarity: an essay on the 40th anniversary of the Hicks-Allen revolution in demand theory. *J. Econ. Lit.* 12 (4), 1255–1289.
- Selten, R., Ockenfels, A., 1998. An experimental solidarity game. *J. Econ. Behav. Org.* 34, 517–539.
- SolarAid. <https://solar-aid.org/online-impact-calculator/>, Accessed 2018.
- Stojanovski, O., Thurber, M., Wolak, F.A., Muwowo, G., Harrison, K., 2018. Assessing opportunities for solar lanterns to improve educational outcomes in rural off-grid regions: cChallenges and lessons from a randomized controlled trial. Draft Manuscript, Stanford University.
- von Winterfeldt, D., 1980. Additivity and expected utility in risky multiattribute preferences. *J. Math. Psychol.* 21 (1), 66–82.
- Wilcox, N.T., 2008. Stochastic models for binary discrete choice under risk: a critical primer and econometric comparison. In: Cox, J.C., Harrison, G.W. (Eds.), *Risk Aversion in Experiments*, Research in Experimental Economics, 12. Emerald, Bingley, UK.