

An Endowment Effect for Risk: Experimental Tests of Stochastic Reference Points*

Charles Sprenger[†]

University of California, San Diego

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Abstract

The endowment effect has been widely documented. Recent models of reference-dependent preferences indicate that expectations play a prominent role in the presence of the phenomenon. A subset of such expectations-based models predicts an endowment effect for risk when reference points change from certain to stochastic. In two purposefully simple risk preference experiments, eliminating often-discussed confounds, I demonstrate both between and within-subjects an endowment effect for risky gambles. While subjects are virtually risk neutral when choosing between fixed gambles and changing certain amounts, a high degree of risk aversion is displayed when choosing between fixed amounts and changing gambles. These results provide needed separation between expectations-based reference-dependent models, allow for evaluation of recent theoretical extensions, and may help to close a long-standing debate in decision science on inconsistency between probability and certainty equivalent methodology for utility elicitation.

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[†]University of California at San Diego, Department of Economics, 9500 Gilman Drive, La Jolla, CA 92093; csprenge@ucsd.edu.

1 Introduction

The endowment effect refers to the frequent finding in both experimental and survey research that willingness to pay (WTP) for a given object is generally lower than willingness to accept (WTA) for the same good.¹ Though standard economics argues the two values should be equal apart from income effects, differences between WTA and WTP have been documented across a variety of contexts from public services and environmental protection to private goods and hunting licences (Thaler, 1980; Knetsch and Sinden, 1984; Brookshire and Coursey, 1987; Coursey, Hovis and Schulze, 1987; Knetsch, 1989; Kahneman, Knetsch and Thaler, 1990; Harbaugh, Krause and Vesterlund, 2001). Horowitz and McConnell (2002) provide a survey of 50 studies and find a median ratio of mean WTA to mean WTP of 2.6.

The endowment effect has been cited as a key example of loss aversion relative to a reference point (Knetsch, Tang and Thaler, 2001). Reference-dependent preferences with disproportionate treatment of losses predicts sizable differences between WTA and WTP . If losses are felt more severely than commensurate gains, paying for a good one does not own involves incurring monetary loss, reducing WTP . Meanwhile, giving up a good one does own involves incurring physical loss, increasing WTA . The preference structure of loss aversion drives a wedge between the two values, resulting in $WTA > WTP$.

Theoretical models of reference-dependent preferences with asymmetric treatment of losses originated in the prospect theory work of Kahneman and Tversky (1979). These models have gained traction, rationalizing not only the endowment effect, but also a number of other important anomalies from labor market decisions (Camerer, Babcock, Loewenstein and Thaler, 1997; Goette and Fehr, 2007), to consumer behavior (Hardie, Johnson and Fader, 1993; Sydnor, Forthcoming), and finance (Odean, 1998; Barberis and Huang, 2001; Barberis, Huang and Santos, 2001), among others.

Critical to reference-dependent models is the determination of the reference point around which losses and gains are encoded. Originally, the reference point was left undetermined, taken to be the status quo, current level of assets, or a level of aspiration or expectation (Kahneman and Tversky, 1979). Indeed, the freedom of the reference point may be the reason why reference dependence is able to rationalize such a large amount of behavior. Model extensions have added discipline. Particular attention has been given to expectations-based mechanisms for the determination of fixed reference points in models of Disappointment Aversion (DA) (Bell, 1985; Loomes and Sugden,

¹Though I will refer to WTP and WTA as exchanging money for goods, these terms can also be thought of as willingness to exchange goods for goods such as mugs for pens and vice versa.

1986; Gul, 1991), or for the determination of stochastic reference distributions in the more recent models of Koszegi and Rabin (2006, 2007) (KR).² In DA the referent is modeled as the expected utility certainty equivalent of a gamble, while in the KR model the referent is the full distribution of expected outcomes.

The DA and KR models provide coherent structure for the determination of reference points, and have found support in a number of studies. A recent body of field and laboratory evidence has highlighted the importance of expectations for reference-dependent behavior (Post, van den Assem, Baltussen and Thaler, 2008; Ericson and Fuster, 2009; Gill and Prowse, 2010; Pope and Schweitzer, Forthcoming; Crawford and Meng, Forthcoming; Abeler, Falk, Goette and Huffman, Forthcoming; Card and Dahl, Forthcoming). Additionally, Koszegi and Rabin (2006) and Knetsch and Wong (2009) argue that a sensible account of expectations may help to organize the discussion of the conditions under which the endowment effect is observed in standard exchange experiments (Plott and Zeiler, 2005, 2007).³

Though the accumulated data do demonstrate the importance of expectations for reference dependence, the data is generally consistent with either DA or the KR model and is often presented as such. That is, the body of evidence is unable to distinguish between the DA and KR models. Achieving such a distinction is critical for evaluating applications of the two models in a variety of settings where their predictions differ. Such settings include, but are not limited to theoretical extensions, experimental anomalies, financial decision making and marketing.

This paper presents evidence from two experiments focused on identifying a particular prediction of the KR model which is not shared with disappointment aversion: an endowment effect for risk. The KR model predicts that when risk is expected, and therefore the referent is stochastic, behavior will be different from when risk is unexpected and the referent is certain. In particular, when the referent is stochastic, and an individual is offered a certain amount, the KR model predicts near risk neutrality. Conversely, when the referent is a fixed certain amount, and an individual is offered a

²Disappointment Aversion can refer to a number of different classes of models. I focus primarily on Bell (1985) and Loomes and Sugden (1986) who capture disappointment aversion in functional form by fixing the referent as the certainty equivalent of a given gamble and develop a reference-dependent disappointment-elation function around this point. Shalev (2000) provides a similar functional form in a loss-averse game-theoretic context with the reference point fixed at a gamble's certainty equivalent. Though similar in spirit to these models, Gul (1991) provides a distinct axiomatic foundation for disappointment aversion relaxing the independence axiom. The resulting representation's functional form is similar to prospect theory probability weighting (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992) with disappointment aversion making a particular global restriction on the shape of the probability weighting function (Abdellaoui and Bleichrodt, 2007).

³Expectations of exchange may also help organize results such as documented differences in endowment-effect behavior between experienced traders and novices List (2003, 2004).

gamble, the KR model predicts risk aversion. Hence, the KR model features an endowment effect for risk. Disappointment aversion makes no such asymmetric prediction as to the relationship between risk attitudes and reference points, because gambles are always evaluated relative to a fixed referent, the gamble's certainty equivalent.⁴

Prior studies have provided only limited evidence on the critical KR prediction of an endowment effect for risk. Knetsch and Sinden (1984) demonstrate that a higher proportion of individuals are willing to pay \$2 to keep a lottery ticket with unknown odds of winning around \$50, than to accept \$2 to give up the same lottery ticket if they already possess it. Kachelmeier and Shehata (1992) show that *WTA* for a 50%-50% gamble over \$20 is significantly larger than subsequent *WTP* out of experimental earnings for the same gamble.

Though intriguing, these studies and others on the endowment effect suffer from potential experimental confounds. Plott and Zeiler (2005, 2007) discuss a variety of issues. In particular, they argue that when providing subjects with actual endowments via language, visual cues or physical cues, subjects may view the endowment as a gift and be unwilling to part with it. When using neutral language and elicitation procedures based on the Becker, Degroot and Marschak (1964) mechanism, Plott and Zeiler (2005) document virtually no difference between *WTA* and *WTP* for university-branded mugs.⁵ Plott and Zeiler (2007) demonstrate, among other things, the extent to which the endowment effect could be related to subjects' interpretation of gift-giving. The authors increase and reduce emphasis on gifts and document corresponding increases and decreases in willingness to trade endowed mugs for pens, and vice versa.

Given the potential confounds of prior experimental methods, it is important to move away from the domain of physical endowments and ownership-related language. I present between and within-subjects results from simple, neutrally-worded experiments conducted with undergraduate students at the University of California, San Diego. In the primary experiment, 136 subjects were separated into two groups. Half of subjects were asked a series of certainty equivalents for given gambles. In each decision the gamble was fixed while the certain amount was changed. The other half were asked a series of probability equivalents for given certain amounts. In each decision the certain amount was fixed while the gamble probabilities were changed. In a second study,

⁴See Koszegi and Rabin (2007) for discussion.

⁵Plott and Zeiler (2005) discuss data from a series of small-scale paid practice lottery conditions, which they argue were contaminated by subject misunderstanding and order effects. Recently these data have been called into question as potentially demonstrating an endowment effect for small-stakes lotteries (Isoni, Loomes and Sugden, Forthcoming). However, the debate remains unresolved as to whether subject misunderstanding of the Becker et al. (1964) mechanism or other aspects of the experimental procedure are the primary factors (Plott and Zeiler, Forthcoming).

portions of the data collected for Andreoni and Sprenger (2010) with an additional 76 subjects and a similar, within-subjects design are presented.

The results are striking. Both between and within-subjects virtual risk neutrality is obtained in the certainty equivalents data, while significant risk aversion is obtained in probability equivalents. In the primary study, subjects randomly assigned to probability equivalent conditions are between three and four times more likely to exhibit risk aversion than subjects assigned to certainty equivalent conditions. This result is maintained when controlling for socio-demographic characteristics, numeracy, cognitive ability and self-reported risk attitudes.

The between-subjects design of the primary study is complemented with additional uncertainty equivalents (McCord and de Neufville, 1986; Magat, Viscusi and Huber, 1996; Oliver, 2005, 2007; Andreoni and Sprenger, 2010). Uncertainty equivalents ask subjects to choose between a given gamble and alternate gambles outside of the given gamble's outcome support. The KR preference model predicts risk aversion in this domain and risk neutrality in the inverse. That is, individuals should be risk averse when endowed with a gamble $(p; y, x)$, $y > x > 0$ and trading for gambles $(q; y, 0)$, but should be risk neutral when endowed with a gamble $(p; y, 0)$ and trading for gambles $(q; y, x)$.⁶ These predictions are generally supported.

Finding evidence of an endowment effect for risk, particularly in a neutral environment like that presented in these studies, provides support for the KR preference model. Unlike prior work demonstrating the importance of expectations for reference points, these results are able to distinguish between KR preferences and other expectations-based models such as disappointment aversion. Gaining separation between these models is an important experimental step and necessary for evaluating theoretical developments that depend critically on the stochasticity of the referent (Koszegi and Rabin, 2006, 2007; Heidhues and Koszegi, 2008; Koszegi and Rabin, 2009). Additionally, the distinction between the KR and DA models is important in a variety of applied settings where the two models make different predictions. In particular, the DA model predicts first order risk aversion in the sense of Segal and Spivak (1990) over all gambles, while the KR model predicts first order risk aversion only when risk is unexpected.⁷ Applications include financial decisions where first order risk aversion is argued to influence stock market participation (Haliassos and Bertaut, 1995; Barberis, Huang and Thaler, 2006) and returns (Epstein and Zin, 1990;

⁶Standard theories and disappointment aversion again predict no difference in risk preference across this changing experimental environment.

⁷By unexpected I mean when risky outcomes lie outside the support of the referent. This is the case when the referent is fixed and when the referent is stochastic but outcomes are more variable.

Barberis and Huang, 2001); insurance purchasing where first order risk aversion potentially influences contract choice (Sydnor, Forthcoming), and decision science where researchers have long debated the inconsistency between probability equivalent and certainty equivalent methods for utility assessment (Hershey, Kunreuther and Schoemaker, 1982; McCord and de Neufville, 1985, 1986; Hershey and Schoemaker, 1985; Schoemaker, 1990).

In addition to providing techniques for modeling stochastic referents, Koszegi and Rabin (2006, 2007) propose a refinement of their model, the Preferred Personal Equilibrium (PPE), in which the referent is revealed by choice behavior. The PPE refinement predicts identical risk attitudes across the experimental conditions. Since the findings reject disappointment aversion, which predicts the same pattern, it necessarily rejects this refinement. A more likely non-PPE candidate for organizing the behavior is that the referent is established as the fixed element in a given series of decisions, which was always presented first. Koszegi and Rabin (2006) provide intuition in this direction suggesting “a person’s reference point is her probabilistic beliefs about the relevant consumption outcome held between the time she first focused on the decision determining the outcome and shortly before consumption occurs” [p. 1141]. “First focus” may plausibly be drawn to the fixed, first element in a series of decisions and the intuition is in line with both the psychological literature on “cognitive reference points” (Rosch, 1974)⁸ and evidence from multi-person domains where behavior is organized around initial reactions to experimental environments (Camerer, Ho and Chong, 2004; Costa-Gomes and Crawford, 2006; Crawford and Iriberri, 2007; Costa-Gomes, Crawford and Iriberri, 2009). The potential sensitivity of expectations-based referents to minor contextual changes has implications for both economic agents, such as marketers, and experimental methodology.

The paper proceeds as follows. Section 2 presents conceptual considerations for thinking about certainty and probability equivalents in standard theories, reference-dependent theories and the KR model. Section 3 presents experimental design and Section 4 presents results. Section 5 provides interpretation and discusses future avenues of research and Section 6 is a conclusion.

⁸Rosch (1974) describes a cognitive reference point as the stimulus “which other stimuli are seen ‘in relation to’” [p. 532]. In the present studies this relationship is achieved by asking subjects to make repeated choices between the fixed decision element and changing alternatives.

2 Conceptual Considerations

In this section several models of risk preferences are discussed. With one exception, the models predict equivalence of risk attitudes across certainty equivalents and probability equivalents. The exception is the KR model, which predicts an endowment effect for risk.

Consider expected utility. Any complete, transitive, continuous preference ordering over lotteries that also satisfies the independence axiom will be represented by a standard expected utility function, $v(\cdot)$, that is linear in probabilities. Under such preferences, a certainty equivalent for a given gamble will be established by a simple indifference condition. Take a binary p gamble over two positive values, y and $x \leq y$, $(p; y, x)$, and some certain amount, c , satisfying the indifference condition

$$v(c) = p \cdot v(y) + (1 - p) \cdot v(x).$$

Under expected utility, it will not matter whether risk preferences are elicited via the certainty equivalent, c , or the probability equivalent, p ; the elicited level of risk aversion, or the curvature of $v(\cdot)$, should be identical. There should be no endowment effect for risk.

A similar argument can be made for reference-dependent prospect theory which establishes loss-averse utility levels relative to some fixed referent and relaxes the independence axiom's implied linearity in probability (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992; Tversky and Fox, 1995; Wu and Gonzalez, 1996; Prelec, 1998; Gonzalez and Wu, 1999; Abdellaoui, 2000; Bleichrodt and Pinto, 2000). Let $u(\cdot|r)$ represent loss-averse utility given some fixed referent, r . The cumulative prospect theory indifference condition is

$$u(c|r) = \pi(p) \cdot u(y|r) + (1 - \pi(p)) \cdot u(x|r),$$

where $\pi(\cdot)$ represents some arbitrary non-linear probability weighting function. Under such a utility formulation, certainty and probability equivalents again yield identical risk attitudes as the reference point is fixed at some known value.

Extensions to reference-dependent preferences have attempted to explain behavior by establishing what the reference point should actually be. Models of disappointment aversion fix the prospect theory reference point via expectations as a gamble's expected utility certainty equivalent (Bell, 1985; Loomes and Sugden, 1986). Disappointment aversion's fixed referent does not change the predicted equivalence of risk preferences

across probability and certainty equivalents as gambles are always evaluated relative to their certainty equivalents. In effect, disappointment aversion selects r in the above indifference condition as the expected utility certainty equivalent, $p \cdot v(y) + (1-p) \cdot v(x)$, and selects a linear probability weighting function.⁹

2.1 KR Preferences

The KR model builds upon standard reference-dependent preferences in two important ways. First, similar to disappointment aversion, the referent is expectations-based, and second, the referent may be stochastic. Together these innovations imply that behavior when risk is expected, and therefore the referent is stochastic, will be substantially different from when risk is unexpected, and the referent is certain. In particular, KR preferences as presented below predict risk neutrality in specific cases where the referent is stochastic and risk aversion in cases where the referent is certain.

Let r represent the referent potentially drawn according to measure G . Let x be a consumption outcome potentially drawn according to measure F . Then the KR utility formulation is

$$U(F|G) = \iint u(x|r) dG(r) dF(x)$$

with

$$u(x|r) = m(x) + \mu(m(x) - m(r)).$$

The function $m(\cdot)$ represents consumption utility and $\mu(\cdot)$ represents gain-loss utility relative to the referent, r . Several simplifying assumptions are made. First, following Koszegi and Rabin (2006, 2007) small stakes decisions are considered such that consumption utility, $m(\cdot)$, can plausibly be taken as approximately linear, and a piecewise-linear gain-loss utility function is adopted,

$$\mu(y) = \left\{ \begin{array}{ll} \eta \cdot y & \text{if } y \geq 0 \\ \eta \cdot \lambda \cdot y & \text{if } y < 0 \end{array} \right\},$$

where the utility parameter λ represents the degree of loss aversion. For simplicity and to aid the exposition, $\eta = 1$ is assumed, and only binary lotteries are considered such that G and F will be binomial distributions summarized by probability values p and q , respectively.

Consider two cases, first where the referent is certain and consumption outcomes are stochastic, and second where the referent is stochastic and consumption outcomes

⁹See Bell (1985); Loomes and Sugden (1986) for the exact functional forms.

are certain. The above KR model predicts risk averse behavior in the first case and risk neutrality in the second. This is illustrated next.

2.1.1 Probability Equivalent: Certain Referent, Binary Consumption Gamble

Consider a referent, r , and a binary consumption gamble with outcomes $x_1 \geq r$ with probability q and $x_2 \leq r$ with probability $1 - q$.¹⁰ Write the KR utility as

$$U(F|r) = q \cdot u(x_1|r) + (1 - q) \cdot u(x_2|r).$$

The first term refers to the chance of expecting r as the referent and obtaining x_1 as the consumption outcome. The second term is similar for expecting r and obtaining x_2 . If $x_1 \geq r > x_2$, the KR model predicts loss aversion to be present in the second term. Under the assumptions above, this becomes

$$U(F|r) = q \cdot [x_1 + 1 \cdot (x_1 - r)] + (1 - q) \cdot [x_2 + \lambda \cdot (x_2 - r)]. \quad (1)$$

Compare this to the utility of the certain amount, $U(r|r) = r$. The lottery will be preferred to the certain referent if $U(F|r) > U(r|r)$ and the indifference point, or *probability equivalent*, will be obtained for some F^* , with corresponding probability q^* , such that $U(F^*|r) = U(r|r)$,

$$r = q^* \cdot [x_1 + 1 \cdot (x_1 - r)] + (1 - q^*) \cdot [x_2 + \lambda \cdot (x_2 - r)];$$

$$q^* = \frac{r - x_2 - \lambda \cdot (x_2 - r)}{[x_1 - x_2] + [1 \cdot (x_1 - r) - \lambda \cdot (x_2 - r)]}. \quad (2)$$

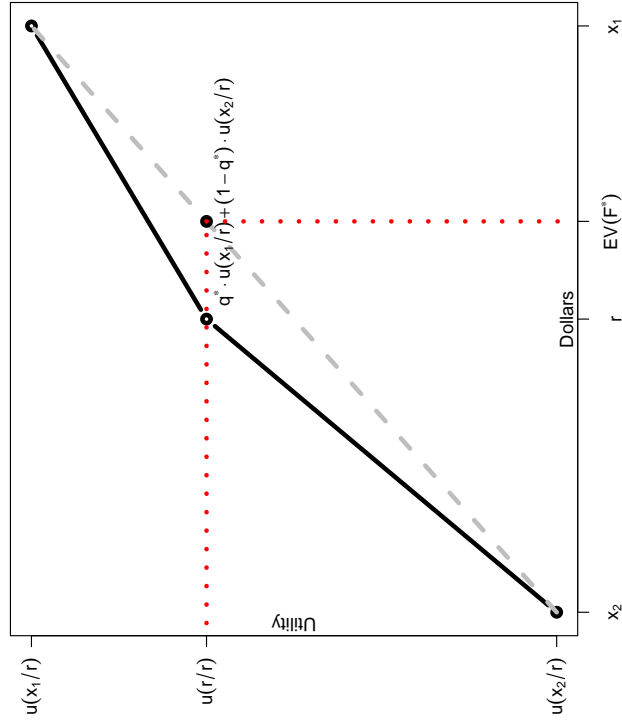
The interpretation of the relationship between risk aversion elicited as q^* and loss aversion, λ , is straightforward. For an individual who is not loss averse, $\lambda = 1$, $q^* = (r - x_2)/(x_1 - x_2)$. This equates the expected value of the probability equivalent and the referent value, $r = q^* \cdot x_1 + (1 - q^*) \cdot x_2$. Risk neutral behavior is exhibited by individuals who are not loss averse.

For loss averse individuals with $\lambda > 1$, $q^* > (r - x_2)/(x_1 - x_2)$ for $x_1 > r > x_2 \geq 0$. The gamble F^* will have higher expected value than r . Figure 1, Panel A illustrates

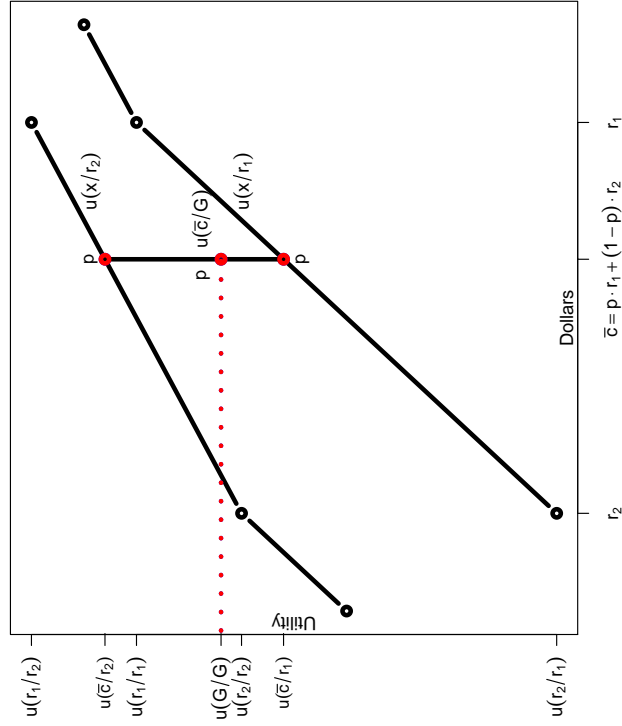
¹⁰I assume $x_2 \geq 0$ and that at least one of the inequalities is strict such that consumption gamble is non-degenerate.

Figure 1: KR Probability and Certainty Equivalents

Panel A : Probability Equivalent



Panel B : Certainty Equivalent



Note: The figure illustrates probability and certainty equivalents under KR preferences. For probability equivalents in Panel A, the KR model predicts apparent risk averse behavior as the expected value of the probability equivalent gamble, $EV(F^*)$, is greater than the referent, r . For certainty equivalents in Panel B, KR predicts risk neutrality at all levels of loss aversion as the utility of the expected value of a gamble, $u(\bar{c}|G)$, is equal to the value of the gamble, $u(G|G)$.

the decision for a loss averse individual. Additionally $dq^*/d\lambda > 0$ for $x_1 > r > x_2 \geq 0$, such that probability equivalents are increasing in the degree of loss aversion.¹¹ If endowed with a fixed amount in a probability equivalent task and trading for a gamble, a loss-averse individual will appear risk averse.

Note that as x_1 approaches r , then q^* approaches 1, and as x_2 approaches r , then q^* approaches 0. Hence q^* will accord with the risk neutral level, $(r - x_2)/(x_1 - x_2)$, at the limits $x_1 = r$ and $x_2 = r$. This implies a hump shaped deviation between q^* and the risk neutral level of q if $\lambda > 1$.

2.1.2 Certainty Equivalent: Binary Referent Gamble, Certain Consumption

Now consider a binary referent gamble and the prospect of certain consumption. Let r_1 be the referent with probability p and $r_2 \leq r_1$ be the referent with probability $1 - p$. The utility of the binary referent gamble is

$$U(G|G) = p \cdot p \cdot u(r_1|r_1) + (1-p) \cdot (1-p) \cdot u(r_2|r_2) + p \cdot (1-p) \cdot u(r_1|r_2) + p \cdot (1-p) \cdot u(r_2|r_1).$$

The first term refers to the chance of expecting r_1 as the referent and obtaining r_1 as the consumption outcome. The second term is similar for r_2 . The third term refers to the chance of expecting r_2 as the referent and obtaining r_1 as the consumption outcome. The fourth term refers to the chance of expecting r_1 as the referent and obtaining r_2 as the consumption outcome. With $r_1 \geq r_2$, the KR model predicts loss aversion to be present in the fourth term. Under the assumed utility formulation this reduces to

$$U(G|G) = p^2 \cdot r_1 + (1-p)^2 \cdot r_2 + p \cdot (1-p) \cdot [r_1 + 1 \cdot (r_1 - r_2)] + p \cdot (1-p) \cdot [r_2 + \lambda \cdot (r_2 - r_1)];$$

$$U(G|G) = p \cdot r_1 + (1-p) \cdot r_2 + p \cdot (1-p) \cdot [1 \cdot (r_1 - r_2) + \lambda \cdot (r_2 - r_1)].$$

Given this stochastic referent, consider the utility of a certain outcome, x , with $r_1 \geq x \geq r_2$,

$$U(x|G) = p \cdot u(x|r_1) + (1-p) \cdot u(x|r_2),$$

$$U(x|G) = x + p \cdot [\lambda \cdot (x - r_1)] + (1-p) \cdot [1 \cdot (x - r_2)].$$

The indifference point, or *certainty equivalent* c , is obtained for $U(c|G) = u(G|G)$,

$$p \cdot r_1 + (1-p) \cdot r_2 + p \cdot (1-p) \cdot [1 \cdot (r_1 - r_2) + \lambda \cdot (r_2 - r_1)] = c + p \cdot [\lambda \cdot (c - r_1)] + (1-p) \cdot [1 \cdot (c - r_2)].$$

¹¹The derivative $dq^*/d\lambda = \frac{-(x_2-r) \cdot (2x_1-2r)}{[x_1-x_2+1 \cdot (x_1-r) - \lambda \cdot (x_2-r)]^2} > 0$ for $x_1 > r > x_2 \geq 0$.

To demonstrate that individuals will be risk neutral in certainty equivalent decisions, one need only establish the expected value as the risk neutral benchmark, $\bar{c} = p \cdot r_1 + (1 - p) \cdot r_2$. Substituting $c = \bar{c}$ in the right hand side of the above equation, one obtains

$$p \cdot r_1 + (1 - p) \cdot r_2 + p \cdot [\lambda(p \cdot r_1 + (1 - p) \cdot r_2 - r_1)] + (1 - p) \cdot [1(p \cdot r_1 + (1 - p) \cdot r_2 - r_2)],$$

which reduces to

$$p \cdot r_1 + (1 - p) \cdot r_2 + p \cdot (1 - p) \cdot [1(r_1 - r_2) + \lambda(r_2 - r_1)],$$

and is identical to the left hand side of the above equation. Hence, indifference occurs at the risk neutral benchmark, $c = \bar{c} = p \cdot r_1 + (1 - p) \cdot r_2$. Figure 1, Panel B illustrates the certainty equivalent of a gamble as the gamble's expected value, \bar{c} . If endowed with a gamble in a certainty equivalent task and trading for a fixed amount, a loss-averse individual will appear risk neutral, regardless of the level of loss aversion. This is in contrast to probability equivalents where loss-averse individuals will appear risk averse.

2.1.3 Equilibrium Behavior

Koszegi and Rabin (2006, 2007) present a rational expectations equilibrium concept, the Unacclimating Personal Equilibrium (UPE), in which consumption outcomes correspond to expectations. The objective of the UPE concept is to represent the notion that rational individuals will only expect consumption outcomes that they will definitely consume given the expectation of said consumption outcomes. To select among the potential multiplicity of such equilibria, the KR model features a refinement, the Preferred Personal Equilibrium (PPE). The PPE concept maintains that the UPE with the highest ex-ante expected utility is selected.¹²

The development above demonstrates that KR preferences may allow for a difference in elicited risk behavior between certainty equivalents and probability equivalents. However, this difference is not predicted under PPE. The probability equivalent, $U(F^*|r)$, and the certainty equivalent, $U(c|G)$, are not UPE values as the referent and consumption outcomes do not coincide.

If the referent is revealed in choice behavior, then when an individual is observed ac-

¹²Another equilibrium concept in Koszegi and Rabin (2006, 2007) is the Choice-acclimating Personal Equilibrium (CPE) which applies to decisions made far in advance of the resolution of uncertainty. In the present context CPE and PPE have similar implications, as both are based on the coincidence of referent and consumption outcomes.

cepting some gamble, F^* , over some fixed amount, r , the PPE concept establishes only that $U(F^*|F^*) > U(r|r)$. That is, $(F^*|F^*)$ provided the higher ex-ante expected utility. If $U(F^*|F^*) > U(r|r)$ is the PPE revealed preference in a probability equivalent, then it cannot be that the opposite is revealed in a certainty equivalent. Under PPE, the KR model predicts no difference between certainty equivalents and probability equivalents. However, equilibrium behavior may be a challenging requirement. Individuals may naively change their referent in accordance with changes in contextual variables. Koszegi and Rabin (2006) provide intuitive support for such naivete suggesting that the referent is established as the probabilistic beliefs held at the moment of “first focus” on a decision. To the extent that first focus is drawn to different aspects of decisions, one might expect very similar decisions in theory to induce different probabilistic referents in practice. The experimental design is indeed predicated on the notion that minor changes in experimental context, particularly what element is fixed and presented first in a decision environment, can effectively change the perceived referent.

3 Experimental Design

Motivated by the conceptual development above, a primary between-subjects two condition experiment was designed. A secondary within-subjects design with similar methods and data from Andreoni and Sprenger (2010) is discussed in Section 4.3. In Condition 1, subjects completed two series of probability equivalents tasks. The tasks were designed in price-list style with 21 decision rows in each task. Each decision row was a choice between ‘Option A’, a certain amount, and ‘Option B’, an uncertain gamble. The certain Option A was fixed for each task, as were the gamble outcomes. The probability of receiving the gamble’s good outcome increased from 0% to 100% as subjects proceeded through the task. In Condition 1.1, subjects completed 8 tasks with fixed certain amounts chosen from $\{\$6, \$8, \$10, \$14, \$17, \$20, \$23, \$26\}$ and gambles over \$30 and \$0. In Condition 1.2, subjects completed 6 tasks with fixed certain amounts chosen from $\{\$12, \$14, \$17, \$20, \$23, \$26\}$ and gambles over \$30 and \$10. Most subjects began each task by preferring Option A and then switched to Option B such that the probability at which a subject switches from Option A to Option B provides bounds for their probability equivalent. Figure 2, Panel A features a sample probability equivalent task. If the fixed Option A element in each task is perceived as the referent, the KR model predicts risk aversion in these probability equivalents.

In Condition 2, subjects completed two series of certainty equivalents tasks. The tasks were similarly designed in price-list style with 22 decision rows in each task. Each

Figure 2: Probability and Certainty Equivalents (Conditions 1.1 and 2.1)

<i>Panel A : Probability Equivalent</i>		<i>Panel B : Certainty Equivalent</i>	
Option A	or	Option A	or
Certain Payment of \$10	Chance of \$0	Chance of \$0	Certain Amount
1) \$10	<input type="checkbox"/> 100 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$0.00 with certainty
2) \$10	<input type="checkbox"/> 95 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$0.50 with certainty
3) \$10	<input type="checkbox"/> 90 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$1.00 with certainty
4) \$10	<input type="checkbox"/> 85 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$1.50 with certainty
5) \$10	<input type="checkbox"/> 80 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$2.50 with certainty
6) \$10	<input type="checkbox"/> 75 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$3.50 with certainty
7) \$10	<input type="checkbox"/> 70 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$4.50 with certainty
8) \$10	<input type="checkbox"/> 65 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$6.50 with certainty
9) \$10	<input type="checkbox"/> 60 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$8.50 with certainty
10) \$10	<input type="checkbox"/> 55 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$10.50 with certainty
11) \$10	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$13.50 with certainty
12) \$10	<input type="checkbox"/> 45 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$16.50 with certainty
13) \$10	<input type="checkbox"/> 40 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$19.50 with certainty
14) \$10	<input type="checkbox"/> 35 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$21.50 with certainty
15) \$10	<input type="checkbox"/> 30 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$23.50 with certainty
16) \$10	<input type="checkbox"/> 25 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$25.50 with certainty
17) \$10	<input type="checkbox"/> 20 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$26.50 with certainty
18) \$10	<input type="checkbox"/> 15 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$27.50 with certainty
19) \$10	<input type="checkbox"/> 10 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$28.50 with certainty
20) \$10	<input type="checkbox"/> 5 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$29.00 with certainty
21) \$10	<input type="checkbox"/> 0 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$29.50 with certainty
22) \$10	<input type="checkbox"/> 0 in 100	<input type="checkbox"/> 50 in 100	<input type="checkbox"/> \$30.00 with certainty

decision row was a choice between ‘Option A’, a gamble, and ‘Option B’, a certain amount. The Option A gamble was fixed for each task. The certain amount increased as subjects proceeded down the task. In Condition 2.1, subjects completed 7 tasks with gamble outcomes of \$30 and \$0, probabilities chosen from $\{0.05, 0.10, 0.25, 0.50, 0.75, 0.90, 0.95\}$, and certain amounts ranging from \$0 to \$30. In Condition 2.2 subjects completed a further 7 tasks with gamble outcomes of \$30 and \$10, probabilities chosen from $\{0.05, 0.10, 0.25, 0.50, 0.75, 0.90, 0.95\}$, and certain amounts ranging from \$10 to \$30. Most subjects began each task by preferring Option A and then switched to Option B such that the certain value at which a subject switched from Option A to Option B provides bounds for their certainty equivalent. Figure 2, Panel B features a sample certainty equivalent task. If the fixed Option A element in each task is perceived as the referent, the KR model predicts risk neutrality in these certainty equivalents.

3.1 Additional Measures

The probability and certainty equivalents tasks of Conditions 1.1, 1.2, 2.1 and 2.2 provide a simple comparison of elicited risk attitudes. This design is complemented with a third set of tasks for which the KR model can also predict experimental differences. Condition 1.3, completed by subjects assigned to Condition 1, was a series of 8 uncertainty equivalent tasks with 21 decision rows in each task. Option A was a fixed gamble over \$30 and \$10 with probabilities chosen from $\{0.00, 0.05, 0.10, 0.25, 0.50, 0.75, 0.90, 0.95\}$. Option B was a changing gamble over \$30 and \$0. Condition 2.3, completed by subjects assigned to Condition 2, was a series of inverted uncertainty equivalent tasks with 21 decision rows in each task. Option A was a fixed gamble over \$30 and \$0 with probabilities chosen from $\{0.35, 0.40, 0.50, 0.60, 0.75, 0.85, 0.90, 0.95\}$. Option B was a changing gamble over \$30 and \$10. Figure 3, Panels A and B provide a sample uncertainty equivalent and the inverse.

The KR preference model can predict a marked difference in elicited risk attitudes across Conditions 1.3 and 2.3 if the referent is perceived as the fixed element in each task. The KR model predicts a particular shape of quadratically declining risk aversion in Condition 1.3, the standard uncertainty equivalent. The reason is that at the lowest probability, 0, the task is identical to a probability equivalent of \$10 for sure. As discussed in Section 2.1.1, risk aversion is predicted. From there, both the referent and the outcomes are stochastic such that the uncertainty equivalent $(q; 30, 0)$ for a given gamble $(p; 30, 10)$ will be a convex function of p related to the squared probability, p^2 .

Figure 3: Uncertainty Equivalents (Conditions 1.3 and 2.3)

<i>Panel A : Uncertainty Equivalent</i>		<i>Panel B : Inverted Uncertainty Equivalent</i>	
Option A		Option B	
Chance of \$10	Chance of \$30	Chance of \$0	Chance of \$30
1)	50 in 100	or	0 in 100
2)	50 in 100	or	5 in 100
3)	50 in 100	or	10 in 100
4)	50 in 100	or	15 in 100
5)	50 in 100	or	20 in 100
6)	50 in 100	or	25 in 100
7)	50 in 100	or	30 in 100
8)	50 in 100	or	35 in 100
9)	50 in 100	or	40 in 100
10)	50 in 100	or	45 in 100
11)	50 in 100	or	50 in 100
12)	50 in 100	or	55 in 100
13)	50 in 100	or	60 in 100
14)	50 in 100	or	65 in 100
15)	50 in 100	or	70 in 100
16)	50 in 100	or	75 in 100
17)	50 in 100	or	80 in 100
18)	50 in 100	or	85 in 100
19)	50 in 100	or	90 in 100
20)	50 in 100	or	95 in 100
21)	50 in 100	or	100 in 100

Option A		Option B	
Chance of \$0	Chance of \$30	Chance of \$10	Chance of \$30
1)	50 in 100	or	0 in 100
2)	50 in 100	or	5 in 100
3)	50 in 100	or	10 in 100
4)	50 in 100	or	15 in 100
5)	50 in 100	or	20 in 100
6)	50 in 100	or	25 in 100
7)	50 in 100	or	30 in 100
8)	50 in 100	or	35 in 100
9)	50 in 100	or	40 in 100
10)	50 in 100	or	45 in 100
11)	50 in 100	or	50 in 100
12)	50 in 100	or	55 in 100
13)	50 in 100	or	60 in 100
14)	50 in 100	or	65 in 100
15)	50 in 100	or	70 in 100
16)	50 in 100	or	75 in 100
17)	50 in 100	or	80 in 100
18)	50 in 100	or	85 in 100
19)	50 in 100	or	90 in 100
20)	50 in 100	or	95 in 100
21)	50 in 100	or	100 in 100

The deviation from linearity depends on the degree of loss aversion λ and Appendix Section A.1 provides the mathematical detail. This is in contrast to the prediction of expected utility where q should be a linear function p . This is also in contrast to cumulative prospect theory probability weighting (Tversky and Kahneman, 1992) where q is predicted to be a concave function of p .¹³

Interestingly, the KR model predicts risk neutrality in Condition 2.3, the inverted uncertainty equivalent. The logic is as follows: having prospective gamble outcomes inside of the support of the referent gamble is similar to having a perturbed certainty equivalent task. Just as risk neutrality is predicted in certainty equivalents, the KR model also predicts risk neutrality in the inverted uncertainty equivalents. Appendix Section A.1 again provides the mathematical detail.

3.2 Design Details

In order to eliminate often-discussed confounds (Plott and Zeiler, 2005, 2007), neutral language such as ‘Option A’ and ‘Option B’ was used throughout. Subjects were never told that they were trading nor was exchange ever mentioned in the instructions. Subjects were told,

In each task you are asked to make a series of decisions between two options: Option A and Option B. In each task Option A will be fixed while Option B will vary. For example, ... [EXAMPLE].... For each row all you have to do is decide whether you prefer Option A or Option B.

The full instructions are provided as Appendix Section A.3. In each condition, the decisions were blocked into tasks corresponding to the three sub-conditions discussed above. New instructions were read at the beginning of each task block explaining the new procedures and encouraging subjects to take each decision carefully. Subjects were provided with calculators should they wish to use them in making their decisions.

Two orders of the tasks were used in each condition to examine order effects: X.1, X.3, X.2 and X.2, X.3, X.1. The uncertainty equivalents were left in the middle as a buffer between the more similar tasks. No order effects were observed. In addition to varying the order, an attempt was also made to manipulate slightly the physical representation of Option A in each decision. This was done for around half of subjects by stapling miniature copies of the appropriate number of bills, or bills with appropriate

¹³See Andreoni and Sprenger (2010) for a discussion of uncertainty equivalents and their value in separating between competing models of risk preferences.

percentages at the top of each decision sheet. The stapling was done such that subjects would be forced to hold the representation of Option A in order to make the first few decisions. Though I imagined that this nuance might influence the degree of attachment to Option A, it had virtually no effect.¹⁴ A total of 136 subjects participated in the study across 10 experimental sessions. Table 1 provides the dates, times, orders and details of all sessions.

Table 1: Experimental Sessions

Number	Date	Time	Condition	Order	Representation	# Obs
1	May 11, 2010	12:00 pm	1	(1) X.1, X.3, X.2	No	10
2	May 11, 2010	2:30 pm	1	(2) X.2, X.3, X.1	No	12
3	May 12, 2010	12:00 pm	2	(1) X.1, X.3, X.2	No	19
4	May 12, 2010	2:30 pm	2	(2) X.2, X.3, X.1	No	16
5	May 18, 2010	12:00 pm	1	(1) X.1, X.3, X.2	No	11
6	May 18, 2010	2:30 pm	1	(2) X.2, X.3, X.1	No	6
7	May 25, 2010	12:00 pm	1	(1) X.1, X.3, X.2	Yes	15
8	May 25, 2010	2:30 pm	1	(2) X.2, X.3, X.1	Yes	16
9	May 26, 2010	12:00 pm	2	(1) X.1, X.3, X.2	Yes	15
10	May 26, 2010	2:30 pm	2	(2) X.2, X.3, X.1	Yes	16
Total						136

Notes: ‘Representation’ refers to whether or not Option A was physically represented by stapling miniature bills or bills and percentages to the decision sheet.

In order to provide incentive for truthful revelation of preferences, subjects were randomly paid for one of their choices.¹⁵ The instructions fully described the payment procedure and the mechanism for carrying out randomization of payments, two ten-sided die. The randomization was described in independent terms. That is, mention was made of rolling die first for Option A and then for Option B and an example was given. Subjects earned, on average, \$23 from the study including a \$5 minimum payment that was added to all experimental earnings.

¹⁴Andreoni and Sprenger (2010) use uncertainty equivalents to test expected utility and investigate violations of first order stochastic dominance near to certainty. In the non-representation treatments for Condition 1.3 the findings are reproduced. However, in the representation treatments for Condition 1.3, stochastic dominance violations at certainty are reduced to zero. See Sections 4.2 and 4.3 for discussion.

¹⁵This randomization device introduces a compound lottery to the decision environment as each individual made around 440 choices over their 22 tasks. Reduction of compound lotteries does not change the general equivalence predictions for standard expected utility, prospect theory and disappointment aversion discussed above. However, to the extent that the compound lottery changes perceived referents, the randomization introduces complications into the KR analysis as it creates a potential link between choices and referents across tasks. See Section 4.1 for further discussion.

4 Results

The results are presented in three sub-sections. The first sub-section provides a brief summary of the elicited risk attitudes across the two conditions and non-parametric tests demonstrating risk aversion in the probability equivalent tasks and virtual risk neutrality in the certainty equivalent tasks. Second, motivated by these non-parametric results, the KR utility model is estimated and compelling out-of-sample predictions for uncertainty equivalent tasks at both the aggregate and individual level are provided. The third sub-section is devoted to discussing within-subjects results with data from Andreoni and Sprenger (2010), which also demonstrate significant differences in elicited risk preferences between certainty and probability equivalent techniques.

4.1 Risk Attitudes

Of the 136 individuals who participated in the primary experiment, 70 individuals participated in Condition 1 and 66 participated in Condition 2. As in most price-list style experiments, a number of subjects switch from Option A to Option B and then back to Option A.¹⁶ Three subjects (4.3%) in Condition 1 and eleven subjects (16.7%) in Condition 2 featured multiple switch points in at least one task. The majority of multiple switching occurred in Condition 2.3, indicating that this task may have been confusing to subjects.¹⁷ Attention is given to the 122 subjects who had unique switch points in all 22 decision tasks.¹⁸ This results in 1474 individual decisions in Condition 1 and 1210 decisions in Condition 2. Of these 2684 total decision tasks, in a small percentage (0.60%) the subject preferred Option A for all rows and in a larger percentage (4.14%) the subject preferred Option B for all rows. These responses provide only one-sided bounds on the interval of the subject's response. The other bound is imputed via top and bottom-coding accordingly.¹⁹

¹⁶Around 10 percent of subjects feature multiple switch points in similar price-list experiments (Holt and Laury, 2002; Meier and Sprenger, 2010), and as many as 50 percent in some cases (Jacobson and Petrie, 2009). Because such multiple switch points are difficult to rationalize and may indicate subject confusion, researchers often exclude such observations or mechanically enforce single switch points. See Harrison, Lau, Rutstrom and Williams (2005) for discussion.

¹⁷Five of 11 multiple switchers in Condition 2, had multiple switching in only Condition 2.3, one had multiple switching in Conditions 2.1 and 2.3, two had multiple switching in Conditions 2.2 and 2.3, and three had multiple switching in all three subconditions.

¹⁸All results are maintained when including multiple switchers and taking their first switch point as their choice. See Appendix Table A1 for details.

¹⁹For example if an individual chose Option A at all rows in a probability equivalent including when Option B was a 100% chance of getting \$30, I topcode the interval as [100, 100]. Virtually all of the bottom-coded responses, 100 of 111, were decisions in Condition 2.3 where the bottom-coded choice would be preferring \$10 with certainty to a given gamble over \$0 and \$30. No bottom-coded responses

A variety of demographic, cognitive and attitudinal data were collected after the study was concluded in order to provide a simple balancing test. Table 2 compares data across experimental conditions for survey respondents.²⁰ Though some differences do exist, particularly in academic year, subjects were broadly balanced on observable characteristics, simple numeracy and cognitive ability scores, and subjectively reported risk attitudes.²¹ An omnibus test from the logit regression of condition assignment on all survey variables for 111 of 122 individuals with complete survey data does not reject the null hypothesis of equal demographic, cognitive and attitudinal characteristics across conditions ($\chi^2 = 14.1$, $p = 0.12$). Because the randomization is at the session level, this helps to ensure that accidental selection issues are not driving the experimental results. Additional within-subjects results unaffected by selection are provided in Sub-Section 4.3, along with demonstrations of robustness to controlling for demographic differences.

I begin by investigating behavior in Conditions 1.1, 1.2, 2.1 and 2.2. With the exception of the KR preference model, all discussed theories predict experimental equivalence across these conditions. That is, elicited risk attitudes should be identical whether one asks the probability equivalent of a given certain amount or the certainty equivalent of a given gamble. Figure 4 presents median data for the 122 individuals with unique switch points along with a dashed black line corresponding to risk neutrality. The experimentally controlled parameter is presented on the horizontal axis and the median subject response is presented on the vertical axis.

Apparent from the median data is the systematic difference in elicited risk attitudes between certainty and probability equivalents. When fixing a stochastic gamble and trading for increasing certain amounts in Conditions 2.1 and 2.2, subjects display virtual risk neutrality. When fixing a certain amount and trading for increasing gambles in Conditions 1.1 and 1.2 subjects display risk aversion.

For each experimental task, decisions are classified as being risk neutral, risk averse or risk loving. These classifications recognize the interval nature of the data. For

arose in Condition 1 or 2.1 where the lowest Option B outcome was \$0 with certainty.

²⁰111 of 122 subjects completed all survey elements. 60 of 67 subjects in Condition 1 and 51 of 55 subjects in Condition 2 provided complete survey responses. Non-response is unrelated to condition as Condition 1 accounts for 54-55 percent of the data in both the respondent and full samples.

²¹Numeracy is measured with a six question exam related to simple math skills such as division and compound interest previously validated in a number of large and representative samples (Lusardi and Mitchell, 2007; Banks and Oldfield, 2007; Gerardi, Goette and Meier, 2010). Cognitive ability is measured with the three question Cognitive Reflection Test introduced and validated in Frederick (2005). Subjective risk attitudes are measured on a 7 point scale with the question, “How willing are you to take risks in general on a scale from 1 (unwilling) to 7 (fully prepared)” previously validated in a large representative sample (Dohmen, Falk, Huffman, Sunde, Schupp and Wagner, 2005).

Table 2: Summary Statistics and Balancing Test

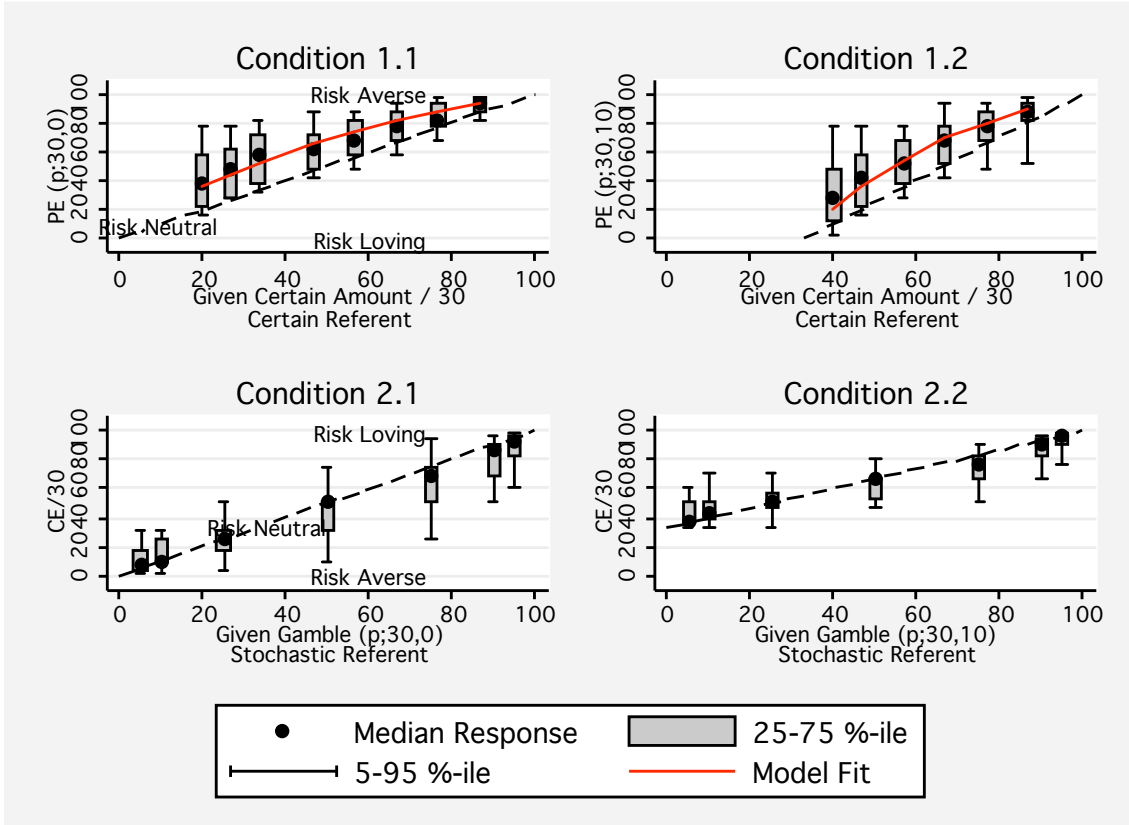
Variable	# Obs	Total	Condition 1	Condition 2	<i>t</i> -statistic	<i>p</i> -value
		N = 122	N = 67	N = 55		
		Mean (s.d)	Mean (s.d)	Mean (s.d.)		
Male (=1)	119	0.46 (0.50)	0.42 (0.50)	0.52 (0.50)	1.12	(<i>p</i> =0.27)
Academic Year	122	2.63 (1.08)	2.45 (1.05)	2.85 (1.08)	2.10	(<i>p</i> =0.04)
Grade Point Average	120	3.20 (.42)	3.25 (.44)	3.15 (.39)	-1.26	(<i>p</i> =0.21)
English 1 st Language (=1)	122	0.56 (0.50)	0.51 (0.50)	0.62 (0.49)	1.22	(<i>p</i> =0.22)
Smoker (=1)	122	0.04 (0.20)	0.03 (0.17)	0.05 (0.23)	0.68	(<i>p</i> =0.50)
Weekly Spending (\$)	122	89.68 (89.49)	85.00 (68.63)	95.38 (110.12)	0.64	(<i>p</i> =0.53)
Risk Attitudes (1-7)	122	3.84 (1.19)	3.70 (1.22)	4.00 (1.14)	1.39	(<i>p</i> =0.17)
Cognitive Ability Score (1-3)	117	1.79 (1.05)	1.86 (1.08)	1.70 (1.01)	-0.83	(<i>p</i> =0.41)
Numeracy Score (1-6)	120	5.75 (0.54)	5.78 (0.52)	5.71 (0.57)	-0.76	(<i>p</i> =0.45)
Omnibus $\chi^2 = 14.1$, (<i>p</i> = 0.12)						

Notes: Summary statistics for 122 subjects with unique switch points in all 22 decision tasks. # Obs refers to the number of responses to each question. Omnibus χ^2 test statistic corresponding to the null hypothesis of zero slopes in logit regression with 111 subjects with complete survey data of condition assignment on all survey variables with robust standard errors.

example, a decision is coded as risk neutral if the risk neutral response lies in the interval generated by the subject’s switch point. Figure 5, Panel A presents these classifications. Whereas the distributions of risk averse, neutral and loving responses are somewhat even in the certainty equivalents of Condition 2, the majority of responses are risk averse in the probability equivalents of Condition 1. Proportionately nearly twice as many responses are classified as risk averse in probability equivalents relative to certainty equivalents. As this may be a strict classification of responses, Figure 5, Panel B extends the interval of the switch point to \pm one choice. By this wider interval measure the majority of the data in Condition 1 remains risk averse, while the majority of the data in Condition 2 is now classified as risk neutral.

Table 3 presents ordered logit regressions for the classification of responses of Figure 5, Panel A with standard errors clustered on the individual level. The dependent

Figure 4: Conditions 1.1, 1.2, 2.1, and 2.2 Responses

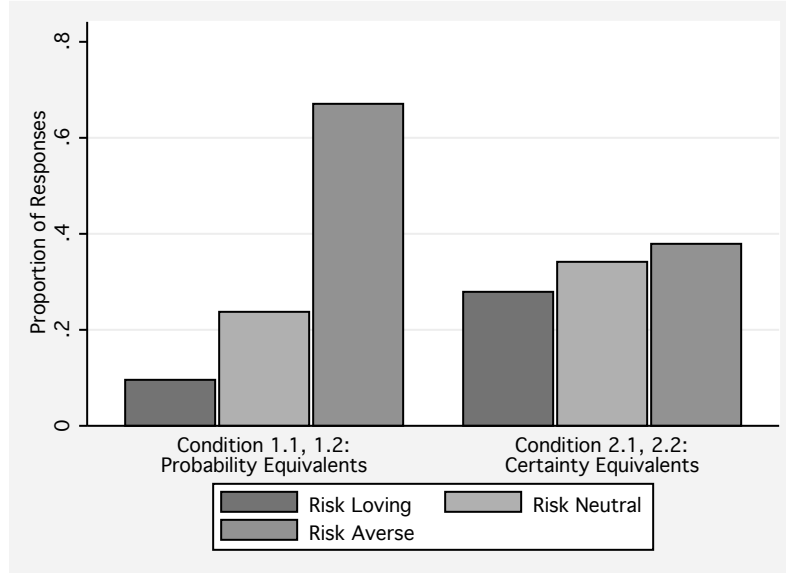


Note: Median data from 122 experimental subjects with unique switching points in all 22 decision tasks. Dashed black line corresponds to risk neutrality. Solid red line for Conditions 1.1 and 1.2 corresponds to KR model fit with $\hat{\lambda} = 3.4$. The KR model predicts risk aversion for probability equivalents in Conditions 1.1 and 1.2 and risk neutrality for certainty equivalents in Conditions 2.1 and 2.2.

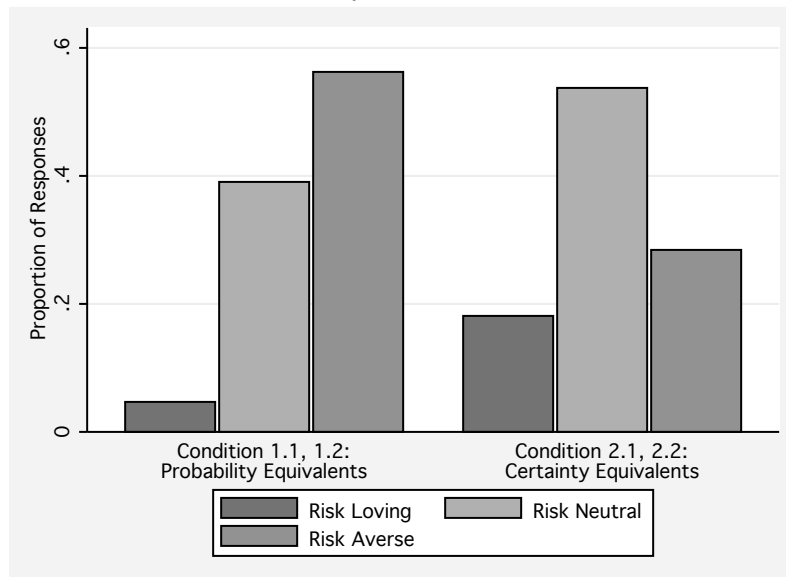
variable is *Risk Attitude*, which takes the value -1 for a risk loving classification, 0 for risk neutrality, and +1 for a risk averse response. The natural order of *Risk Attitude* corresponds to increasing risk aversion. These regressions control for condition and the variable *Risk Neutral Response*. *Risk Neutral Response* is coded from 0 to 100 and expresses in percentage terms the dashed line of risk neutrality in Figure 4. That is, *Risk Neutral Response* is either the given certain amount's risk neutral probability equivalent (in Condition 1), or the given gamble's expected value divided by 30 (in Condition 2). This helps to control for experimental variation that might be related to elicited risk attitudes under non-EU preference models such as non-linear probability weighting. Certain specifications additionally control for order and representation effects as well as the collected demographic and attitudinal characteristics for individuals who responded

Figure 5: Conditions 1.1, 1.2, 2.1, and 2.2 Classifications

Panel A: Classification



Panel B: Classification – Wide Interval



Note: The figure presents classifications of responses from 122 experimental subjects with unique switching points in all 22 decision tasks. The KR model predicts risk aversion for probability equivalents in Conditions 1.1 and 1.2 and risk neutrality for certainty equivalents in Conditions 2.1 and 2.2. Panel A provides the classifications based on the interval of a subject's switch point. Panel B provides classifications based on a wider interval of the switch point \pm one choice.

in full to the post-study survey. Across specifications, subjects in Condition 1 are significantly more likely to have risk averse responses. Odds ratios for being classified as risk averse relative to risk neutral or risk loving are provided in brackets. Subjects randomly assigned to Condition 1 are between three and four times more likely to exhibit risk aversion than those assigned to Condition 2.²²

These simple tests indicate an endowment effect for risk. In certainty equivalents tasks, subjects are generally risk neutral. In probability equivalents tasks, subjects are generally risk averse. Standard expected utility, prospect theory and disappointment aversion all predict experimental equivalence across these two environments. The data are potentially consistent with the KR model, with its possibility of a stochastic reference distribution. However, the obtained data are not directly consistent with the refined PPE concept, which would also predict identical behavior across conditions.

In applying the equilibrium concepts from KR, I consider some form of narrow bracketing within a given row of a choice task. That is, the subject considers a choice in a given row between Option A, representing some fixed amount or gamble, G , and Option B, representing some fixed amount or gamble, F . As discussed in Section 2.1.3, choosing Option A over Option B therefore implies the PPE relation $U(G|G) > U(F|F)$. However in the KR model there is some ambiguity in the bracketing of the referent. It is possible, for instance, to consider the referent to be the distribution induced by all choices in the task, or even all choices in the entire experiment. Such a specification could potentially revive PPE as a viable organization of the data. However solving for a PPE in these cases is computationally intensive and a somewhat implausible calculation on the part of subjects. The narrow bracketing used in this analysis is a direct application of the KR equilibrium in choices between lotteries.

Equilibrium behavior even in its simplest form may be a stringent requirement for experimental subjects. A body of evidence from strategic environments argues against equilibrium logic in the laboratory (Camerer et al., 2004; Costa-Gomes and Crawford, 2006; Crawford and Iriberri, 2007; Costa-Gomes et al., 2009). Resulting process models such as level- k thinking are argued to be organized around initial reactions to experimental environments. Koszegi and Rabin (2006) provide a similar indication, suggesting that referents are established as probabilistic beliefs held at the moment an individual first focused on a decision. In our environment, subjects may first focus their thinking on the fixed element in a given series of decisions. If so, then the referent may

²²Results are maintained with the inclusion of multiple switchers. Additionally, no interactions for order or representation effects were obtained. Appendix Table A1 provides these additional regressions.

Table 3: Probability and Certainty Equivalent Risk Attitude Regressions

	(1)	(2)	(3)
<i>Dependent Variable:</i>	<i>Risk Attitude Classification</i>		
Probability Equivalents: Condition 1 (=1)	1.330*** (0.225) [3.782]	1.329*** (0.224) [3.778]	1.172*** (0.241) [3.230]
Risk Neutral Response	0.008** (0.003)	0.008** (0.003)	0.008** (0.003)
Male (=1)			-0.087 (0.236)
Academic Year			-0.223* (0.094)
Grade Point Average			0.275 (0.266)
English 1 st Language (=1)			-0.368 (0.248)
Smoker (=1)			-0.323 (0.502)
Weekly Spending (\$)			0.001 (0.001)
Risk Attitudes (1-7)			-0.128 (0.107)
Cognitive Ability Score (1-3)			-0.052 (0.110)
Numeracy Score (1-6)			0.014 (0.248)
Order 2 (=1)		0.074 (0.214)	-0.008 (0.218)
Representation (=1)		0.023 (0.215)	0.063 (0.218)
Constant 1	-0.517* (0.220)	-0.471 (0.270)	-0.959 (1.467)
Constant 2	0.993*** (0.215)	1.040*** (0.252)	0.559 (1.464)
# Observations	1708	1708	1554
# Clusters	122	122	111
Log-Likelihood	-1609.620	-1609.275	-1443.404

Notes: Coefficients from ordered logit of *Risk Attitude* classification on control variables, measured from probability and certainty equivalents of Conditions 1.1, 1.2, 2.1, and 2.2. *Risk Attitude* takes the value -1 for risk loving, 0 for risk neutral, and +1 for risk averse. Standard errors clustered on the individual level in parentheses. Odds ratios for Condition 1 in brackets, calculated as the exponentiated coefficient. Column (3) features data from 111 subjects who also completed the post-study survey. *Level of significance:* * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

sensibly change across the conditions of our experiment. In certainty equivalents the referent will be stochastic, while in probability equivalents the referent will be certain. See Section 5 for further discussion.

4.2 Estimating KR Preferences

Under the assumption that subjects organize their thinking around the fixed element in a series of decisions, the KR model with exogenously manipulated referents rationalizes the data. Importantly, such a model is easily implemented econometrically. The KR model motivated above is described by one key parameter, λ , the degree of loss aversion, which can be estimated at either the group or individual level via non-linear least squares.

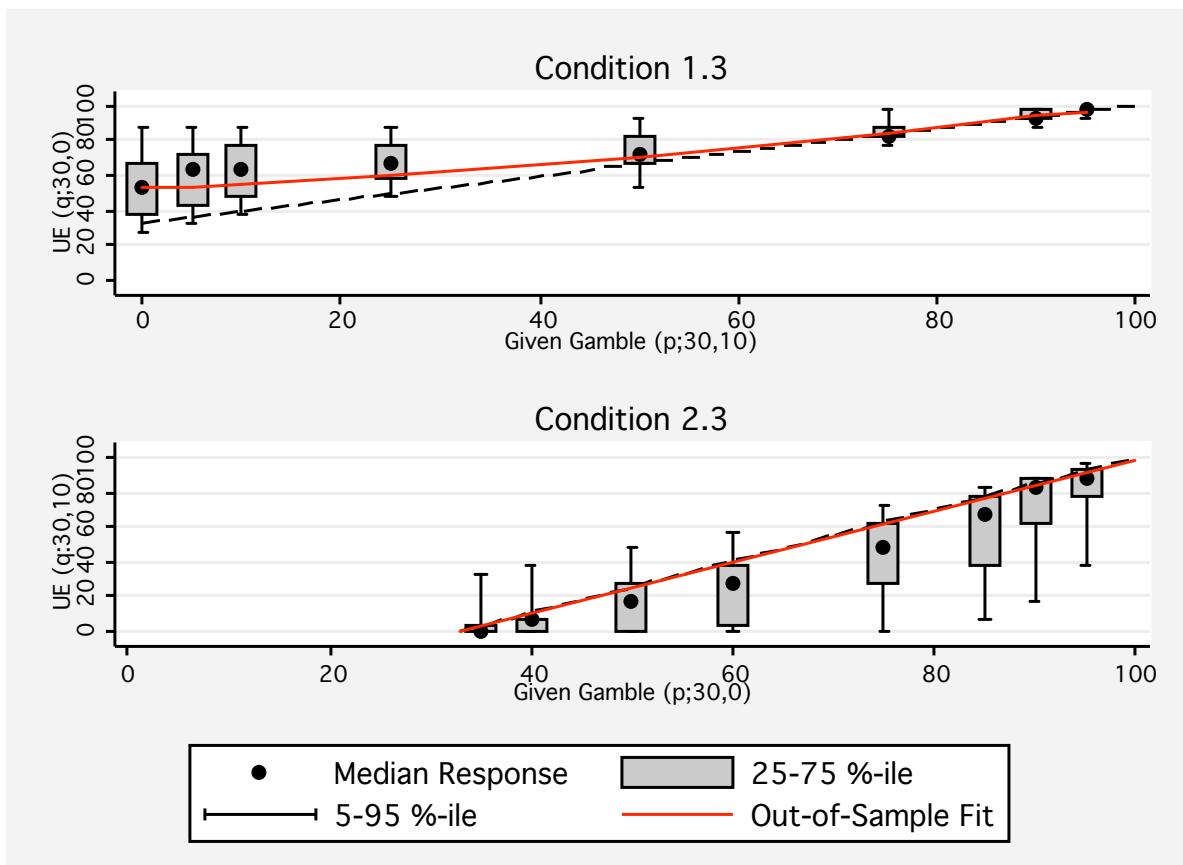
Using the data from probability equivalent Conditions 1.1 and 1.2, the midpoint of the interval implied by a subject’s switch point is taken as the value q^* in equation (2). Equation (2) is then estimated via non-linear least squares with standard errors clustered on the subject level. The aggregate estimate is $\hat{\lambda} = 3.41$ ($s.e. = 0.34$). The null hypothesis of zero loss aversion, $\lambda = 1$, is rejected $F_{1,66} = 49.06$, $p < 0.01$. This value of loss aversion is consistent with loss aversion estimates from other contexts (Tversky and Kahneman, 1992; Gill and Prowse, 2010; Pope and Schweitzer, Forthcoming) and is closely in line with the often discussed benchmark of losses being felt twice as severely as gains, $\lambda = 3$, $\eta = 1$ (Koszegi and Rabin, 2006, 2007).²³ Figure 4 presents predicted values from this aggregate regression as the solid red line for Conditions 1.1 and 1.2. The aggregate data matches well the fitted model’s predicted hump-shaped deviation from risk neutrality. Of course, the KR preference model predicts risk neutrality in Conditions 2.1 and 2.2.

In order to evaluate the predictive validity of the KR preference model, it can be tested out of sample with alternative segments of the data. As noted above, the KR preference model with a stochastic referent predicts risk neutrality in Condition 2.3 and predicts a particular shape of quadratically declining risk aversion in Condition 1.3. Figure 6 presents data from these conditions as well as out-of-sample predictions for KR model with the estimated $\hat{\lambda} = 3.4$. Though the KR prediction of risk neutrality breaks down at the intermediate probabilities of Condition 2.3, in Condition 1.3, the out-of-sample prediction closely matches aggregate behavior.²⁴

²³The functional form of Tversky and Kahneman (1992) does not feature consumption utility and so the loss aversion estimate of $\hat{\lambda} = 2.25$ in their paper is a direct measure of losses being felt twice as severely as gains.

²⁴Additionally, Condition 1.3 reproduces the general shape and level of the uncertainty equivalents discussed in Andreoni and Sprenger (2010) demonstrating a slightly convex relationship between given gambles and their uncertainty equivalents. However, Andreoni and Sprenger (2010) document the convexity becoming sharper as the given gamble approaches certainty, and this result is not present in the data. Minor differences in experimental detail may account for the difference at $p = 0$ between the present results and Andreoni and Sprenger (2010) including a different number and order of tasks and slightly changed tasks. The Andreoni and Sprenger (2010) price lists were designed with decision aids of checked top and bottom rows. The task used in Condition 1.3 was not. More

Figure 6: Conditions 1.3 and 2.3



Note: Median data from 122 experimental subjects with unique switching points in all 22 decision tasks. Dashed black line corresponds to risk neutrality. Solid red lines correspond to out-of-sample KR model prediction with $\hat{\lambda} = 3.4$ as estimated in Conditions 1.1 and 1.2.

In addition to aggregate out-of-sample predictions, for the 67 subjects in Condition 1, individual analyses can be conducted. Using the data from Conditions 1.1 and 1.2, the degree of loss aversion, λ_i , can be estimated following equation (2). These individual estimates, $\hat{\lambda}_i$, can be correlated with behavior in Condition 1.3. As discussed in Section 3.1, the deviation from risk neutrality is predicted to increase with λ_i .

importantly, however, appears to be the presence of the physical representation of Option A. The sharpened convexity at $p = 0$ in Andreoni and Sprenger (2010) is driven by individuals who violate first order stochastic dominance close to certainty. They document individual dominance violation rates between $p = 0$ and $p = 0.05$ of around 17.5 percent across three tasks. When Option A is not physically represented, a similar violation rate of 13.5 percent is found. However, when Option A is physically represented, zero violations of stochastic dominance at certainty are observed. The effect of physical representation on the proportion of individuals violating stochastic dominance at certainty is significant ($z = 2.09$, $p < 0.05$).

The log deviation from risk neutrality, *Log Deviation*, is measured for each individual by taking the log difference between the area under the linear interpolation of their responses to Condition 1.3 and the area under the dashed risk neutral response line. Hence, *Log Deviation* would take the value 0 for risk neutrality, a positive value for risk aversion and a negative value for risk loving. Figure 7, Panels A and B provide histograms of the individual estimates of loss aversion $\hat{\lambda}_i$ and *Log Deviation*. The median $\hat{\lambda}_i$ is 3.6, echoing the aggregate result. The median *Log Deviation* is 0.15, indicating a deviation towards risk aversion in Condition 1.3. Figure 7, Panel C correlates loss aversion, $\hat{\lambda}_i$, estimated from Conditions 1.1 and 1.2 with the *Log Deviation* calculated from Condition 1.3.²⁵ Individuals who are more loss averse in Conditions 1.1 and 1.2, deviate more from risk neutrality in Condition 1.3. The correlation is significant at all conventional levels ($\rho = 0.48$, $p < 0.01$). Additionally, individuals with estimated $\hat{\lambda}_i$ close to 1 have calculated *Log Deviation* close to the risk neutral level of 0. This indicates both experimental consistency across conditions and the predictive validity of loss aversion estimates at the individual level.

4.3 Secondary Study Within-Subjects Design

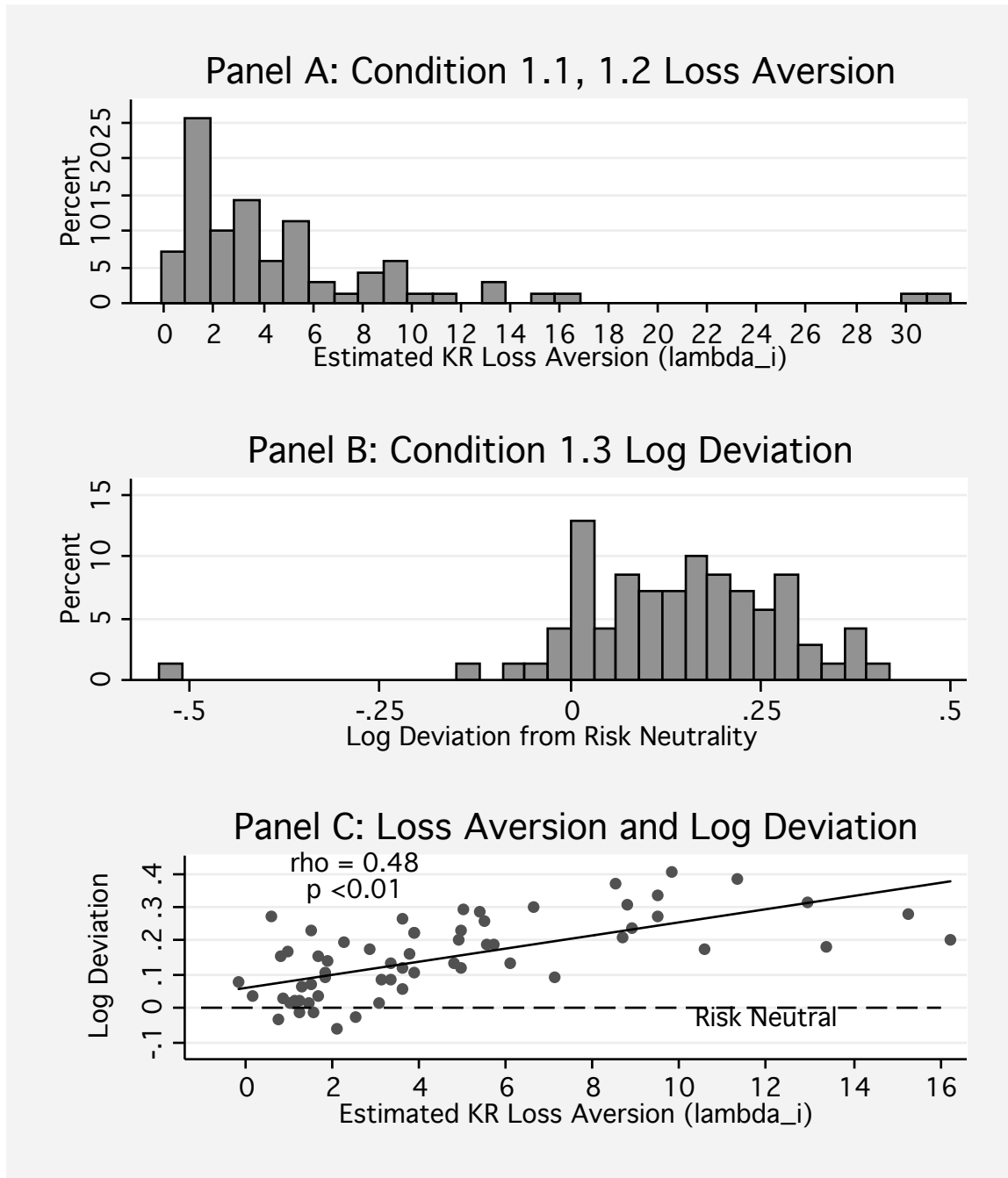
The results to here have been from a primary between-subjects design. Though the data demonstrate a sizeable endowment effect for risk and the KR preference model is able to organize the results, questions may naturally arise about the robustness of the phenomenon to issues of selection. In this section, I discuss portions of the data obtained for Andreoni and Sprenger (2010), a within-subjects study of 76 subjects designed primarily with uncertainty equivalents similar to Condition 1.3 and certainty equivalents similar to Condition 2.1.²⁶ Two Holt and Laury (2002) risk tasks were implemented as a buffer between uncertainty equivalents and certainty equivalents in Andreoni and Sprenger (2010) and decisions were collected between conditions.

Importantly, the uncertainty equivalent for $p = 0$ is identical to a probability equivalent. Subjects are asked to provide the gamble probability over \$30 and \$0 that makes them indifferent to a 100% chance of receiving \$10. This single probability equivalent can be compared to the subject's own range of certainty equivalents. One finds the gamble probability over \$30 and \$0 at which the certainty equivalent is revealed to be \$10. Under the assumption that the referent is perceived as the fixed element in a

²⁵Three subjects with extreme values, $\hat{\lambda}_i > 20$ or *Log Deviation* < -0.5 , are not included in Figure 7, Panel C for space, though their data is used in analysis and presented correlations.

²⁶Some minor experimental differences exist such as the use of pre-checked boxes as decision aids, differing orders and no representation in Andreoni and Sprenger (2010). See Section 4.2 and Andreoni and Sprenger (2010) for more details.

Figure 7: Individual Loss Aversion ($\hat{\lambda}_i$) and *Log Deviation* From Risk Neutrality



Note: Individual loss aversion estimate $\hat{\lambda}_i$ of equation (2) using data from Conditions 1.1 and 1.2. *Log Deviation* from risk neutrality calculated from Condition 1.3. Three subjects with extreme values, $\hat{\lambda}_i > 20$ or *Log Deviation* < -0.5 , are not included in Panel C for space, but included in reported correlation.

task, comparison of this gamble probability to the revealed probability equivalent of \$10 gives a within-subjects measure of the endowment effect for risk.

For certainty equivalents tasks, the probability of winning \$30 that yields a certainty equivalent of \$10 is identified by finding the smallest probability, p , at which the certainty equivalent is higher than \$10, the largest probability, p' , at which the certainty equivalent is smaller than \$10, and taking the average $\bar{p} = (p + p')/2$.²⁷ The average value of \bar{p} is 0.306 (*s.d.* 0.210). The average $(q; 30, 0)$ probability equivalent of \$10 for sure is 0.541 (0.220). The difference is significant at all conventional levels ($t = 7.16$, $p < 0.001$).²⁸ Additionally, these values are remarkably consistent with the between-subjects evidence documented in Sections 4.1 and 4.2 where subjects are close to risk neutral in certainty equivalents and reveal average probability equivalents for \$10 with certainty of 0.547 (0.189) in Condition 1.3 and 0.546 (0.185) in Condition 1.1.

The within-subjects results demonstrate an endowment effect for risk. Subjects are close to risk neutral when revealing the gamble for which the certainty equivalent is \$10. The same subjects are risk averse when revealing the probability equivalent gamble for \$10. The KR model with the standard values of $\lambda = 3$, $\eta = 1$ and the assumption that the referent is perceived as the fixed element of a task would predict \$10 certainty equivalents to arise at a 33% chance of winning \$30 and probability equivalents of \$10 for sure to arise at a 50% chance of winning \$30. The within-subjects data are therefore consistent with the KR preference model with standard values and those obtained in the between-subjects estimates of Section 4.2.

5 Discussion

The obtained results are supportive of the KR preference model. Unlike prior work demonstrating the importance of expectations for reference points, these results are able to distinguish between KR preferences and other expectations-based models such as disappointment aversion. Gaining separation between these models is an important experimental step and necessary for evaluating theoretical developments that depend critically on the stochasticity of the referent (Koszegi and Rabin, 2006, 2007; Heidhues and Koszegi, 2008; Koszegi and Rabin, 2009). Additionally, the distinction between the KR and DA models is important in a variety of applied settings where the two

²⁷There are 13 cases where p' is not observed because the individuals' certainty equivalents always exceeded \$10. There is one case where p is not observed because the individual's certainty equivalent never exceeded \$10. In these cases the non-missing value is used. Eliminating these observations does not influence the result.

²⁸The difference remains significant when comparing $(q; 30, 0)$ to either p ($t = 4.32$, $p < 0.001$), or p' ($t = 8.57$, $p < 0.001$) for individuals with non-missing values of p and p' , respectively.

models make different predictions. In particular, the DA model predicts first order risk aversion in the sense of Segal and Spivak (1990) over all gambles, while the KR model predicts first order risk aversion only when risk is unexpected. When outcomes lie within the support of expectations, risk neutrality is predicted. Several applications in finance, insurance purchasing and decision science can be considered.

First, in finance first-order risk aversion is argued to influence stock market participation (Haliassos and Bertaut, 1995; Barberis et al., 2006) and returns (Epstein and Zin, 1990; Barberis and Huang, 2001). The KR model indicates that individuals will accept fair bets within expectations, but grow more risk averse as outcomes exceed expectations. As such, the KR model would predict first-order risk aversion, with corresponding participation and returns effects, only when potential outcomes lie outside prior expectations. In contrast, under the DA model individuals are first-order risk averse over all gambles, never accepting a fair investment bet.²⁹

Second, a comparison can be made for insurance purchasing where first order risk aversion potentially influences contract choice (Sydnor, Forthcoming). First-order risk aversion predicts a desire for full insurance even when insurance is not actuarially fair (Segal and Spivak, 1990). Hence, a disappointment averse consumer may fully insure under positive insurance profits. The KR model predicts insurance only for potential outcomes outside of expectations. As such, the KR model gives a suggestion as to what gambles will be insured and how they relate to expectations.³⁰ This is in contrast to disappointment aversion where full insurance is desired for all gambles. Future work should explore these different predictions of the KR and DA models in real-world financial decision-making and experimental settings.

Third, a gap between KR and DA models is apparent in decision science where researchers have long debated the inconsistency between probability equivalent and certainty equivalent methods for utility assessment (Hershey et al., 1982; McCord and de Neufville, 1985, 1986; Hershey and Schoemaker, 1985; Schoemaker, 1990). The general finding is that probability equivalents yield more risk aversion. This difference in elicited utility is predicted by the KR model but not DA. Though there are some hints in the literature that such experimental inconsistency may be due to a “response mode

²⁹Additionally, there is no natural way to model an outcome being outside of expectations in disappointment aversion. All gambles are evaluated relative to their own expected utility certainty equivalents.

³⁰Of course, risks can lie outside of expectations by endogenously constructing a fixed referent and risks can coincide with expectations by constructing a stochastic referent. It may be UPE to insure and have a fixed referent as well as not insure and have a stochastic referent. Hence the necessity of the PPE concept to select among such UPE choices. Koszegi and Rabin (2007) provide a detailed discussion of the relationship between insurance purchasing and expectations under the KR preference model.

bias,” where probability equivalent tasks are reframed as mixed gambles with gains and losses (Hershey et al., 1982; Hershey and Schoemaker, 1985), many other explanations for the inconsistency have been proposed (McCord and de Neufville, 1985; Schoemaker and Hershey, 1992; Schoemaker, 1993). The present results and use of the KR model help to resolve this long-standing issue. If referents are changed from stochastic to certain as the environment moves from a certainty to a probability equivalent, then the specific KR structure of preferences and not some idiosyncratic bias organizes this long-debated inconsistency in utility elicitation.

Though the findings are supportive of the KR model and provide direction for further analysis, a distinction must be made between the results presented and the equilibrium predictions of the KR model. Koszegi and Rabin (2006, 2007) present a rational expectations equilibrium concept, the Unacclimating Personal Equilibrium (UPE), in which consumption outcomes correspond to expectations. To select among the potential multiplicity of equilibria, the Preferred Personal Equilibrium (PPE) concept is introduced. The Preferred Personal Equilibrium (PPE) concept of KR requires the coincidence of expectations and behavior. Under the PPE refinement, the KR model, similar to disappointment aversion, predicts no endowment effect for risk. Because the data reject disappointment aversion, they necessarily reject the PPE refinement.

PPE logic may be a stringent requirement for experimental subjects. Koszegi and Rabin (2006) suggest that “a person’s reference point is her probabilistic beliefs about the relevant consumption outcome held between the time she first focused on the decision determining the outcome and shortly before consumption occurs” [p. 1141]. “First focus” in the present studies is plausibly drawn to the fixed element in a given series of decisions. Hence the referent may be established as this fixed element and deviated from when alternatives become sufficiently attractive. It is likely that the different fixed elements induced different stochastic referents as the the data are systematically organized by the KR model under this assumption.

The non-PPE finding is in line with a body of evidence from strategic environments arguing against equilibrium logic and organizing behavior with initial reactions to decision environments (Camerer et al., 2004; Costa-Gomes and Crawford, 2006; Crawford and Iriberri, 2007; Costa-Gomes et al., 2009). Additionally it suggests that expectations-based referents may be quickly changed by context. This supports field findings such as Pope and Schweitzer (Forthcoming) and Post et al. (2008) where referents and risk taking behavior change with both minor contextual shifts such as field performance on specific holes in golf tournaments and major contextual variables such as unwon large-value prizes in sequential game shows.

The potential sensitivity of expectations-based referents to contextual changes has implications for both economic agents and experimental methodology. First, from a methodological perspective, if fixed elements can serve as referents, slightly changed choice environments may induce very different behavior. This is of particular importance for the experimental measurement of preferences and willingness to pay where similar techniques are used and resulting estimates are given economic significance. Second, if expectations-based referents can be manipulated via simple framing devices without physical endowments, then scope exists for marketers and policy-makers to deeply influence behavior with menus alone.

6 Conclusion

Reference-dependent preferences with loss-aversion relative to a reference point has been widely adopted in both theoretical and empirical research, rationalizing not only endowment effect behavior but a host of other anomalies from labor supply, to consumer behavior, to finance. Critical to such reference-dependent models is the determination of the referent around which losses and gains are encoded. Though initially the referent was left a virtual free parameter, extensions to reference dependence have added discipline. Attention has focused on expectations-based mechanisms for the determination of fixed reference points in models of Disappointment Aversion (DA) (Bell, 1985; Loomes and Sugden, 1986; Gul, 1991), or for the determination of stochastic reference distributions in the models of Koszegi and Rabin (2006, 2007) (KR).

A body of field and laboratory evidence has highlighted the importance of expectations for reference-dependent behavior consistent with these expectation-based models. Though accumulated data does demonstrate the importance of expectations for reference dependence, the data is generally consistent with either the DA or the KR model. That is, prior evidence cannot distinguish between the two models.

This paper presents evidence from two experiments focused on identifying a particular prediction of the KR model which is not shared with DA: an endowment effect for risk. The endowment effect for risk is closely related to the potential stochasticity of the referent. When the referent is stochastic, and an individual is offered a certain amount, the KR model predicts risk neutrality. Conversely, when the referent is a fixed certain amount, and an individual is offered a gamble, the KR model predicts risk aversion. Disappointment aversion makes no such prediction of differential behavior as gambles are always evaluated relative to a fixed referent, the gamble's expected utility certainty equivalent.

To date, little evidence exists exploring the KR implication of an endowment effect for risk. In purposefully simple risk preference experiments, eliminating often-discussed confounds, I test both between- and within-subjects for an endowment effect for risky gambles. In the primary study discussed, half of subjects make probability equivalent choices between fixed certain amounts and changing gambles. Half of subjects make certainty equivalent choices between fixed gambles and changing certain amounts. Importantly, both standard models and most reference-dependent models including disappointment aversion predict equivalence of risk attitudes across the experimental conditions. One exception is the KR preference model. Under the assumption that the fixed element in a series of decisions serves as the referent, the KR model predicts that subjects will be risk averse in probability equivalents and risk neutral in certainty equivalents.

Both between- and within-subjects the data indicate an endowment effect for risk. In the primary study, subjects are between three and four times more likely to be risk averse if randomly faced with a probability equivalent as opposed to a certainty equivalent. In a secondary, within-subjects study, the phenomenon is also observed. Under the assumption that the experimental variation changes the perceived referent, the KR preference model organizes the data at both the aggregate and individual level and both between and within-subjects.

Finding evidence of an endowment effect for risk, particularly in a neutral environment, provides critical support for the KR preference model. Unlike prior work demonstrating the importance of expectations for reference points, these results clearly distinguish between KR preferences and disappointment aversion. Providing separation between these competing accounts of expectations-based reference dependence represents an important experimental step and a necessary contribution for evaluating theory models and applications that rely specifically on stochastic referents. Demonstrating methodology for distinguishing between the expectations-based reference-dependent preferences is additionally important as the different models provide notably different accounts of financial decision-making, insurance purchasing behavior, and long-standing anomalies in decision science. Future work should test these competing accounts, particularly in the domain of financial behavior, with both field and laboratory evidence.

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A Appendix: Not For Publication

A.1 KR Preferences and Uncertainty Equivalents

I demonstrate two results: 1) that the KR preference models predicts quadratically declining risk aversion in uncertainty equivalents where individuals are endowed with gambles $(p; y, x)$, $y > x > 0$ and trading for gambles $(q; y, 0)$; and 2) that the KR preference model predicts risk neutrality in inverted uncertainty equivalents where individuals are endowed with gambles $(p; y, 0)$ and trading for gambles $(q; y, x)$.

A.1.1 Uncertainty Equivalents

Uncertainty equivalents feature a binary referent gamble, G , summarized by the probability p . Let r_1 be the referent with probability p and $r_2 < r_1$ be the referent with probability $1 - p$. Given the linear KR model, the utility of the referent is

$$U(G|G) = p \cdot r_1 + (1 - p) \cdot r_2 + p \cdot (1 - p) \cdot [1 \cdot (r_1 - r_2) + \lambda \cdot (r_2 - r_1)].$$

Now, I consider a binary consumption gamble, F , summarized by the probability q . Let $x_1 = r_1$ be the gamble outcome with probability q and $x_2 < r_2$ be the gamble outcome with probability $1 - q$. I write the KR utility as

$$U(F|G) = q \cdot p \cdot x_1 + (1 - q) \cdot p \cdot [x_2 + \lambda \cdot (x_2 - r_1)] + q \cdot (1 - p) \cdot [x_1 + 1 \cdot (x_1 - r_2)] + (1 - q) \cdot (1 - p) \cdot [x_2 + \lambda \cdot (x_2 - r_2)].$$

For simplicity I carry out the uncertainty equivalent replacements, $x_1 = r_1$ and $x_2 = 0$ such that this reduces to

$$U(F|G) = q \cdot \{r_1 + (1 - p) \cdot [r_1 - r_2] + p \cdot \lambda \cdot r_1 + (1 - p) \cdot \lambda \cdot r_2\} - \lambda \cdot p \cdot r_1 - \lambda \cdot (1 - p) \cdot r_2.$$

The uncertainty equivalent will be the consumption gamble, F^* , with corresponding probability q^* satisfying $U(F^*|G) = U(G|G)$.

$$p \cdot r_1 + (1 - p) \cdot r_2 + p \cdot (1 - p) \cdot [1 \cdot (r_1 - r_2) + \lambda \cdot (r_2 - r_1)] = q^* \cdot \{r_1 + (1 - p) \cdot [r_1 - r_2] + p \cdot \lambda \cdot r_1 + (1 - p) \cdot \lambda \cdot r_2\} - \lambda \cdot p \cdot r_1 - \lambda \cdot (1 - p) \cdot r_2$$

$$q^* = \frac{(1 + \lambda) \cdot p \cdot r_1 + (1 + \lambda) \cdot (1 - p) \cdot r_2 + (1 - \lambda) \cdot p \cdot (1 - p) \cdot (r_1 - r_2)}{\{r_1 + (1 - p) \cdot [r_1 - r_2] + p \cdot \lambda \cdot r_1 + (1 - p) \cdot \lambda \cdot r_2\}} \quad (3)$$

The uncertainty equivalent q^* can be evaluated at two critical points, $p = 0$ and $p = 1$. At $p = 0$,

$$q_0^* = \frac{(1 + \lambda) \cdot r_2}{2r_1 + (\lambda - 1) \cdot r_2}.$$

This is simply the probability equivalent for r_2 with certainty when $x_2 = 0$. To see this, I compare to the probability equivalent of equation (2) with $r = r_2$, $x_2 = 0$, and

$$x_1 = r_1,$$

$$q^* = \frac{r - x_2 - \lambda \cdot (x_2 - r)}{[x_1 - x_2] + [1 \cdot (x_1 - r) - \lambda \cdot (x_2 - r)]},$$

$$q^* = q_0^* = \frac{(1 + \lambda) \cdot r_2}{2r_1 + (\lambda - 1) \cdot r_2}.$$

As in the development of 2.1.1, I predict risk aversion for loss averse individuals, $\lambda > 1$, at $p = 0$.

At intermediate probabilities, the uncertainty equivalent follows equation (3) above which depends upon the squared probability term $p \cdot (1 - p)$. The function $q^*(p)$ can be traced to demonstrate quadratically declining risk aversion. One such trace is provided as the out of sample prediction in Figure 4. Risk neutrality is slowly approached such that at $p = 1$, $q^* = 1$. I evaluate q^* at $p = 1$, and show

$$q_1^* = \frac{(1 + \lambda) \cdot r_1}{(1 + \lambda) \cdot r_1} = 1.$$

A.1.2 Inverted Uncertainty Equivalents

Inverted uncertainty equivalents, like uncertainty equivalents feature a binary referent gamble, G , summarized by the probability p . Let r_1 be the referent with probability p and $r_2 < r_1$ be the referent with probability $1 - p$. Given the linear KR model, the utility of the referent is

$$U(G|G) = p \cdot r_1 + (1 - p) \cdot r_2 + p \cdot (1 - p) \cdot [1 \cdot (r_1 - r_2) + \lambda \cdot (r_2 - r_1)].$$

For simplicity I carry out the inverted uncertainty equivalent replacement, $r_2 = 0$ such that this reduces to

$$U(G|G) = p \cdot r_1 + p \cdot (1 - p) \cdot (1 - \lambda) \cdot r_1,$$

$$U(G|G) = p \cdot r_1 \cdot [1 + (1 - p) \cdot (1 - \lambda)],$$

$$U(G|G) = p \cdot r_1 \cdot [2 + p \cdot \lambda - p - \lambda].$$

It will be convenient to write this as

$$U(G|G) = p \cdot r_1 \cdot [2 + p \cdot \lambda - p] - p \cdot \lambda \cdot r_1.$$

Now, I consider a binary consumption gamble, F , summarized by the probability q . Let $x_1 = r_1$ be the gamble outcome with probability q and $x_2 > r_2$ be the gamble outcome with probability $1 - q$. I write the KR utility as

$$U(F|G) = q \cdot p \cdot x_1 + (1 - q) \cdot p \cdot [x_2 + \lambda \cdot (x_2 - r_1)] + q \cdot (1 - p) \cdot [x_1 + 1 \cdot (x_1 - r_2)] + (1 - q) \cdot (1 - p) \cdot [x_2 + 1 \cdot (x_2 - r_2)]$$

and note that only one term features loss aversion λ as $x_2 > r_2$. I carry out the

replacements $r_2 = 0$ and $x_1 = r_1$ such that this reduces to

$$U(F|G) = q \cdot p \cdot r_1 + (1 - q) \cdot p \cdot [x_2 + \lambda \cdot (x_2 - r_1)] + q \cdot (1 - p) \cdot 2r_1 + (1 - q) \cdot (1 - p) \cdot 2x_2,$$

$$U(F|G) = [q \cdot r_1 + (1 - q) \cdot x_2] \cdot [2 + p \cdot \lambda - p] - p \cdot \lambda \cdot r_1.$$

The inverted uncertainty equivalent will be the consumption gamble, F^* , with corresponding probability q^* satisfying $U(F^*|G) = U(G|G)$,

$$p \cdot r_1 \cdot [2 + p \cdot \lambda - p] - p \cdot \lambda \cdot r_1 = [q^* \cdot r_1 + (1 - q^*) \cdot x_2] \cdot [2 + p \cdot \lambda - p] - p \cdot \lambda \cdot r_1;$$

$$p \cdot r_1 = q^* \cdot r_1 + (1 - q^*) \cdot x_2.$$

Note that the left hand side corresponds to the expected value of the referent gamble with $r_2 = 0$. The right hand side corresponds to the expected value of the consumption gamble with $x_1 = r_1$. The inverted uncertainty equivalent reveals where the gamble expected values are equal and so, independent of loss aversion, λ , risk neutrality is expected.

A.2 Appendix Tables

Table A1: Additional Risk Attitude Regressions

	(1)	(2)	(3)
<i>Dependent Variable:</i>	<i>Risk Attitude Classification</i>		
<i>Panel A: Including Multiple Switchers</i>			
Condition 1 (=1)	1.303*** (0.206)	1.304*** (0.207)	1.128*** (0.223)
Risk Neutral Response	Yes	Yes	Yes
Demographic Controls	No	No	Yes
Order and Representation	No	Yes	Yes
# Observations	1904	1904	1750
# Clusters	136	136	125
<i>Panel B: All Treatment Interactions</i>			
Condition 1 (=1)	1.330*** (0.225)	1.784*** (0.409)	1.450** (0.540)
Condition 1 (=1) x Order 2 (=0) x Rep (=1)		-0.402 (0.613)	-0.153 (0.684)
Condition 1 (=1) x Order 2 (=1) x Rep (=0)		-0.709 (0.584)	-0.200 (0.746)
Condition 1 (=1) x Order 2 (=1) x Rep (=1)		-0.738 (0.593)	-0.634 (0.686)
Condition 1 (=0) x Order 2 (=0) x Rep (=1)		0.050 (0.377)	-0.114 (0.394)
Condition 1 (=0) x Order 2 (=1) x Rep (=0)		0.271 (0.351)	-0.178 (0.435)
Condition 1 (=0) x Order 2 (=1) x Rep (=1)		0.443 (0.287)	0.326 (0.321)
Condition 1 (=0)	-	-	-
Risk Neutral Response	Yes	Yes	Yes
Demographic Controls	No	No	Yes
# Observations	1708	1708	1554
# Clusters	122	122	111

Notes: Coefficients from ordered logit of *Risk Attitude* classification on control variables, measured from probability and certainty equivalents of Conditions 1.1, 1.2, 2.1, and 2.2. *Risk Attitude* takes the value -1 for risk loving, 0 for risk neutral, and +1 for risk averse. Standard errors clustered on the individual level in parentheses. Demographics, Order and Representation correspond to variables in Table 3.

Level of significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

A.3 Experimental Materials

A.3.1 Instructions

Hello and Welcome.

ELIGIBILITY FOR THIS STUDY: To be in this study, you must be a UCSD student. There are no other requirements. The study will be completely anonymous. We will not collect your name, student PID or any other identifying information. You have been assigned a participant number and it is on the note card in front of you. This number will be used throughout the study. Please inform us if you do not know or cannot read your participant number.

EARNING MONEY: To begin, you will be given a \$5 minimum payment. This \$5 is yours. Whatever you earn from the study today will be added to this minimum payment. All payments will be made in cash at the end of the study today.

In this study you will make decisions between two options. The first option will always be called OPTION A. The second option will always be called OPTION B. Each decision you make is a choice. For each decision, all you have to do is decide whether you prefer OPTION A or OPTION B.

These decisions will be made in 3 separate blocks of tasks. Each block of tasks is slightly different, and so new instructions will be read at the beginning of each task block.

Once all of the decision tasks have been completed, we will randomly select one decision as the decision-that-counts. Each decision has an equal chance of being the decision-that-counts. If you preferred OPTION A, then OPTION A would be implemented. If you preferred OPTION B, then OPTION B would be implemented.

Throughout the tasks, either OPTION A, OPTION B or both will involve chance. You will be fully informed of the chance involved for every decision. Once we know which is the decision-that-counts, and whether you prefer OPTION A or OPTION B, we will then determine the value of your payments.

For example, OPTION A could be a 75 in 100 chance of receiving \$10 and a 25 in 100 chance of receiving \$30. This might be compared to OPTION B of a 50 in 100 chance of receiving \$30 and a 50 in 100 chance of receiving nothing. Imagine for a moment which one you would prefer. You have been provided with a calculator should you like to use it in making your decisions.

If this was chosen as the decision-that-counts, and you preferred OPTION A, we would then randomly choose a number from 1 to 100. This would be done by throwing two ten-sided die: one for the tens digit and one for the ones digit (0-0 will be 100). If the chosen number was between 1 and 75 (inclusive) you would receive \$10 (+5 minimum payment) = \$15. If the number was between 76 and 100 (inclusive) you would receive \$30 (+5 minimum payment) = \$35. If, instead, you preferred OPTION B, we would again randomly choose a number from 1 to 100. If the chosen number was between 1 and 50 (inclusive) you'd receive

\$0 (+5 minimum payment) = \$5. If the number was between 51 and 100 (inclusive) you'd receive \$30 (+5 minimum payment) = \$35.

In a moment we will begin the first task.