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# An Experimental Comparison of Risky and Riskless Choice—Limitations of Prospect Theory and Expected Utility Theory†

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*Prospect theory, used descriptively for decisions under both risk and certainty, presumes concave utility over gains and convex utility over losses; a pattern widely seen in lottery tasks. Although such discontinuous gain-loss reference-dependence is also used to model riskless choices, only limited empirical evidence supports this use. In incentive-compatible experiments, we find that gain-loss reflection effects are not observed under riskless choice as predicted by prospect theory, even while in the same subjects gain-loss reflection effects are observed under risk. Our empirical results challenge the application of choice models across both risky and riskless domains.* (*JEL* C91, D12, D81)

Early ordinal neoclassical models focused primarily on riskless choice and indifference curves. With the introduction of expected utility theory, risky choice was examined and models like expected utility were quickly expanded to the study of riskless choice. Prospect theory as originally proposed was intended to address positive failures of the expected utility model (von Neumann and Morgenstern 1944), but only when predicting decisions under risk. Indeed, the title of Kahnemann and Tversky's classic 1979 paper is "Prospect Theory: An Analysis of Decision under Risk," and it specified an alternative to the neoclassical utility function. Even as late as 1992, Kahneman and Tversky stated that their theory was aimed to specifically engage decision-making under risk: "( … ) *we presented a model of choice, called prospect theory, which explained the major violations of expected utility theory in choices between risky prospects with a small number of outcomes*." Over the last few decades, however, that model and its derivatives, have also been extended to the study of riskless choice, though mostly in a qualitative way. This effort to unite risky

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and riskless choice with expected utility, or prospect theory, or more modern models like Kőszegi-Rabin (2006, 2007, 2009) has, however, been the subject of only limited theoretical inquiry and empirical testing. Here we: (i) define the relationship between *utility specifications under risk and indifference curves under riskless choice* for all three theories and (ii) empirically measure both utility functions under risk and indifference curves in the absence of risk. We find a pattern of discontinuity in the empirical data that is not predicted by any existing theory.

Expected utility relies on the notion that a single continuous utility function can be used to model choice behavior in risky and riskless domains. Of course expected utility theory does not distinguish between losses and gains, so no discontinuity between the domains of losses and gains is implied in that model. In contrast, the tilted and kinked, S-shaped utility function that Kahneman and Tversky (1979) proposed rests fundamentally on the notion that there is a discontinuity between gains and losses; that preferences change relative to a reference point. This model derives from data suggesting such a discontinuity in preferences, and many subsequent models have adopted this feature (Kőszegi and Rabin 2006, 2007; Tversky and Kahneman 1992).[1]

While prospect theory was originally intended specifically as a theory of choice under risk, subsequent and widespread work has applied many of the elements of prospect theory to riskless choice in a range of domains (Camerer et al. 1997; Fehr and Schmidt 1999; Genesove and Mayer 2001; Hardie, Johnson, and Fader 1993; Kahneman, Knetsch, and Thaler 1991). The assumption of this work has been that while discontinuities do arise around a reference point that separates gains and losses, risky and riskless choice show an essentially similar pattern in this regard. However, most of the work has relied theoretically on loss aversion as a tool to account for the observed gain-loss discontinuities. For example, when first introduced, the famous endowment effect observed in riskless choice (Kahneman, Knetsch, and Thaler 1991; Thaler 1980; Thaler et al. 1997) was explained as a function of the phenomenon of loss aversion as initially defined in risky choice. But despite the endowment effect being considered evidence for the extensibility of prospect theory to riskless choice, increasing evidence points to the fact that loss aversion may not accurately capture all existing empirical evidence on the endowment effect (Plott and Zeiler 2005). Inspired by this evidence, our main objective is to examine the applicability of another of prospect theory's key assumptions—the changing curvature of the value function across the loss and gain domains (*diminishing marginal sensitivity*)—in the domain of riskless choice.

The work most immediately relevant to our paper, Tversky and Kahneman (1991), extended prospect theory to riskless choice by describing indifference curves predicted by the theory under some classes of prospect theoretic preferences. That paper, however, restricts its formal analysis to constant (rather than diminishing or increasing) marginal sensitivities, which may limit its generality. Less than two pages of the paper are devoted to providing an intuition on the relationship between

[1] Friedman and Savage (1948) accounted for the dependence of risk attitude on current wealth without requiring a reference point, but a large body of evidence now suggests that greater flexibility with regard to wealth-level is required than Friedman and Savage had imagined.

diminishing marginal sensitivity and indifference curves, focusing instead on the role of loss aversion in relating risky and riskless choice.

In this paper, we readdress that issue by extending the logic of Tversky and Kahneman (1991) to provide more formal predictions about the shape of indifference curves for gains and losses under the assumption of concave utility in gains and convex utility in losses, prospect theory's central *reflection effect*. We show that for most types of goods, prospect theory predicts typical bowed-in (convex) indifference curves in gains. In losses, however, the theory suggests bowed-out (concave) indifference curves. This is a discontinuity between gains and losses that mirrors, in the riskless domain, the discontinuity of the prospect theoretic value function in the risky domain. We argue below that this is a critical feature for the extension of prospect theory to riskless choice, and one that is paradoxical. We find this prediction paradoxical because, for most types of goods, such an indifference curve shape predicts that in the loss domain people prefer retaining all of one type of good to any mixed bundles. Faced with losses, prospect theoretic consumers should avoid shopping carts with a mixture of goods in favor of shopping carts filled with a single good.

This theoretical observation made us wonder empirically whether the assumption that the utility function is discontinuous across gains and losses under risk is a good approximation under riskless choice. Several existing papers have argued for just such an approximation, assuming diminishing sensitivity and reflection in utility curvature in riskless choices (Abdellaoui, Barrios, and Wakker 2007; Kahneman and Tversky 1979; Stalmeier and Bezembinder 1999; Tversky and Kahneman 1991, 1992; Thaler 1980; Wakker 2010).

Surprisingly, however, there have been only a few empirical investigations of diminishing sensitivity from the reference point under riskless choice. In the existing literature, two main approaches were used to test for diminishing sensitivity in the riskless domain. One method has been to use introspection (Abdellaoui, Barrios, and Wakker 2007; Stalmeier and Bezembinder 1999). Abdellaoui, Barrios, and Wakker (2007), for example, measure riskless utility using a psychological method where the individuals are asked to judge strength-of-preference: the subjective difference of $\$x_i$ over $\$x_{i-1}$ was judged to be the same as that of $\$x_1$ over $\$x_0$, for many $i$. Finding the $\$x_i$ at which differences seem the same allows one to generate normalized utility curvature. Using prospect theory, their results suggest a simple relation between riskless and risky utilities of the kind Tversky and Kahneman (1991) imagined. Stalmeier and Bezembinder (1999) used a similar method with health outcomes, and found that utility is convex in losses. Another approach has been to use an intertemporal choice paradigm to elicit riskless utility estimates over time (Abdellaoui, Attema and Bleichrodt 2010; Abdellaoui et al. 2013). Using an intertemporal choice task, Abdellaoui, Attema, and Bleichrodt (2010) confirmed the prospect theoretic pattern of parameterized concave utility in gains and parameterized convex utility in losses for monetary rewards, in a majority of subjects. This evidence may suggest that the assumption of the reflection in utility curvature around the reference point universally holds in riskless choice. Nevertheless, such reflection in utility leads to puzzling behavioral predictions when people make consumption choices for bundles of goods. It may also be worth noting that the methods used in these studies are unusual from an economic perspective: the first method is not incentive-compatible and the second method has other factors, such as time perception, embedded in it which may influence the estimation of utility curvature.

To address these issues in consumer choice, we designed a novel laboratory experiment with real consumption goods to measure the utility functions and indifference curves in *both* gain and loss domains during risky and riskless choice tasks. Using our method, we found that indifference curves are bowed-in in both the gain and loss domains—preferences across the domains of gain and loss in riskless choice are not discontinuous as prospect theory predicts. This occurs even though the same subjects show the traditional discontinuous reflection effects in utility curvature when making risky choices at the same time and over the same goods. As far as we know, our paper is the first to provide empirical evidence on the shape of indifference curves in the domain of losses.

Our experimental design also, as a secondary feature, allowed us to directly assess whether utility curvature at the single-subject level elicited for a good under conditions of risk, is in any way related to utility curvature for the same good elicited from decisions that do not involve risk. Perhaps, surprisingly, we found no relationship between utility assessed under risk and indifference curves assessed under certainty in the same subjects.

Based on these findings we argue that, at least for goods of the type that we examined, prospect theory appears to make inaccurate predictions about the nature of indifference curves in the loss domain. Further, we argue that none of the currently popular models—expected utility theory, prospect theory, and the Kőszegi and Rabin model—can explain both riskless and risky choice data in their standard forms. Under risk a preference discontinuity around the reference point has now been well documented. This rules out expected utility as a sufficient explanatory framework. Under conditions of riskless choice, we show that such a discontinuity does not exist, at least for our data. This raises questions about whether models with obligate discontinuities between gains and losses are appropriate for riskless choice.

*Structure of the Paper*.—In Section I, we describe how utility curvature relates to the shape of indifference curves. We restrict our attention to goods that have what we call "unremarkable" patterns of substitution and complementarity. More formally, we restrict ourselves to pairs of goods $\{A, B\}$ for which under decreasing (increasing) marginal utility, the marginal impact of A is decreased (increased) more by the addition of units of A than by the addition of units of B. We predict the shape of indifference curves under three currently dominant theories of choice: expected utility theory, prospect theory, and the Kőszegi and Rabin (2006) model.

In Section II, we set out to empirically measure utility (indifference curves) under risk and under certainty. We used two incentive-compatible (randomly interleaved) riskless and risky choice tasks conducted with the same two consumer goods and the same experimental subjects in both the gain and loss domains. Our design allowed us to estimate the curvature of indifference curves for gains and losses in riskless choice and utility curvature for gains and losses in risky choice, both with minimal assumptions, in the same individuals.

As expected, we found that subjects showed risk aversion in gains and risk seeking in losses during risky choice. From this finding, we conclude that our empirical technique for implementing the loss domain induces the classic reflection effect for risky choice around which prospect theory was built. Using the identical loss manipulation in a riskless choice task, in the gain domain, we found the typical pattern of bowed-in indifference curves consistent with concave utility functions. However, the same subjects, when asked to make riskless trade-offs between the same two goods in the loss domain, also showed bowed-in indifference curves. *In other words, we observed that when one shifts from gain to loss domain, the curvature of the utility functions measured under risk "reflects" as expected, but the curvature of indifference curves measured under riskless conditions does not.* We find this to be true on both the group level and individual level.

In the final section, we examine how our paper adds to the existing literature on the notion of utility. We suggest that our findings under conditions of riskless choice are more consistent with traditional economic models than with prospect theory. In a sense, our results fail to demonstrate, during riskless choice, the existence of a reference point of the kind proposed in prospect theory as a reflection in utility curvature. At the same time our findings under conditions of risk are consistent with prospect theory. In summarizing, our findings thus raise some modest questions about the applicability of prospect theory to model riskless choice in the loss domain.

## I. Theoretical Background

In this section, we first establish a general relationship between cardinal utility curvature and the shape of indifference curves. Then, we use three widely studied theories of choice: expected utility theory, prospect theory, and the rational expectations theory of Kőszegi and Rabin (2006, 2009), to make explicit predictions about utility and indifference curve shapes under each theory.

Traditionally, the theory of decision making under certainty has focused on explaining the tradeoffs between goods via the concept of indifference curves that plot the combinations of the quantities of two goods that give the same utility to the consumer. In this type of analysis, the slope of the indifference curves is equal to the negative of the marginal rate of substitution (MRS), which in turn is defined as the ratio of the marginal utilities of these two goods. If one is willing to extend the theory or extrapolate the findings on decision making under risk to decision making under certainty, as many authors have, then, by inferring something about risky utility for two goods, one should in principle be able to place restrictions on admissible marginal rates of substitution between the goods or in other words on the shapes of the indifference curves and vice versa.

Throughout this section we will use the following notation $U_x \equiv \partial U/\partial x$, $U_y \equiv \partial U/\partial y$, $U_{xx} \equiv \partial U_x/\partial x$, $U_{yy} \equiv \partial U_y/\partial y$, and $U_{xy} = U_{yx} \equiv \partial U_x/\partial y = \partial U_y/\partial x$. For clarity, Figure 1 illustrates bowed-in indifference curves (solid) and bowed-out indifference curves (dashed) in both gains and losses.

PROPOSITION 1: *Suppose a continuous preference relation and a continuous and twice differentiable utility $U(x,y)$ exists. The indifference curve is bowed-in*

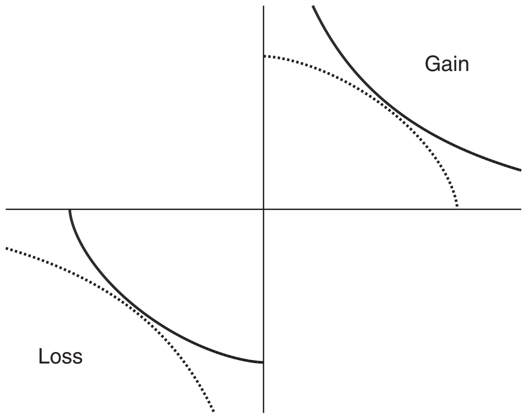


FIGURE 1

*Note:* Illustration for bowed-in indifference curves (solid) and bowed-out indifference curves (dashed) in both gains and losses.

*if* $U_y^2 U_{xx} + U_x^2 U_{yy} - 2U_x U_y U_{xy} < 0$ *and bowed-out if* $U_y^2 U_{xx} + U_x^2 U_{yy} - 2U_x U_y U_{xy} > 0$.

PROOF:

See proof for Proposition 1 in Appendix A.

Proposition 1, originally presented in Arrow and Enthoven (1961), establishes that the curvature of the indifference curve depends on the first and second derivatives of the utility function with respect to each good, and on the mixed derivative $U_{xy}$. If $U_{xy} = 0$ and we assume (as is usually done for most goods in the gain domain) that the consumer has diminishing marginal utility over each of the goods in the bundle, the indifference curves will always be bowed-in. In a more realistic case, the marginal utility of $x$ depends also on the quantity of good $y$ so $U_{xy} \neq 0$. Without loss of much generality, we can assume that for most of the goods, $U_{xy}$ will not overwhelm the effect that marginal utility ($U_{xx}$ and $U_{yy}$) has on preferences. To see this point, assume a pair of goods that at the same time are characterized by diminishing marginal utility and increasing marginal rate of substitution (due to overwhelming effect of $U_{xy}$). An individual with such preferences derives less utility from each additional unit of the good when the quantity of the other good is fixed (an uncontroversial assumption). This also means that as she trades-off units of good $x$ against units of good $y$ to remain on the same indifference curve, *the more $x$ (and less $y$) she has, the more $y$ she is willing to give up to get one more $x$.* It is hard to imagine pairs of goods with diminishing marginal utility that would lead to such unusual pattern of monomaniacal substitution. In this paper, for tractability, we do not study such goods and restrict ourselves to pairs of goods that have what we call *unremarkable* patterns of substitution/complementarity. While this is a restriction, it still allows us to study what is probably a majority of goods, including both substitutes and complements. This is formalized in the assumption below.

ASSUMPTION 1: *For all x and y, individual has unremarkable pattern of substitution (complementarity). This means that if: (i)* $U_{xx} < 0$ *and* $U_{yy} < 0$, *then* $U_y^2 U_{xx} + U_x^2 U_{yy} - 2U_x U_y U_{xy} < 0$, *and (ii)* $U_{xx} > 0$ *and* $U_{yy} > 0$, *then* $U_y^2 U_{xx} + U_x^2 U_{yy} - 2U_x U_y U_{xy} > 0$.

To stress how common assumption this is, recall that in the extremely popular constant elasticity of substitution utility (CES) function $(U(x,y) = (\beta x^\rho + (1-\beta) y^\rho)^{1/\rho})$ introduced by Solow (1956), Assumption 1 is always satisfied. Under a CES utility function, the conditions for bowed-in indifference curves and concavity of the utility function (here we mean $U_{xx} < 0$ and $U_{yy} < 0$) are equivalent and boil down to $\rho < 1$. Note that it also means that under Solow's CES utility function, it is equivalent to say that marginal utility is increasing ($U_{xx} > 0$ and $U_{yy} > 0$) and that the indifference curves are bowed-out. Examples of goods that would violate Assumption 1 could include medication or drugs that interact with one another in a way where taking 1 medication makes an individual more sensitive to some other medication.

Using Proposition 1 and Assumption 1, we can now derive the implications for indifference curves under 3 popular theories of choice: expected utility, prospect theory, and the Kőszegi and Rabin model.

### A. *Expected Utility over Wealth (No Reference Point)*

Before prospect theory, economists imagined utility as an increasing and concave function over terminal wealth. To allow for more flexibility, here we simply maintain that there is no point at which the sign of the second derivative of the utility function changes. This implies that for an individual with wealth $w$ who is considering outcomes of size $x$, the following property holds: for any $x$ if $U_{xx}(w+x) < 0$ then $U_{xx}(w-x) < 0$ (and if $U_{xx}(w+x) > 0$ then $U_{xx}(w-x) > 0$).

PROPOSITION 2: *An individual with preferences described by the expected utility model will:*

(*i*) *have the same utility curvature, that is risk attitude (averse, seeking, or neutral), for gains and losses;*

(*ii*) *have bowed-in (bowed-out) indifference curves for both gains and losses if he/she has* $U_{xx} < 0$ *and* $U_{yy} < 0$ ($U_{xx} > 0$ *and* $U_{yy} > 0$),

*when Assumption* 1 *holds.*

PROOF:

See proof for Proposition 2 in Appendix A.

Hence, under expected utility, we do not expect to see a reflection in utility curvature or in indifference curves.

### B. *Prospect Theory*

Amos Tversky and Daniel Kahneman, inspired by the behavioral patterns that could not be described by the expected utility theory, suggested that utility is defined with respect to a reference point that they implicitly defined as the *status quo* or current wealth level, $w$. Prospect theory says that as people move away from the reference point, their sensitivity toward marginal changes in reward diminishes, which is called diminishing sensitivity. Diminishing sensitivity from the reference point can capture that people, on aggregate, tend to be risk averse for gains and risk seeking for losses. Formally, it is often taken to imply that $U_{xx} < 0$ for $x > 0$ and $U_{xx} > 0$ for $x < 0$. This universal assumption of reflection in the utility function curvature leads to the next proposition.

PROPOSITION 3: *Imagine an individual with preferences described by prospect theory:*

$$u(x,y) = \begin{cases} U(x,y) & \text{if } x \geq 0 \text{ and } y \geq 0 \\ \lambda U(x,y) & \text{if } x < 0 \text{ and } y < 0 \end{cases},$$

*where $\lambda$ is the loss aversion parameter and by definition of prospect theory: $U_{xx} < 0$ and $U_{yy} < 0$ for $x > 0$ and $y > 0$, and $U_{xx} > 0$ and $U_{yy} > 0$ for $x < 0$ and $y < 0$.*

*For goods with unremarkable patterns of substitution/complementarity, this individual will:*

(*i*) *have concave utility in gains and convex utility in losses*;

(*ii*) *have bowed-in indifference curves in gains and bowed-out indifference curves in losses.*

PROOF:

See proof for Proposition 3 in Appendix A.

Notice that since the slope of the indifference curve is equal to the ratio of $U_x$ and $U_y$, loss aversion, as defined in prospect theory, cancels out and is irrelevant for the curvature of the indifference curves in the loss domain in our analysis. Similarly in the risky choice, loss aversion has no impact on whether an individual is classified as risk averse, risk neutral, or risk seeking.

### C. *Kőszegi and Rabin Reference Point*

Kőszegi and Rabin (2006—henceforth, KR) revised prospect theory by providing a new definition of the reference point. In their model, the reference point is given by the outcome expectation instead of the status quo. A decision maker's reference point $r$ is the probability measure $G(r)$. The utility of a consumption outcome $c$

given a referent $r$ is $u(c\,|\,r)$. If $c$ is drawn according to the probability measure $F(c)$, a decision maker calculates the utility by comparing each of its possible outcomes to the reference point in the following way:

$$U(F\,|\,G) = \int\int u(c\,|\,r)\,dG(r)\,dF(c).$$

KR decompose utility into two components: consumption utility, which corresponds to the traditional expected utility, and gain-loss utility that captures behavioral effects associated with the reference point: $U(c\,|\,r) = m(c) + n(c\,|\,r)$, where $m(c)$ is consumption utility and $n(c\,|\,r)$ is gain-loss utility. Both consumption utility and gain-loss utility are assumed to be additively separable across dimensions. The gain-loss utility is defined over the difference between the outcome and the referent in each dimension $k$: $n_k(c_k\,|\,r_k) = \mu(m_k(c_k) - m_k(r_k))$. We follow the usual assumption in the applications of the Kőszegi and Rabin model and assume that

$$\mu(x) = \begin{cases} x & \text{if } x \geq 0 \\ \lambda x & \text{if } x < 0 \end{cases}$$

where $\lambda > 1$ is the loss aversion parameter. Whenever the outcome is smaller than the referent, it gets additionally weighted by the loss aversion parameter so that losses are experienced as more "painful" than equally sized gains.

In true riskless choice, since the individual is certain to get what he chose, the KR model trivially simplifies to a traditional EU framework.

PROPOSITION 4: *An individual with such Kőszegi-Rabin preferences will:*

(*i*) *not switch his/her risk attitude between symmetric loss and gain gambles*;

(*ii*) *have bowed-in (bowed-out) indifference curves for both losses and gains if* $U_{xx} < 0$ *and* $U_{yy} < 0$ ($U_{xx} > 0$ *and* $U_{yy} > 0$).

PROOF:

See proof for Proposition 4 in Appendix A.

Using the KR model under riskless conditions, we make the same predictions as in the expected utility model. Thus, extending KR to riskless conditions, we do not expect to see reflection effects neither in the risky nor in the riskless task. It is interesting that KR (2006, 2007) does not predict the commonly observed switch between risk aversion in gains and risk seeking in losses. Intuitively, this happens because the relative nature of outcome comparisons eliminates the significance of nominal loss and nominal gain. When outcomes are compared to expectation, nominal gains can be experienced as losses if bigger gains were expected and nominal losses can be experienced as gains if bigger losses were expected.

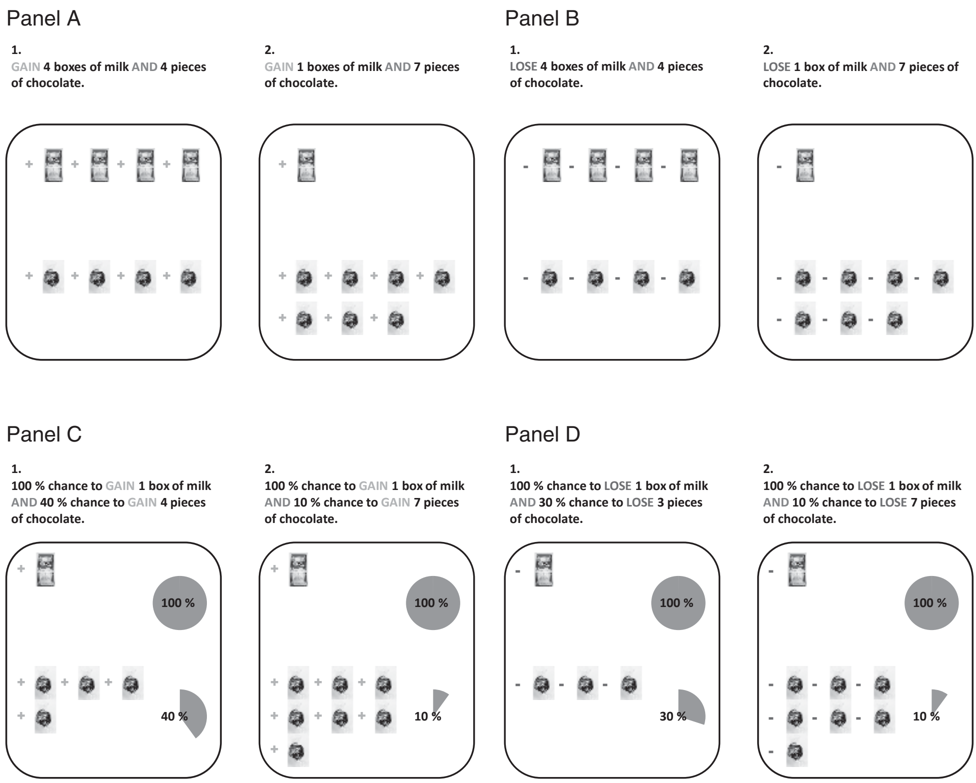


FIGURE 2

*Notes:* Sample screenshots from the riskless choice task in panel A gains and panel B losses and risky choice task in the panel C gains and panel D losses.

## II. Empirical Investigation

### A. *Experimental Design*

The goal of our experiment was to empirically assess, at both aggregate and individual levels, whether utility functions and indifference curves behave consistently in riskless and risky contexts.

In the experiment, the subjects made a series of choices between different bundles of goods that they could gain (gain condition) or lose (loss condition). There were two types of choice tasks in the experiment—*the riskless choice task* and *risky choice task*—each designed to elicit an individual's preferences in the domain of gains and losses. To ensure that subjects could differentiate between the loss and gain conditions, we used textual (gain versus lose), symbolic (+ versus −), and color (green versus red) cues all together in the displays. To make sure that the only difference between the tasks was the contrast between probabilistic versus certain choice, we designed the tasks to be identical in everything other than the probabilistic versus certain nature of the decision. See Figure 2 for examples of decision screens in the risky and riskless choice tasks.

In both of the tasks, the subjects made decisions between bundles that consisted of some quantity of beverage and snack. Before the experiment began, we gave subjects a selection of beverages and snacks to choose from to ensure that they liked the products that constituted the rewards in the experiment. The available beverages were: Horizon Organic UHT milk, Juicy Juice apple juice, and Juicy Juice orange juice. The snacks were: Lindt chocolates, a small package of Pepperidge Farm brand Goldfish crackers, and Nature Valley granola bars. We chose these goods for our study so that they satisfy the assumption of unremarkable patterns of substitution and complementarity. Upon arrival, subjects picked their favorite beverage and snack, understanding that a bundle of these goods would serve as partial payment for participation. As it was possible to lose some quantity of the beverage and snack in the experiment, at the very beginning of the study we endowed subjects with eight of their preferred beverage and eight of their preferred snack, an amount equal to the maximum possible loss in the experiment.[2] To reinforce that the endowed goods belonged to the subject, we asked each subject to put his/her beverages and snacks in his/her bag or leave them on the desk next to where he/she sat.

After subjects had received their endowment, they read the instructions (available in online Appendix B). They were given an opportunity to ask questions, they answered several comprehension questions, and they completed several practice rounds, all to make sure they were familiar with the experimental procedure and software before starting the experimental session. They performed the task by themselves, one subject per each experimental session.

The task was programmed using EPrime software. The important feature of the design was that options were presented to the chooser in the same way in both of the tasks (risky and riskless) to ensure that any differences we observed were not due to some peculiar experimental confound (see Figure 2 for screenshots). The order in which the subjects completed the riskless and risky choice task was randomized. Additionally, we randomized the order of gain condition and loss condition trials within each task as well as the order of trials within each condition. There was no time limit in the experiment. In total, there were 308 experimental trials plus 36 *test trials*, all mixed together (subjects did not know in advance how many trials would be presented in the experiment). The experimental trials were used to estimate the utility function curvature and the curvature of the indifference curves. Test trials were used only for screening purposes and choices made in these trials were not used to estimate individuals' utility and indifference curves. An embedded set of test trials examined first-order stochastically dominated options and allowed us to identify subjects whose preferences could not be represented by a monotonic utility function over the quantities of goods we employed. In the paper, we present results based on the analysis of all subjects, and, in the Appendix, we show that these findings remained qualitatively the same if we focused only on the subset of subjects who never violated first-order stochastic dominance.

[2] While the use of an endowment to study losses is always a concern in laboratory studies, there is reason to believe it is effective (Etchart-Vincent and L'Haridon 2011). Our data, presented below, clearly showed the expected pattern of change in risk attitude in the gain and loss domains for risky choice trials, consistent with reflection in utility curvature. We take this as evidence of successful implementation of the gain-loss framing in our experiment.

The experimental program randomly determined which option was shown on the left side and right side of the display screen, and this varied from trial-to-trial and from subject-to-subject. At the end of the experiment, subjects were paid privately according to their choice in one randomly selected trial. Subjects earned a $20 participation fee in some combination of beverages and/or snacks from the experiment.

Sixty subjects (28 male, average age: 23.017, standard deviation: 4.541) participated in the study. All subjects gave informed consent. The study was conducted at New York University and was approved by the University Committee on Activities Involving Human Subjects at New York University. The subjects were recruited using flyers posted in New York University buildings and on the departmental website. The duration of the experiment depended on individual response times. All subjects finished the experimental session within one hour.

*Riskless Choice Task.*—To estimate the shape of the indifference curves (and to infer some restrictions on the utility function it implied) under conditions of *certainty*, we asked subjects repeatedly to choose between two bundles containing different quantities of each product. Figure 3 graphically presents the set of all questions we asked in the gain domain, and should be helpful in understanding the rationale behind the experimental design. Each of the dots in the graph represents one particular bundle of snacks and beverages that was offered. The black dot represents a *fixed bundle* of four units of beverage and four units of snack that was available (as one of the options) in every one of the gain trials (see also Table 1).

For the gain trials, subjects chose between this fixed bundle and a second bundle that changed from trial to trial. To form a full gain-domain choice set of 32 trials, the fixed bundle was paired once with every other bundle marked as a dot in Figure 3, panel A (every combination of goods from the first row and the third column in Table 1). For example, when paired with the bundle marked with an light grey dot in Figure 3, panel A, this corresponds to a choice between the fixed bundle (four milk boxes and four chocolates) and a bundle with seven chocolates and one milk box (the choice situation shown in Figure 2, panel A). Figures 3, panels B and C show example choices represented in this space. Light grey (empty) dots indicate that the changing (fixed) bundle was preferred to the fixed (changing) bundle. As illustrated in these figures, we can use a subject's simple binary choices over this set to draw a single indifference curve, allowing us to estimate whether this indifference curve is bowed-in or bowed-out in a completely nonparametric fashion.

Figure 2, panel A and Figure 2, panel B show a typical gain and a typical loss trial. In Figure 2, panel A, the subject is asked to decide whether he/she would prefer to receive a bundle of four milk boxes and four chocolates or a bundle of one milk box and seven chocolates. In Figure 2, panel B, the subject is asked to decide whether he/she prefers to lose (from his/her endowment) a bundle of four milk boxes and four chocolates or to lose a bundle of one milk box and seven chocolates. The choices are not trivial. Each decision involves a trade-off between the two goods; having more of one always results in having less of the other one. The complete set of choices presented to each subject is shown in Table 1.

As the most interesting and distinctive prediction from prospect theory is about the choices over losses, we attempted to gather as precise an estimate of the utility

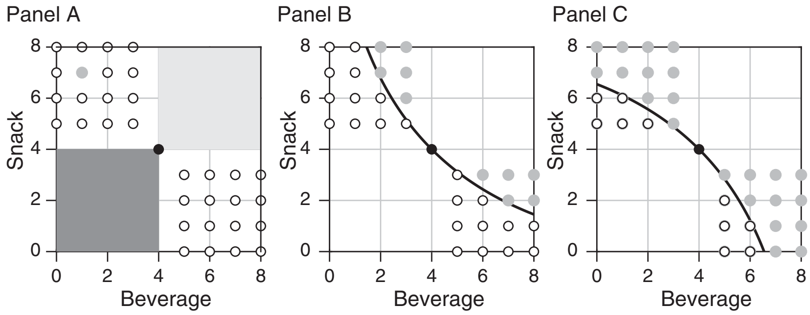


Figure 3

*Notes:* Graphical presentation of the riskless choice task in gains. Panel A: the fixed bundle (black) was paired with each of the other bundles (light gray and empty dots) to form 32 unique choice situations. Panel B: example of a bowed-in indifference curve. Panel C: example of a bowed-out indifference curve. Light gray (empty) dots indicate that the subject preferred the changing (fixed) bundle to the fixed (changing) bundle.

Table 1—Riskless Choice Task Questions

| | Fixed bundle | Changing bundle |
|---|---|---|
| Gain | (4, 4) | (5, 3); (6, 3); (7, 3); (8, 3); (5, 2); (6, 2); (7, 2); (8, 2); (5, 1); (6, 1); (7, 1); (8, 1); (5, 0); (6, 0); (7, 0); (8, 0); (3, 5); (3, 6); (3, 7); (3, 8); (2, 5); (2, 6); (2, 7); (2, 8); (1, 5); (1, 6); (1, 7); (1, 8); (0, 5); (0, 6); (0, 7); (0, 8) |
| | (−3, −3) | (−4, −2); (−5, −2); (−6, −2); (−7, −2); (−8, −2); (−4, −1); (−5, −1); (−6, −1); (−7, −1); (−8, −1); (−4, 0); (−5, 0); (−6, 0); (−7, 0); (−8, 0); (−2, −4); (−2, −5); (−2, −6); (−2, −7); (−2, −8); (−1, −4); (−1, −5); (−1, −6); (−1, −7); (−1, −8); (0, −4); (0, −5); (0, −6); (0, −7); (0, −8) |
| Loss | (−4, −4) | (−5, −3); (−6, −3); (−7, −3); (−8, −3); (−5, −2); (−6, −2); (−7, −2); (−8, −2); (−5, −1); (−6, −1); (−7, −1); (−8, −1); (−5, 0); (−6, 0); (−7, 0); (−8, 0); (−3, −5); (−3, −6); (−3, −7); (−3, −8); (−2, −5); (−2, −6); (−2, −7); (−2, −8); (−1, −5); (−1, −6); (−1, −7); (−1, −8); (0, −5); (0, −6); (0, −7); (0, −8) |
| | (−5, −5) | (−6, −4); (−7, −4); (−8, −4); (−6, −3); (−7, −3); (−8, −3); (−6, −2); (−7, −2); (−8, −2); (−6, −1); (−7, −1); (−8, −1); (−6, 0); (−7, 0); (−8, 0); (−4, −6); (−4, −7); (−4, −8); (−3, −6); (−3, −7); (−3, −8); (−2, −6); (−2, −7); (−2, −8); (−1, −6); (−1, −7); (−1, −8); (0, −6); (0, −7); (0, −8) |

*Notes:* Each fixed option was paired once with each of the changing options in the same row for a total of 124 unique choice situations. The quantities in the parentheses correspond to the quantity of each good (beverage, snack) that was offered. See Figure 2, panel A and Figure 2, panel B for the examples of graphical presentation.

function and indifference curves as possible in the loss domain. To do this, we examined three complete sets of choices of the kind used in the gain domain. We did this by employing three different fixed options and measuring full sets of binary choices against each of these different fixed options in a total of 92 choice trials. For the full set of questions asked in the loss domain see Table 1.

To assess whether the subjects obeyed monotonicity, we embedded 12 additional test trials (6 for gains and 6 for losses). They involved choosing between bundles on the diagonal line going through the fixed bundle to the upper right in the bright gray and dark gray regions (Figure 3, panel A). A subject who obeys monotonicity should always (never) choose the fixed bundle over any bundle in the dark gray (light gray) area.

*Risky Choice Task*.—The risky choice task served two purposes: (i) we used it as a control to verify that our manipulation of gain-loss framing was successful, and

(ii) it allowed us to assess whether there was correlation in utility curvature estimated in the risky and riskless conditions in the same individuals for the same goods.

In the risky choice task, subjects made decisions over lottery bundles with varying levels of risk and reward. What differentiates our study from most is that the rewards were snacks and beverages rather than money. *This was essential* because we sought to demonstrate the standard prospect theory pattern of diminishing sensitivity in the gain and loss domain over the same exact goods as used in our riskless choice task. Figure 2, panel C and Figure 2, panel D show example screenshots from risky gain and loss trials. In Figure 2, panel C, on the left, the subject is offered a choice between a bundle that consists of 1 more milk box for sure and a 40 percent chance of receiving 4 more chocolates and a bundle that consists of 1 more milk box for sure and a 10 percent chance of receiving 7 more chocolates. In Figure 2, panel D, the subject is offered a choice between a bundle that would result in losing 1 milk box for sure and a 40 percent chance of losing 4 chocolates and a bundle that would result in losing 1 milk box for sure and a 10 percent chance of losing 7 chocolates.

Importantly, in any choice situation both of the options always included one unit of beverage (snack) and a probabilistic quantity of snack (beverage). This design allowed us to estimate the curvature of the utility function over beverages and snacks (as in the bundle experiment), taking the complementarities between the goods into account, rather than estimating utility over only one reward type in isolation. Just as in the riskless choice task, a fixed option, this time a lottery bundle, was paired with other lottery bundles that changed from trial to trial. As in the riskless trials, there was one set of choices in the gain domain and three sets of choices in the loss domain. Table 2 lists the complete choice set. Each question was asked once for the beverage and once for the snack. Overall, subjects made 184 choices: 24 for each good in the gain and 68 for each good in the loss domain. There were an additional 24 test questions where 1 option was first-order stochastically dominated (6 trials in each domain and each good). For example, option A: 1 more piece of chocolate for sure and 40 percent chance of receiving 4 more boxes of milk dominated option B: 1 more piece of chocolate for sure and 30 percent chance of receiving 3 more boxes of milk.

## B. *Econometric Approach*

*Riskless Choice: Utility Estimation–Parametric Analysis.*—To estimate the indifference curves in the riskless choice task we used a constant elasticity of substitution (CES) function, which we fit separately for all gain and all loss trials.[3] The utility of a bundle $\{x, y\}$ is then given by

$$(1)\quad U(x,y) = \begin{cases} \left[\beta_g x^{\rho_g} + (1-\beta_g) y^{\rho_g}\right]^{1/\rho_g} & \text{when } x \geq 0 \text{ and } y \geq 0 \\ -\left[\beta_l |x|^{\rho_l} + (1-\beta_l) |y|^{\rho_l}\right]^{1/\rho_l} & \text{when } x < 0 \text{ and } y < 0 \end{cases},$$

[3] We used the CES utility function because of its generality (it allows for both bowed-in and bowed-out indifference curves) and its popularity for examining preferences over bundles of goods. It accommodates other popular functional forms such as Cobb-Douglas (when $\rho$ approaches 0), linear (when $\rho = 1$), and Leontief (when $\rho$ approaches negative infinity) as special cases. We note here that CES function is homothetic $(U(\eta X, \eta Y) = \eta U(X,Y))$.

TABLE 2—RISKY CHOICE TASK QUESTIONS

| | Fixed option | Variable option |
|---|---|---|
| Gain | (4, 40%) | (5, 30%); (6, 30%); (7, 30%); (8, 30%); (5, 20%); (6, 20%); (7, 20%); (8, 20%); (5, 10%); (6, 10%); (7, 10%); (8, 10%); (3, 50%); (3, 60%); (3, 70%); (3, 80%); (2, 50%); (2, 60%); (2, 70%); (2, 80%); (1, 50%); (1, 60%); (1, 70%); (1, 80%) |
| | (−3, 30%) | (−4, 20%); (−5, 20%); (−6, 20%); (−7, 20%); (−8, 20%); (−4, 10%); (−5, 10%); (−6, 10%); (−7, 10%); (−8, 10%); (−2, 40%); (−2, 50%); (−2, 60%); (−2, 70%); (−2, 80%); (−1, 40%); (−1, 50%); (−1, 60%); (−1, 70%); (−1, 80%) |
| Loss | (−4, 40%) | (−5, 30%); (−6, 30%); (−7, 30%); (−8, 30%); (−5, 20%); (−6, 20%); (−7, 20%); (−8, 20%); (−5, 10%); (−6, 10%); (−7, 10%); (−8, 10%); (−3, 50%); (−3, 60%); (−3, 70%); (−3, 80%); (−2, 50%); (−2, 60%); (−2, 70%); (−2, 80%); (−1, 50%); (−1, 60%); (−1, 70%); (−1, 80%) |
| | (−5, 50%) | (−6, 40%); (−7, 40%); (−8, 40%); (−6, 30%); (−7, 30%); (−8, 30%); (−6, 20%); (−7,20%); (−8, 20%); (−6, 10%); (−7, 10%); (−8, 10%); (−4, 60%); (−4, 70%); (−4, 80%); (−3, 60%); (−3, 70%); (−3, 80%); (−2, 60%); (−2, 70%); (−2, 80%); (−1, 60%); (−1, 70%); (−1, 80%) |

*Notes:* The first number in parentheses corresponds to the quantity of the reward, and the second to the odds of receiving this quantity. Each fixed option was paired with each variable option in the same row once for each good type. When the questions were about beverage (snack), one unit of snack (beverage) received with 100 percent probability was added to both the fixed and variable option. See Figure 2, panel C and Figure 2, panel D for the examples of graphical presentation of choices.

where $x$ and $y$ are the amounts of beverage and snack respectively and $\beta \in [0, 1]$ is the distribution parameter. The key parameter of interest is $\rho$, as it determines the sign of the second derivative and thus the curvature of the indifference functions. We use $g$ $(l)$ subscript for gains (losses). In the gain domain, if $\rho_g$ is smaller (larger) than 1, then the utility function is concave (convex), i.e., the indifference curve is bowed-in (bowed-out). In the loss domain, if $\rho_l$ is smaller (larger) than one, then the utility function is convex (concave), i.e., the indifference curve is bowed-out (bowed-in).

To allow for a random error in choice, we fit our data using a logistic choice function in which the probability that the subject selected a fixed option is given by

$$\text{(2)} \qquad \Pr(\mathit{fixed}) = \frac{1}{1 + e^{-\gamma \Delta U}},$$

where $\Delta U$ is the difference in utility of the fixed and changing option and $\gamma$ is the steepness parameter ($\gamma_g$ for gains and $\gamma_l$ for losses separately). We used maximum likelihood estimation to estimate each parameter. In the representative agent analysis that pools all data together, we clustered standard errors on the level of the subject. We also estimated each parameter for each subject individually.

*Riskless Choice: Model-Free Approach–Nonparametric Analysis.*—To draw the indifference curve without assuming any functional form of the utility, we simply counted how often each bundle was selected against the fixed bundle. We nonparametrically drew an indifference curve through the bundles that were chosen by our subjects 50 percent of the time, assuming that if the bundle was chosen

50 percent of the time this indicates indifference at the aggregate level. To fill in the missing points on the indifference curves and find the exact quantities at which subjects were indifferent, we used interpolation and extrapolation methods.[4] Additionally, we used a binomial distribution to statistically determine whether each particular bundle was preferred or not preferred to the fixed option. Using a 95 percent confidence interval, we calculated that a bundle that is indifferent to the fixed bundle should be selected between 24 and 36 times by our 60 subjects.

We performed one more simple test to verify the shape of the indifference curves in our sample. We calculated how often the representative agent with a linear indifference curve would choose the changing bundles over the fixed bundle. Since at an aggregate level our subjects placed equal weight on beverages and snacks ($\beta$ not statistically different from 0.5), we assumed that this linear indifference function was simply a diagonal passing through the central point.[5] A representative agent with a diagonal indifference line always chooses the "changing bundles" above the diagonal line and never chooses the bundles below the diagonal line. Due to our symmetric design, such choosers would select the "changing" bundles 50 percent of the time. If our subjects had indifference curves that are bowed-in, they should choose fewer "changing bundles" that lie above the diagonal line, resulting in, selecting fewer changing bundles than an agent with a diagonal indifference line. However, if our subjects had indifference curves that are bowed-out, they should choose more "changing bundles" than an representative agent with a diagonal indifference lie.

*Risky Choice: Utility Estimation–Parametric Analysis*.—To assess the utility of beverages and snacks in the risky task, we fit the data with a CRRA utility function and probability weighting function (Tversky and Kahneman 1992). The expected utility of $x$ units of a good gained (lost) with probability $p$ is then given by

$$EU\left(x \mid y = 1\right) = \begin{cases} w_g(p)\, x^{\alpha_g} & \text{when } x \geq 0 \\ -w_l(p)\, |x|^{\alpha_l} & \text{when } x < 0 \end{cases}, \tag{3}$$

where $\alpha_g$ $(\alpha_l)$ estimates the curvature of the utility function in the gain (loss) domain. In gains, $\alpha_g < (>)$ 1 implies concave (convex) utility. In losses, $\alpha_g < (>)$ 1 implies convex (concave) utility. These were estimated separately for each good and each domain. Here, $w_g$ $(w_l)$ is the subjective probability weighting function in gains (losses). We assume it takes the popular form, first proposed by Tversky and Kahneman (1992):

$$\begin{cases} w_g(p) = \dfrac{p^{\delta_g}}{\left[p^{\delta_g} + (1-p)^{\delta_g}\right]^{1/\delta_g}} & \text{when } x \geq 0 \\[2ex] w_l(p) = \dfrac{p^{\delta_l}}{\left[p^{\delta_l} + (1-p)^{\delta_l}\right]^{1/\delta_l}} & \text{when } x < 0 \end{cases}, \tag{4}$$

[4] To draw these indifference curves we used the "contour" function in Matlab.

[5] Of course, had the distribution parameter been different (significantly smaller or larger than 0.5), we would have to perform our comparisons relative to a line with a different slope.

where $\delta_g$ ($\delta_l$) estimates the distortion of subjective probability. We used the logistic choice function and maximum likelihood estimation to estimate each parameter. The steepness parameters $\gamma$ of the logistic choice function were estimated separately for each domain. In the representative agent analysis that pools all data together, we cluster standard errors on the level of the subject.[6]

It may seem unusual that we fit a power utility function defined over only one good instead of a CES function defined over two goods *because each choice option in our study* (*even in risky trials*) *always included both a snack and a beverage.* We selected this approach for the following reasons: First, our approach allows us to estimate the curvature of the utility function separately for beverages and snacks and thus allows us to test whether the implicit assumption imposed by CES, that the exponent for both types of reward is the same, is empirically valid. Second, given that the CES utility function is traditionally used for choice under certainty, there is no established practice for its use in risky choice. Third, we believe that the approach is specifically appropriate for our design because the quantity and probability of one of the goods in the bundle was always fixed (at 1 unit received for sure). Finally, we note that our findings do not fundamentally rely on this parametric analysis.

*Risky Choice: Model-Free Approach–Nonparametric Analysis*.—In each choice situation, we defined the more risky lottery bundle as the one with a higher coefficient of variation (CV):

$$CV = \frac{SD(\text{standard deviation})}{|EV(\text{expected value})|}. \tag{5}$$

We then calculated the proportion of times that each individual selected the more risky option. A risk neutral (averse/seeking) individual would pick it (less than/more than) 45.83 percent of the time for gains and 48.53 percent of the time for losses in this choice set.

## C. *Results*

In this section, we first analyze the data at the aggregate level[7] and show that indifference curves (and the utility functions they imply) do not *reflect* between gains and losses in the riskless choice task even though *in the same sample of subjects*

[6] In addition to this model, we have also fit three other models: (i) CRRA utility estimated separately for gains and losses and identical probability weighting, for gains and losses, (ii) CRRA utility estimated separately for gains and losses without probability weighting, and (iii) a traditional expected utility model with CRRA utility function defined over total wealth gained in the experiment (where $x$ = endowment $+/-$ the quantity of the good offered on the current trial). Using the Bayesian information criterion (BIC), we found that the model with probability distortion presented in the main text fits the data slightly better than the model with identical probability weighting in gains and losses (BIC = 12,260.99 versus BIC = 12,262.36), better than the model without probability weighting (BIC = 12,322.61), and much better than utility over total wealth gained in the experiment model (BIC = 14,457.87). The results remain qualitatively the same as in the main text, independent of what assumptions we make about the probability weighting function. Detailed results from the alternative analyses are presented in online Appendix D.

[7] Using Stata13.

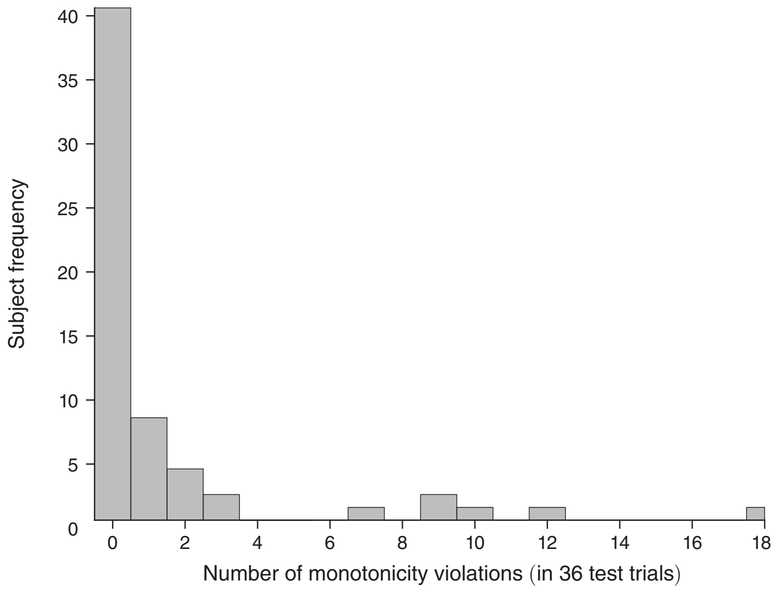


FIGURE 4

*Note:* Distribution of the monotonicity and first-order stochastic dominance violations in 36 test trials.

utility curves clearly reflect in choice under risk. This discontinuity between riskless and risky choices is our principle result. We show that this result is robust to modeling specifications. We then examine individual behavior[8] and show that while it is consistent with the representative agent results in general, it reveals that on the individual level some patterns of behavior implied by the representative agent analysis do not occur. We conclude by showing that, oddly there is no correlation between utility parameters estimated from choices made under risky and deterministic conditions at the individual subject level.

Choices on our test trials revealed that most subjects (40 subjects) showed no first-order stochastic dominance violations. The majority (90 percent) of subjects made violations in less than 5 out of a possible 36 times (Figure 4). In the main text, we present an analysis based on the choices of all 60 subjects. In the online Appendix C, we demonstrate that the results do not qualitatively change when we analyze only the 40 subjects who never violated first-order stochastic dominance.

*Aggregate Level: Riskless Choice*.—We found that at the aggregate level our subjects' behavior was consistent with *bowed-in indifference curves in both gains and losses* (Figure 5). In the gains, $\rho_g$ was smaller than 1 ($\rho_g = 0.737$; *robust SE* $= 0.06$), and in the losses, $\rho_l$ was larger than 1 ($\rho_l = 1.467$; *robust SE* $= 0.099$). Values of $\rho_g$ and $\rho_l$ were significantly different ($p < 0.001$). These results are presented in Figure 5 and Figure 6, panel A. The distributions parameter ($\beta$) was essentially

[8] Using Matlab scripts.

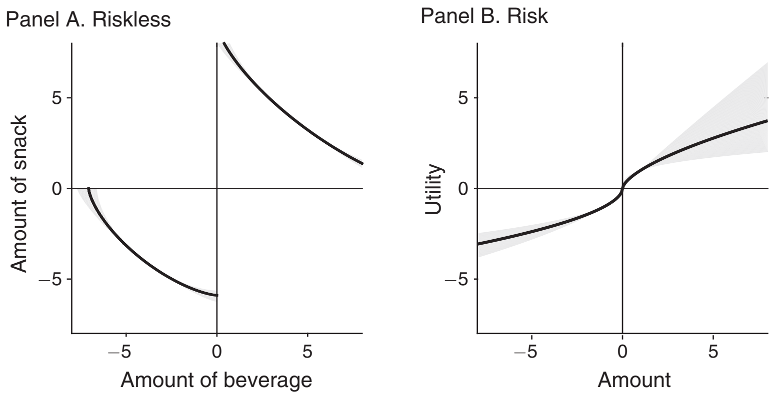


Figure 5

*Notes:* Panel A: estimated indifference curves in the gains and losses in the riskless choice task. Panel B: estimated utility function (pooled data for beverages and snacks) in the gains and losses in the risky choice task. Gray shaded region indicates 95 percent CI.

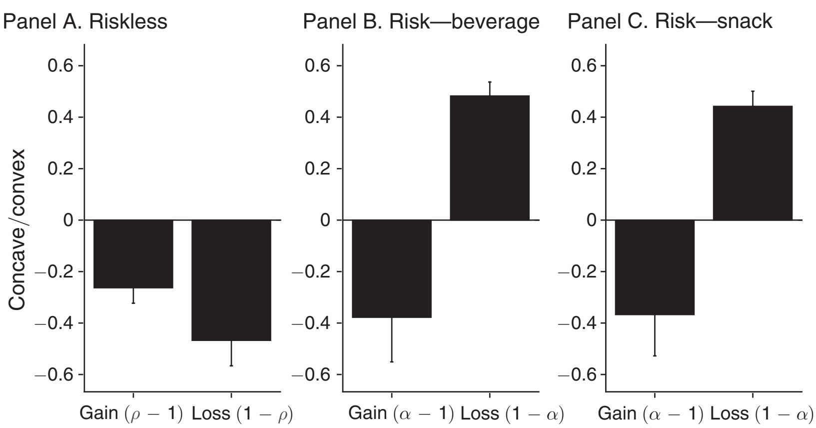


Figure 6

*Notes:* Curvature estimates for panel A: riskless and panels B and C: risky choice task. The utility curvature estimates are normalized so that the positive estimates indicate convex utility and negative estimates indicate concave utility (error bars represent the robust SE).

the same in the gains and losses ($\beta_g = 0.449$; *robust SE* $= 0.04$ and $\beta_l = 0.434$; *robust SE* $= 0.039$) with subjects having preference for approximately equal distribution of each good in the bundle; $\beta_g$ and $\beta_l$ were not significantly different from 0.5 ($p = 0.202$ and $p = 0.093$).

To verify that our result was not an artifact of the functional forms that we used, for each bundle, we calculated the proportion of times it was selected across 60 subjects. Figure 7 presents the results as a heat map, where the bundles selected more (least) frequently than the fixed bundle are lighter (darker). Here, we also nonparametrically drew indifference curves through the bundles chosen 50 percent of the time (dashed curves in Figure 7). Confirming our model-based analysis,

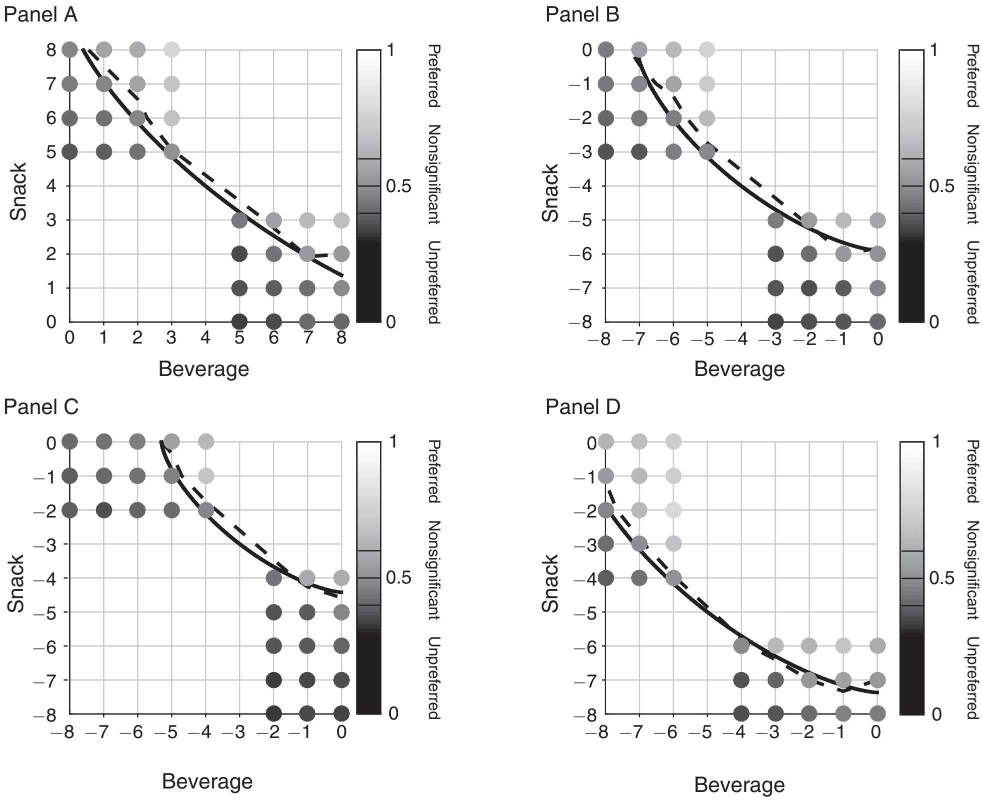


FIGURE 7

*Notes:* Model-free indifference curves. Different shades of gray illustrate the proportion of times that each bundle was selected in the riskless task. The most (least) frequently selected bundles are lighter (darker). The dashed indifference curves are drawn through the bundles chosen half of the time. The solid indifference curves are drawn based on the aggregate level estimates of the CES utility function.

model-free (dashed curve) and model-based (solid curve) indifference curves are close together, and the bundles close to the estimated indifference curve were selected at a proportion not statistically different from 50 percent (at a 95 percent confidence interval calculated using a binomial distribution).

We performed one more type of analysis to confirm the shape of the indifference curves that best describe our sample of subjects. Given that the distribution parameter $\beta$ was not significantly different from 0.5 in both domains, we assumed that if our subjects were best described by a linear indifference curve it should be the diagonal going through the fixed bundle. Empirically, we observed that, on average, our subjects chose the "changing bundles" less often (41.25 percent for gains and 40.22 percent for losses) than our representative agent with a diagonal indifference curve (50 percent for both domains). *This pattern is consistent with bowed-in indifference curves.*

*We conclude that the indifference curves, assessed at the aggregate level, were bowed-in in gains and in losses, consistent with concave utility and diminishing rate of substitution in both gains and losses and* ***inconsistent with the reflection effect in utility curvature assumed by prospect theory.***

*Aggregate Level: Risky Choice*.—In line with numerous previous studies, in the risky task we found behavior consistent with reflection in the utility curvature estimated at the aggregate level: concave utility in gains and convex in losses both for beverages and for snacks (see Figure 6, panels B and C). The estimates for each of the goods were not significantly different, suggesting that imposing the same curvature for both goods in the CES utility function is without penalty in generality. In the gains, we found that $\alpha_g = 0.622$ (*robust SE* $= 0.173$) for beverages and $\alpha_g = 0.633$ (*robust SE* $= 0.161$) for snacks, consistent with risk aversion and concave utility. These parameters were not significantly different for beverages and for snacks ($p = 0.759$). In the loss domain, we found $\alpha_l = 0.518$ (*robust SE* $= 0.054$) for beverages and $\alpha_l = 0.558$ (*robust SE* $= 0.059$) for snacks, suggesting risk-seeking and convex utility. These parameters were not significantly different for beverages and for snacks ($p = 0.272$). We estimated the probability weighting parameters to be $\delta_g = 1.294$ (*robust SE* $= 0.334$) in gains and $\delta_l = 0.612$ (*robust SE* $= 0.056$) in losses.

To verify that the result was not confounded by the particular functional forms that we used in estimation, we confirmed the general trend of risk aversion in gains and risk seeking in losses using perhaps the most intuitive and simple risk measure, the proportion of times that a subject selected the more risky of the two sets of lottery bundles. A majority (75 percent) of subjects showed the reflection effect, selecting more of the riskier choices for losses (comparing to the gains). Averaging across all the subjects we found that they were on average risk averse in gains and risk seeking in losses. The proportion of riskier choices for beverages increased significantly from 0.3 (*SD* $= 0.218$; *median* $= 0.25$) in the gain domain to 0.542 (*SD* $= 0.226$; *median* $= 0.529$) in the loss domain ($t(59) = -5.338$, $p < 0.001$). Similarly, the proportion of riskier choices for snacks increased from 0.333 (*SD* $= 0.23$; *median* $= 0.292$) in the gain domain to 0.511 (*SD* $= 0.232$; *median* $= 0.493$) in the loss domain ($t(59) = -3.694$, $p = 0.002$).

Summing up, just as in many previous experiments with risky lotteries over money, an average subject in our study showed behavior consistent with concave utility (risk aversion) in gains and convex utility (risk seeking) in losses, a discontinuity that implies in our study, a reference point in gambles that involved food rewards. This happened even though in riskless choices *made over the same goods and at the same time*, *the same representative agent showed concave utility in both gains and losses*.

Although informative, the representative agent approach presents only averaged and not necessarily even the most frequent pattern of behavior. Therefore, we now turn to an individual subject level analysis.

*Individual Level: Riskless Choice*.—We estimated the parameters of the CES utility function separately for each subject in each domain. Table 3 summarizes this analysis by classifying individuals by their CES utility function curvature in gains and in losses. Some of the subjects remain unclassified[9] because either they had a strong preference

[9] We set these thresholds because for the extreme values of $\rho$, the indifference curve takes an L-shape (perfect complements), for which the utility curvature cannot be easily interpreted. The thresholds are arbitrary and without these thresholds, our conclusions still hold.

TABLE 3—CLASSIFICATION OF UTILITY CURVATURE IN RISKLESS CHOICES

| | | Loss | | | |
|---|---|---|---|---|---|
| | | Concave | Convex | Unclassified | Total |
| *Gain* | Concave | **22** | 12 | 4 | 38 |
| | Convex | 6 | 4 | 1 | 11 |
| | Unclassified | 7 | 1 | 3 | 11 |
| | Total | 35 | 17 | 8 | 60 |

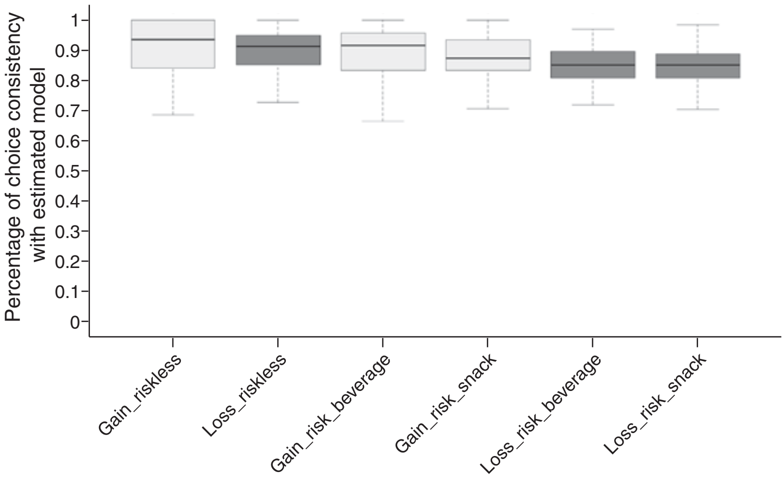


FIGURE 8

*Notes:* Box-and-whisker plots of the proportion of individuals' choices that are consistent with their individual estimates. The thick line shows the group median, the surrounding boxes delimit the twenty-fifth to seventy-fifth percentiles, and the whiskers correspond to approximately 99.3 percent coverage.

for one of the goods ($\beta = 1$ or $\beta = 0$), in which case we could not correctly estimate their utility curvature, or they were estimated to have an extreme $\rho$ above 4 or below $10^{-8}$. For the remaining subjects, in the gain domain, if $\rho_g$ is smaller (larger) than one, then the utility function is *concave* (*convex*). In the loss domain if $\rho_l$ is smaller (larger) than one, then the utility function is *convex* (*concave*). We checked that the individual estimates of the CES function capture behavior well—the median of the fraction of choices that are consistent with our individual estimates is 93.75 percent for gains and is 91.3 percent for losses (Figure 8).

If the traditional reflection effects were to hold, we would expect all of the observations to fall in the gain-concave-loss-convex cell. To the contrary, only 20 percent of our subjects showed concave utility in gains and convex utility in losses. At the same time, the percentage of subjects who showed concave utility in both gains and losses was about double that number. The median of $\rho_g$ was 0.742 and the median of $\rho_l$ was 1.289. The estimated $\beta$ parameters were also consistent with the aggregate estimation. The median of $\beta_g$ was 0.497 and the median of $\beta_l$ was 0.497 (Figure 9).

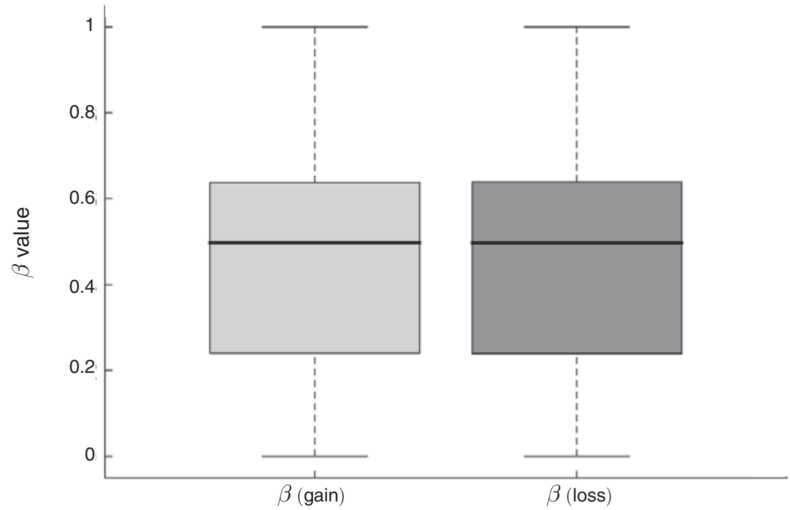


Figure 9

*Notes:* Box-and-whisker plots of the estimated $\beta$s. The thick line shows the group median, the surrounding boxes delimit the twenty-fifth to seventy-fifth percentiles, and the whiskers correspond to the minimum and the maximum.

*Individual Level: Risky Choice*.—We fit beverage data and snack data separately for each subject. The individual curvature estimates $(\alpha)$ for beverages and snacks were highly correlated within individuals ($r(58) = 0.992$ in gains and 0.929 in losses, $p < 0.001$). Therefore, for the ease of exposition, for each individual we refit his/her curvature parameter for the pooled data of beverage and snack choices, separately in gains and losses.[10] Again our estimated utility functions captured individual behavior well, correctly classifying over 85 percent of the observed choices (Figure 8).

We classified individuals into different categories, based on their utility curvature (Table 4). Those with extreme curvature parameters ($\alpha$ above 4 or below $10^{-8}$) were left unclassified. Under prospect theory, we would expect the individuals to fall into the gain-concave-loss-convex cell. Indeed, *the most frequent pattern*, 32 *out of* 60 (53.33 *percent*) *subjects*, *showed the traditional reflection effect during risky choices*. The median of $\alpha_g$ was 0.518 and the median of $\alpha_l$ was 0.626, consistent with concave utility in gains and convex utility in losses. Interestingly, in the loss domain, about half of the subjects (29) showed convex utility functions for risky choices but a bowed-in indifference curves (concave utility) under riskless conditions.

*Relationship between Utility Estimates in Riskless and Risky Task*.—Finally, we investigated whether the utility estimates in the riskless and risky choice tasks were correlated. Even though we used different functions to estimate utility curvature in the risky and riskless tasks (CRRA power utility and CES utility respectively), these

[10] The results are qualitatively the same if we perform the analysis separately for beverages and for snacks.

TABLE 4—CLASSIFICATION OF UTILITY CURVATURE IN RISKY CHOICES

| | | Loss | | | |
|---|---|---|---|---|---|
| | | Concave | Convex | Unclassified | Total |
| *Gain* | Concave | 8 | **32** | 2 | 42 |
| | Convex | 1 | 10 | 0 | 11 |
| | Unclassified | 3 | 4 | 0 | 7 |
| | Total | 12 | 46 | 2 | 60 |

functions can be easily related to each other in our sample. In particular, the slope of the indifference curve under CES is given by

$$(6) \qquad MRS_{CES} = \frac{MU_x}{MU_y} = \frac{\beta}{1-\beta}\left(\frac{x}{y}\right)^{\rho-1},$$

where $x$ is an index for beverage and $y$ is an index for snack. The slope of the indifference curve under CRRA power utility function is given by

$$MRS_{CRRA} = \frac{\alpha_x x^{\alpha_x - 1}}{\alpha_y y^{\alpha_y - 1}}.$$

Given that we found that $\beta$ is not significantly different from 0.5 and $\alpha_x$ is essentially perfectly correlated with $\alpha_y$, these reduce to approximately

$$MRS_{CES} = \left(\frac{x}{y}\right)^{\rho-1}$$

and

$$MRS_{CRRA} = \left(\frac{x}{y}\right)^{\alpha-1},$$

allowing for meaningful comparisons between the estimates in both tasks.

We could reliably classify both risky and riskless utility curvatures for 41 subjects in the gain domain and 51 subjects in the loss domain. We found that there was no relationship between utility curvature estimated using our riskless $(\rho)$ and risky tasks $(\alpha)$ neither in gains $(r(39) = 0.184, p = 0.249)$ nor in losses $(r(49) = 0.121, p = 0.399)$. These results are graphically presented in Figure 10.

## III. Discussion

While we find reflection effects in risky choice as expected, we see no evidence of such phenomena in randomly interleaved, nearly identical, riskless choices from the same subjects in the same experimental session. Our key finding is that in the domain of losses, in riskless choice over bundles, our subjects have a consistently concave utility function, rather than convex. We note that taken together these findings are not consistent with any of the three "standard" models: expected utility, prospect theory, or Kőszegi-Rabin. Both expected utility and Kőszegi-Rabin fail to explain the

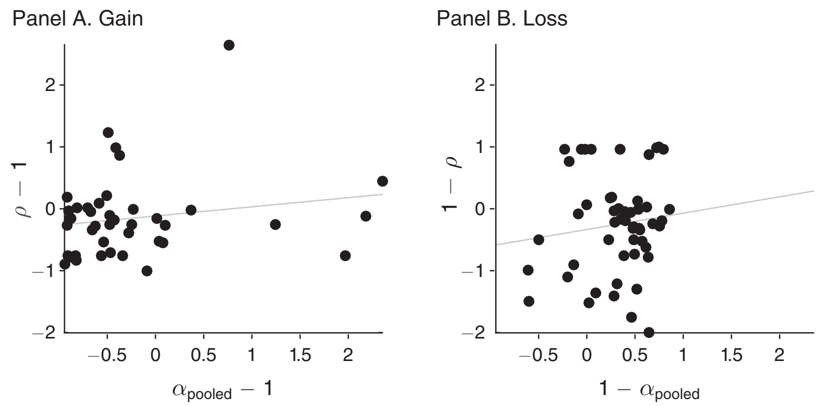


Figure 10

*Notes:* Relationship between utility curvature in riskless and risky choice tasks for A: gains and B: losses. The curvature estimates are normalized such that negative (positive) estimates indicate concave (convex) utility.

reflection in risk attitude between nominal losses and gains in our risky choices task. On the other hand, bowed-in indifference curves for gains and losses found in this paper contradict prospect theory. Our paper thus raises concerns over the suitability of assuming reflection effects in utility curvature to model riskless choice.

It could be argued that our failure to observe a reflection of curvature in the riskless trials occurs because we failed to induce true "losses" in those trials with our endowment. We point out, however, that the same endowment did induce a reflection in the risky trials we studied. These risky trials were randomly interleaved with the riskless trials and were visually almost identical to our riskless trials. Moreover, both our risky and riskless trials involved choices made by the same choosers over the same goods.

Of course diminishing sensitivity is not the only way to define the gain-loss asymmetries in choice. The other key elements of reference dependent theories of choice—loss aversion and probability weighting—deserve some discussion here. Tversky and Kahneman (1991) used loss aversion without diminishing sensitivity to predict the shape of indifference curves at different status quo reference points. In our paper, we eliminate loss aversion by focusing on choices that are either in loss domain only or in gain domain only. We explain in the theoretical background section that in such choice sets the loss aversion parameter cancels and is irrelevant for the curvature of indifference curves. From a purely theoretical perspective, we could in principle infer loss aversion from the spacing of the indifference curves. If we were to draw a map of indifference curves, each one "util" apart, then the spacing of these indifference curves could abruptly change at some wealth level/reference point. Above that reference point the curves would be further apart and below it they would be closer together if losses loomed cardinally larger for the chooser than the equally sized gains. We did not pursue the "loss aversion" path both because it is not at all clear how to empirically infer when the indifference curves are one util apart and because our goal was specifically to examine the curvature of utility and indifference curves in risky and riskless choices and to compare them directly.

The probability weighting function, the other key element of prospect theory, is obviously irrelevant in riskless choice and therefore does not impact the curvature of the indifference curves. Nevertheless, had we not included the probability weighting function, we could have in principle biased our estimates of utility curvature in the risky task and therefore drew incorrect conclusions about the relationship of the utility curvature under risky and riskless conditions. For this reason, we fit the risky choices of our subjects with a domain-specific probability weighting functions (Tversky and Kahneman 1992). With such a specification, the general pattern of reflection in utility curvature in risky choice holds, while it does not hold in riskless choice. Our findings remain the same when we analyzed our data assuming an identical probability weighting function for gains and losses, and when probability weighting was entirely omitted (see online Appendix C and online Appendix D for details).

The striking contrast between utility curvature in the loss domain estimated in a task with lotteries versus the curvature estimated in a riskless choice task is puzzling and seems to run counter to what one might expect. However, more and more evidence has emerged suggesting a separation between utility under risk and utility under certainty (Abdellaoui et al. 2013, Andreoni and Sprenger 2012, Cheung 2015). Further, more and more studies in the recent years have begun to suggest that rather than being a general phenomenon, the reflection effect may depend on context (Andreoni and Harbaugh 2009; Harbaugh, Krause, and Vesterlund 2001; Hertwig et al. 2004; Laury and Holt 2008), and may not be observed when subjects are analyzed at the individual rather than at the aggregate level (Baucells and Villasís 2010; Cohen, Jaffray, and Said 1987; Schoemaker 1990; Tymula et al. 2013; Tymula and Glimcher 2016). Summing up, it has become increasingly clear that reflection effects are not as general a phenomenon as initially suspected. Here we find an additional condition when they do not hold: riskless choice between bundles of goods.

We note that our results cannot be captured by other common types of reference dependent preferences. It is true that in our study we carried out our analysis assuming the status quo to be the reference point and many papers have argued that expectation is a better candidate for a reference point (e.g., Kőszegi and Rabin 2006). Nevertheless, as we show in the theoretical background section, our results cannot be explained by the KR model without additional assumptions beyond loss aversion, because our subjects show reflection in utility curvature in our risky task.

More generally, our findings cannot be explained by existing models that define the reference point as an expectation rather than as the status quo. This is true firstly, because we instantiated gain-loss conditions using the same manipulations in both risky and riskless tasks. Whether in the risky or riskless tasks, subjects should expect to lose when they are in a loss domain and should expect to gain when they are in a gain domain. Secondly, if the reference point was not necessarily the status quo, we should still be able to identify the reference point through the changes in indifference curvature. We do not see evidence of such reflection in curvature in riskless choice, even though we see a change in utility curvature in our risky task at these same levels. Not only we do not see the reflection in indifference curves, but to the contrary, the indifference curve in the loss domain seems to be more convex than the one in the gains. Thirdly, the risky and riskless tasks do not differ in valence or possession and thus cannot be explained by different types of loss aversion in each task (Brenner et al. 2007). *Overall, if one is inclined to consider marginal rates of substitution as reflecting something significant about marginal utilities for the underlying goods, then our data suggest a fundamental change in representation as one moves from risky to riskless conditions.*

So why is this the case? At a mechanistic (neuroeconomic) level, what is it that changes the curvature between gains and losses in one of our tasks but not in the other? One possibility is that there is something substantially different when we integrate information for decisions under risky and under riskless conditions. Consistent with this intuition, a number of papers published in recent years on the elicitation of time preferences have begun to reveal that utility elicited under risk seems to be different from utility elicited from riskless choices (Abdellaoui et al. 2013, Andreoni and Sprenger 2012, Cheung 2015). We suggest that at least some of the effects observed in these papers may be due to a change from certain to uncertain environments. Of course a traditional theorist who treats utility inferred from riskless choice as an ordinal object would not be tempted to make statements about the curvature of the elicited utility function and indifference curves. Like expected utility theory, prospect theory is a cardinal model and the simple extension of a cardinal model to riskless choice raises significant theoretical problems (Pareto 1906, Samuelson 1937). The principle of decreasing marginal utility as well as the definitions of complementarity and substitution between the goods are not unique up to positive affine transformations and, hence, are meaningless under ordinal utility. A theorist with a cardinal view of utility, however, could instead ask about the relationship between the utility in risky and riskless choice and in particular whether currently dominant theories of choice can describe choice in both of these domains. In any case, the debate on unifying risky and riskless utility has been ongoing (Abdellaoui, Attema, and Bleichrodt 2010; Abdellaoui, Barrios, and Wakker 2007; Abdellaoui et al. 2013; Dyer and Sarin 1982; Krzysztofowicz and Koch 1989; McCord and De Neufville 1985; Stalmeier and Bezembinder 1999), and our paper is an empirical contribution to this discussion.

Our paper contributes to the empirical evidence on how consumers allocate their budget to different goods. While there are abundant papers studying risky and intertemporal trade-offs, there are very few papers that empirically study indifference curves in the domain of losses. The early studies of indifference curves were conducted by psychologists, but they did not use methods that would satisfy experimental economists (see review in Moscati 2007).

Summing up, our results suggest that some of the models that were developed to explain decision-making under uncertainty may be inappropriate for modeling choices under certainty. In our data, we did not observe the reflection effect in choice under certainty, which many treat as implied by prospect theory.

# Appendix A

## A. *Proof of Proposition 1*

PROOF:

We need to show

$$\frac{dMRS}{dx} > 0 \Leftrightarrow U_{xy} > \frac{U_y^2 U_{xx} + U_x^2 U_{yy}}{2U_x U_y}$$

and

$$\frac{dMRS}{dx} < 0 \Leftrightarrow U_{xy} < \frac{U_y^2 U_{xx} + U_x^2 U_{yy}}{2U_x U_y}.$$

By definition: $MRS \equiv -U_x/U_y$.

Let $MRS_x \equiv \partial MRS/\partial x$ and $MRS_y \equiv \partial MRS/\partial y$.

Now, derive $dMRS/dx$. The total differential of MRS is given by

$$dMRS = MRS_x dx + MRS_y dy \quad (\text{or, dividing both sides by } dx)$$
$$\frac{dMRS}{dx} = MRS_x + MRS_y \frac{dy}{dx}.$$

Let us calculate each component of $dMRS/dx$ ($MRS_x$, $MRS_y$ and $dy/dx$) separately:

$$MRS_x = \frac{\partial MRS}{\partial x} = \frac{\partial\left(-\frac{U_x}{U_y}\right)}{\partial x} = -\frac{U_{xx}U_y - U_{yx}U_x}{U_y^2},$$
$$MRS_y = \frac{\partial MRS}{\partial y} = \frac{\partial\left(-\frac{U_x}{U_y}\right)}{\partial y} = -\frac{U_{xy}U_y - U_{yy}U_x}{U_y^2},$$
$$\frac{dy}{dx} = -\frac{U_x}{U_y} \quad (\text{by definition of MRS}).$$

Let us substitute each of the above elements in $dMRS/dx$:

$$\frac{dMRS}{dx} = -\frac{U_{xx}U_y - U_{yx}U_x}{U_y^2} + \frac{U_{xy}U_y - U_{yy}U_x}{U_y^2}\frac{U_x}{U_y},$$

which simplifies to

$$\frac{dMRS}{dx} = \frac{2U_x U_y U_{xy} - U_y^2 U_{xx} - U_x^2 U_{yy}}{Uy^3}.$$

Since $U_y > 0$ (monotonicity), we get that

$$\frac{dMRS}{dx} > 0 \Leftrightarrow U_{xy} > \frac{U_y^2 U_{xx} + U_x^2 U_{yy}}{2U_x U_y}$$

and

$$\frac{dMRS}{dx} < 0 \Leftrightarrow U_{xy} < \frac{U_y^2 U_{xx} + U_x^2 U_{yy}}{2U_x U_y},$$

which completes the proof. ∎

B. *Proof of Proposition 2*

PROOF:

(i) Holds by definition.

(ii) We need to show:

**Case 1:** $dMRS/dx > 0 \Leftrightarrow U_{xx} < 0$ and $U_{yy} < 0$, and

**Case 2:** $dMRS/dx < 0 \Leftrightarrow U_{xx} > 0$ and $U_{yy} > 0$.

Let us start with Case 1, where $U_{xx} < 0$ and $U_{yy} < 0$. We need to show that $dMRS/dx > 0$ (IC convexity condition) always holds.

In Proposition 1, we derived the IC convexity condition to be

$$\frac{dMRS}{dx} > 0 \Leftrightarrow U_{xy} > \frac{U_y^2 U_{xx} + U_x^2 U_{yy}}{2U_x U_y}.$$

The IC convexity condition is trivially satisfied for all utility functions such that $U_{xy} \geq 0$. It is straightforward to see that in these cases the left side of the condition is positive, while the right side of the condition is negative.

To show that the IC convexity condition is satisfied also for $U_{xy} < 0$, we need to invoke Assumption 1. By Assumption 1, we impose that $U_{xx} \leq U_{xy} \leq -U_{xx}$ and $U_{yy} \leq U_{xy} \leq -U_{yy}$. The IC convexity condition is hardest to satisfy for the highest admissible $U_{xx}$ and $U_{yy}$. Therefore, we just need to show that the condition is satisfied for $U_{xx} = U_{xy}$ and $U_{yy} = U_{xy}$, as per Assumption 1. Substituting $U_{xx}$ and $U_{yy}$ with $U_{xy}$, we obtain:

$$\frac{dMRS}{dx} > 0 \Leftrightarrow U_{xy} > \frac{U_y^2 U_{xy} + U_x^2 U_{xy}}{2U_x U_y} \Leftrightarrow 0 > U_{xy} \frac{(U_y - U_x)^2}{2U_x U_y},$$

which is satisfied as long as $U_{xy} < 0$, which we assumed in the first place.

Now, let us focus on Case 2, where $U_{xx} > 0$ and $U_{yy} > 0$. We need to show that $dMRS/dx < 0$ (IC concavity condition) always holds.

In Proposition 1 we derived the IC concavity condition to be

$$\frac{dMRS}{dx} < 0 \Leftrightarrow U_{xy} < \frac{U_y^2 U_{xx} + U_x^2 U_{yy}}{2U_x U_y}.$$

This condition is trivially satisfied for all utility functions such that $U_{xy} \leq 0$. It is straightforward to see that in these cases the left side of the inequality is negative while the right hand side is positive.

To show that the IC concavity condition is satisfied also for $U_{xy} > 0$, we need to recall assumption 1. By assumption 1 we impose that $-U_{xx} \leq U_{xy} \leq U_{xx}$ and $-U_{yy} \leq U_{xy} \leq U_{yy}$. The IC concavity condition is hardest to satisfy for the lowest admissible $U_{xx}$ and $U_{yy}$. Therefore, we just need to show that the condition is satisfied for $U_{xx} = U_{xy}$ and $U_{yy} = U_{xy}$. Substituting $U_{xx}$ and $U_{yy}$ with $U_{xy}$, we can rewrite the IC concavity condition as

$$\frac{dMRS}{dx} < 0 \Leftrightarrow U_{xy} < \frac{U_y^2 U_{xy} + U_x^2 U_{xy}}{2U_x U_y} \Leftrightarrow 0 < U_{xy} \frac{(U_y - U_x)^2}{2U_x U_y},$$

which is satisfied as long as $U_{xy} > 0$ which we assumed in the first place.

An important observation to make is that the loss aversion parameter, a crucial element of prospect theory, is irrelevant for determining the curvature of the indifference curve. Under prospect theory, the slope of the indifference curve remains: *MRS* $= -U_x/U_y$ for both gains and losses. Using the result of Proposition 1 and Assumption 1, together with the prospect theory assumption on $U_{xx}$ and $U_{yy}$, we can conclude that indifference curves will be convex in gains and concave in losses for goods that obey the restriction we impose on substitution patterns. This completes the proof. ∎

### C. *Proof of Proposition 3*

PROOF:

(i) Holds by definition of prospect theory.

(ii) The same proof as for expected utility theory. ∎

### D. *Proof of Proposition 4*

PROOF:

(i) We need to show: in risky choice, KR preferences do not predict reflection in risk attitude between nominal losses and gains.

Suppose that an individual is considering two gambles with equal expected value: $g_a$ and $g_b$. Gamble $g_a$ pays $a_1$ with probability $p$ and $a_2$ with probability $1 - p$. Gamble $g_b$ pays $b_1$ with probability $q$ and $b_2$ with probability $1 - q$. A risk neutral chooser would be indifferent between these gambles. A risk averse (seeking) chooser would pick the gamble with smaller (larger) variance. Assuming that the individual has a consistent referent, we now show that she makes the same choice, independent of whether the outcomes are positive or negative. This is inconsistent with the prospect theory idea of diminishing sensitivity from the reference point.

First, assume that all the outcomes are in the gain domain and $g_b$ has higher variance than $g_a$ ($g_b$ is more risky than $g_a$): $0 = b_2 = a_2 < a_1 < b_1$.[11]

Assume that $g_a$ is the referent:[12]

$$\begin{aligned} U(g_a | g_a) &= m(g_a) + n(g_a | g_a) \\ &= pm(a_1) + (1-p)m(a_2) + p(1-p)\mu\big(m(a_1) - m(a_2)\big) \\ &\quad + (1-p)p\mu\big(m(a_2) - m(a_1)\big), \\ U(g_b | g_a) &= m(g_b) + n(g_b | g_a) \\ &= qm(b_1) + (1-q)m(b_2) + p\big[q\mu\big(m(b_1) - m(a_1)\big) \\ &\qquad + (1-q)\mu\big(m(b_2) - m(a_1)\big)\big] \\ &\quad + (1-p)[q\mu\big(m(b_1) - m(a_2)\big) + (1-q)\mu\big(m(b_2) - m(a_2)\big)]. \end{aligned}$$

Simplifying further, we get

$$\begin{aligned} U(g_a | g_a) &= m(g_a) + n(g_a | g_a) = pm(a_1) + p(1-p)m(a_1)(1-\lambda), \\ U(g_b | g_a) &= m(g_b) + n(g_b | g_a) \\ &= qm(b_1) + p\big[q\big(m(b_1) - m(a_1)\big) + (1-q)\lambda\big(-m(a_1)\big)\big] \\ &\quad + (1-p)q\big(m(b_1)\big) \\ &= 2qm(b_1) - m(a_1)p(q + \lambda - \lambda q). \end{aligned}$$

In particular, individual chooses gamble $g_a$ whenever

$$U(g_a | g_a) > U(g_b | g_a) \Leftrightarrow$$

$$n(g_a | g_a) > n(g_b | g_a) \Leftrightarrow$$

$$m(a_1)\big[2p + p(\lambda - 1)(p - q)\big] > 2qm(b_1),$$

$$U(g_a | g_a) > U(g_b | g_a) \Leftrightarrow$$

$$m(a_1)p(\lambda - 1)(p - q) > 2\big[qm(b_1) - pm(a_1)\big].$$

[11] The proof is trivially extended to a case where $0 < b_2 < a_2 < a_1 < b_1$.
[12] The proof is trivially extended to a case where the other gamble is the referent.

What is left to show is that the individual will make the same choice when choosing between symmetric loss gambles: $g_a'$ and $g_b'$. Note that $g_a'$ pays $-a_1$ with probability $p$, and 0 otherwise. Similarly, $g_b'$ pays $-b_1$ with probability $q$, and 0 otherwise. Following the same steps as above, we get that

$$m(-a_1) = -m(a_1),$$

$$m(-b_1) = -m(b_1),$$

$$U(g_a' \,|\, g_a') > U(g_b' \,|\, g_a') \Leftrightarrow$$

$$m(a_1)p(\lambda - 1)(p - q) > (1 + \lambda)\left[pm(a_1) - qm(b_1)\right],$$

$$U(g_a' | g_a') > U(g_b' | g_a') \Leftrightarrow m(a_1)\left[2p + p(\lambda - 1)(p - q)\right] > 2qm(b_1),$$

which is exactly the same condition as for the symmetric gambles in the gain domain. Therefore, under the KR model, and unlike in prospect theory, the individual exhibits the same risk attitude for symmetric gain and loss gambles.

We reach the same conclusion that individual exhibits the same risk attitude for symmetric gain and loss gambles when the riskier option, $g_b$, serves as reference point. Generally speaking, the prediction of the KR model is that people will be risk neutral when the more risky option serves as referent and risk averse when safer option serves as the referent (see Sprenger 2015 for details and proofs) independent of whether the choice is in the gain or in the loss domain.

(ii) In the KR model, "*In deterministic settings*, *choices maximize consumption utility*" (Kőszegi and Rabin 2006) and gain-loss utility is irrelevant. This effectively means that under riskless conditions, the KR model boils down to the EU framework where the curvature of the utility function does not change between gains and losses. This implies that indifference curves have the same curvature in gains and in losses, assuming the restriction on substitution that we impose. ∎

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