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UNCERTAINTY, IDENTIFICATION, AND PRIVACY: EXPERIMENTS IN INDIVIDUAL DECISION-MAKING

by

DAVID RIVENBARK
B.S. Florida State University, 2001
M.S. Florida State University, 2002

A dissertation submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy
in the Department of Economics
in the College of Business Administration
at the University of Central Florida
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Major Professor: Glenn W. Harrison

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ABSTRACT

The alleged privacy paradox states that individuals report high values for personal privacy, while at the same time they report behavior that contradicts a high privacy value. This is a misconception. Reported privacy behaviors are explained by asymmetric subjective beliefs. Beliefs may or may not be uncertain, and non-neutral attitudes towards uncertainty are not necessary to explain behavior. This research was conducted in three related parts.

Part one presents an experiment in individual decision making under uncertainty. Ellsberg's canonical two-color choice problem was used to estimate attitudes towards uncertainty. Subjects believed bets on the color ball drawn from Ellsberg's ambiguous urn were equally likely to pay. Estimated attitudes towards uncertainty were insignificant. Subjective expected utility explained subjects' choices better than uncertainty aversion and the uncertain priors model. A second treatment tested Vernon Smith's conjecture that preferences in Ellsberg's problem would be unchanged when the ambiguous lottery is replaced by a compound objective lottery. The use of an objective compound lottery to induce uncertainty did not affect subjects' choices.

The second part of this dissertation extended the concept of uncertainty to commodities where quality and accuracy of a quality report were potentially ambiguous. The uncertain priors model is naturally extended to allow for potentially different attitudes towards these two sources of uncertainty, quality and accuracy. As they relate to privacy, quality and accuracy of a quality report are seen as metaphors for online security and consumer trust in e-commerce, respectively. The results of parametric structural tests were mixed. Subjects made choices consistent with neutral attitudes towards uncertainty

in both the quality and accuracy domains. However, allowing for uncertainty aversion in the quality domain and not the accuracy domain outperformed the alternative which only allowed for uncertainty aversion in the accuracy domain.

Finally, part three integrated a public-goods game and punishment opportunities with the Becker-DeGroot-Marschak mechanism to elicit privacy values, replicating previously reported privacy behaviors. The procedures developed elicited punishment (consequence) beliefs and information confidentiality beliefs in the context of individual privacy decisions. Three contributions are made to the literature. First, by using cash rewards as a mechanism to map actions to consequences, the study eliminated hypothetical bias as a confounding behavioral factor which is pervasive in the privacy literature. Econometric results support the "privacy paradox" at levels greater than 10 percent. Second, the roles of asymmetric beliefs and attitudes towards uncertainty were identified using parametric structural likelihood methods. Subjects were, in general, uncertainty neutral and believed "bad" events were more likely to occur when their private information was not confidential. A third contribution is a partial test to determine which uncertain process, loss of privacy or the resolution of consequences, is of primary importance to individual decision-makers. Choices were consistent with uncertainty neutral preferences in both the privacy and consequences domains.

To Brittany and our parents for their continuous support.

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CHAPTER 1: INTRODUCTION

As a field, experimental and behavioral economics is familiar with the value of individual anonymity in laboratory interactions. Non-anonymous, face-to-face, interactions motivate altruistic, reciprocal, and other interpersonal comparisons which have been shown to change behavior in significant ways. This idea was first recognized in Siegel and Fouraker (1960). In a small experiment, Alvin E. Roth (1995, p. 297-98) demonstrates a significant decline in disagreement outcomes when bargaining is face-to-face, as opposed to anonymous. The evidence further shows support for Siegel and Fouraker's (196) anonymity (uncontrolled social utility) hypothesis. Disagreement rates are significantly higher in anonymous bargaining (Roth 1995, p. 298). However, face-to-face disagreement rates are not significantly different when communication is constrained. A related literature, beginning with Hoffman, McCabe, Shachat, and Smith (1994), demonstrates a significantly higher incidence of self-regarding behavior under experimenter-subjects anonymity conditions.

What is less understood, however, is how individuals value their own personal privacy, anonymity, and the consequences of privacy loss. What factors influence individual decisions to voluntarily give-up or protect personal privacy? Using the laboratory to simulate real-world exchanges of personal privacy, this thesis seeks to obtain a deeper understanding of how individuals value privacy (confidentiality) in bilateral bargaining situations, and how these valuations may be conditioned on existing states of privacy.

If values of privacy have been understood for centuries (Westin 1967, 2003), why then do individual privacy decisions appear to exhibit what some have called paradoxical behaviors? Acquisti and Grossklags (2005a) reports survey responses for 119 subjects, between 19 and 55 years of age. A majority of responses (89.2%) indicate that subjects are highly concerned about privacy.[1,2] However, 87.5% of those same respondents have signed up for loyalty shopping cards, *potentially* placing themselves in privacy-sensitive situations. For example, the marketing firm HMI Communications, hired by Microsoft to handle a promotional "give-away" of Visual Studio.net, inadvertently allowed personal information such as address, email, and telephone number for thousands of applicants to be made public (Orlowski 2002). Did these individuals consider the likelihood of their identifiable information becoming public, did they consider the likelihood of fraud, conditional on such a release, and how do the benefits of receiving a free copy of Visual Studio.net compare to the potential loss due to an increased risk of fraud? Similar questions can be asked of subscriber to AOL internet service (Barbaro and Zellner 2006). When AOL released 20 million web searches made from the AOL search engine, numerous individuals self-identified themselves through their web searches.

The claim of paradoxical behavior rests on a misconception. Privacy behavior is easily explained as a tradeoff between expected benefits and expected costs. Conditional subjective beliefs account for the behavior reported in Acquisti and Grossklags (2005a). This thesis studies the roles of risk and uncertainty in privacy decision making. To accomplish this goal, laboratory experiments were conducted in three parts. Part one tested the canonical choice problem described by Ellsberg (1961, p. 650) and the role of uncertainty aversion in violations of Savage's (1954) subjective expected utility theory. Part two extended the concept of uncertainty aversion to commodities with more than one

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[1] The term "high concern" is a self-reported qualitative ranking of how concerned survey respondents are about their privacy.

[2] Norberg, Horne, and Horne (2007) observe similar self-reported behaviors.

source of uncertainty. The experimental design of Heath and Tversky (1991) was adapted to partially identify if subjects differentiate between uncertainties from different sources. And, finally, part three expands on the methods developed in parts one and two to study privacy decision-making and the role of uncertainty aversion.

1.1 Experiments in Personal Privacy

Individuals report high values for personal privacy, while at the same time reporting behaviors that would seem to contradict having high privacy values. These reports are self-reports from hypothetical surveys in which there are no real consequences from dishonest reporting. This statement of the alleged privacy paradox describes the canonical "loyalty card" example discussed in Acquisti and Grossklags (2005a) and others. Syverson (2003) and Rifon, LaRose, and Lewis (2007) argue these reports are not indicative of paradoxical behavior. The dichotomy in self reports is attributable to either subject heterogeneity (Spiekermann, Grossklags, and Berendt 2002), or recognition that the alleged paradox assumes that stated attitudes map directly into consistent behavior (Syverson 2003; Rifon, LaRose, and Lewis 2007).

More cachet explanations have included: bounded rationality, incomplete information, psychological distortions, attitudes towards risk/uncertainty[3], and strategic interactions such as trust (Acquisti and Grossklags 2004 and 2005a). Evidence put forward in support of these claims is arguably tainted by confounding factors. These factors are: hypothetical biases, experimenter trust, framing effects, and deceit.

Hypothetical bias in privacy studies is supported by Acquisti and Grossklags (2007), and is also a potential confound in Acquisti and Grossklags (2005b) and

[3] It should be noted that neither risk nor uncertainty aversion are necessary conditions to explain allegedly paradoxical privacy behavior.

Huberman, Adar, and Fine (2005). Huberman et al (2005) elicit real and hypothetical values for pieces of private information. For their real treatment, average willingness-to-accept for loss in weight privacy was $74.06, and 57.56 for age privacy loss.[4] Reported values rose dramatically for hypothetical salary and other unverifiable characteristics. In Acquisti and Grossklags (2005b)[5] values for 13 data categories such as name, SSN, favorite online alias, home address, phone number, email address, sexual fantasies, etc. were elicited using an open-ended hypothetical instrument. Wathieu and Friedman (2007, sec. 1) would use these results as providing "useful dollar values" for privacy valuations. However, Harrison and Rutström (1999) tell us there are probably significant upward biases on these reports. Even if one corrected for hypothetical bias, as illustrated in List and Shogren (2002), instruments used in privacy experiments do not provide mechanisms mapping actions into *controlled* consequences.[6]

The Duhem-Quine problem[7] can be found in Norberg, Horne, and Horne (2007), where deceitful practices and experimenter trust effects are confounding factors. In Norberg et al. (2007) an attempt was made to control for both uncertainty and trust through framing of a hypothetical survey instrument designed to simulate a marketer's request for personal information. Their results offer little, if any, support for paradoxical

---

[4] Huberman, Adar, and Fine (2005) conducted both a theoretically incentive compatible sealed bid real reverse Vickrey auction, and a hypothetical reverse Vickrey auction. Real auctions consisted of selling verifiable personal information, such as weight and age for 127 individuals. Rutström (1998) and Harstad (2000) provide evidence that behavior in Vickrey auctions does not reliably induce truthful responses, despite the theoretical incentive compatibility of the procedure. These bids need to be interpreted with caution. Hypothetical auctions were carried out for "unverifiable" information, such as credit rating, income, and savings. The average demand prices for age and weight were $57.56 and $74.06, respectively.

[5] Acquisti and Grossklags (2005a) and (2005b) use the same subject pool.

[6] Furthermore, results presented in Acquists and Grossklags (2005b) does not test effects of uncertain (ambiguous) consequences on individual privacy decisions. The experimental design varied the framing of benefits as either a payment or discount on a purchase, not with uncertainty.

[7] The Duhem-Quine thesis states that without proving the background assumptions it is impossible to prove or disprove a theory. Absence of order effects is an untested background assumption in Acquists and Grossklags (2005b).

privacy behavior. Violation of the *ceteris paribus* condition, as well as deceitful experimental practices, explained below, confounds their experiment.

The initial experimental treatment in Norberg et al. (2007) was conducted under a hypothetical scenario, asking subjects to behave *as if* they were responding to an information request by a bank. Subjects were instructed that they were taking part in a focus group to aid in the design of a bank's survey instrument. The second treatment removed the *as if* condition but a level of trust (i.e., a bank representative[8]) was added. Treatment two of the "experiment" used dishonest practices. There was in fact no bank, and the bank representative was a fraud designed to cajole subjects into freely revealing personal information.

Deceitful practices question the validity of subject responses, even under the most pristine experimental conditions. Do the subjects in Norberg et al. (2007) have previous experiences with deceitful practices? If so, are they responding truthfully, or are they trying to exhibit behavior that they think the researchers want to see? Or, are they languid with respect to the experimental task, simply reporting systematic responses in an attempt to extract resources (e.g., money or grades) from the experimenter? Hertwig and Ortmann (2001, p. 396-399) offer a detailed survey of potential detriments to deceiving and using subjects whom have previously been deceived by such experimental designs.

Trust affects were also likely confounds in the online shopping experiment reported in Spiekerman, Grossklags, and Berendt (2002), Berendt, Günther, and Spiekerman (2005). In this particular experiment, subjects were given the opportunity to purchase real commodities (a camera or jacket) with their own money during an online

[8] Phase two of the "experiment" presented in Norberg, Horne, and Horne (2007) used dishonest practices. There was no bank representative (ibid., 111, 115).

shopping experience. However, at the outset of the experiment, subjects were instructed "the experiment's goal was to test interaction with a new product search engine." (Spiekerman, Grossklags, and Berendt 2002 p. 40). These instructions, cue subjects to interact with the search engine as an expected behavior during the experiment. Furthermore, provision of rights according to EU privacy directive 95/46/EC and (unspoken) institutional review board policies likely diminish subject apprehensions to providing the experimenter with personal information.

The literature recognizes that stated intentions often contradict (stated) behavior, even for privacy decisions. Subjective beliefs, consistent with Savage's (1954) subjective expected utility, are capable of explaining reported privacy behaviors. As a result, the concept of uncertainty and attitudes towards uncertainty are unnecessary explanations.

This dissertation is organized as follows. Chapter 2 presents a series of numerical examples to demonstrate the role beliefs play in explaining privacy behaviors. The concept of uncertainty is introduced with Ellsberg's (1961) paradox, and rationalized with the uncertain-priors model of Neilson (1993, 2009) and Klibanoff, Marinacci, and Mukerji (2005). Three experiments are proposed to test six hypotheses developed throughout the chapter. Each experiment and findings are presented in chapters 3, 4, and 5 respectively.

Chapter 3 experimentally identifies attitudes towards uncertainty in the classic Ellsberg (1961) framework. A structural econometric model is developed to calibrate estimated attitudes for risk aversion and subjective beliefs. In Chapter 4, the experimental design of heath and Tversky (1991) and linear scoring rule is used to elicit individual preferences for objective, uncertain, and compound uncertain lottery pairs. Structural econometric modeling suggests that subjects may cognitively differentiate multiple uncertain processes. Chapter 5 implements an experimental design replicating privacy behaviors previously documented in the literature. The experimental instruments are designed to mitigate previously identified experimental confounds and biases from hypothetical choice situations, experimenter trust effects, time inconsistent preferences, uncontrolled preferences, and deceitful practices. In addition to replicating privacy behaviors in a controlled environment, the data suggest that subjects respond differently to uncertain of confidentiality loss and uncertain consequences. The results of chapters 4 and 5 also support a hypothesis that trust confounded subject choices in Spiekerman et al. (2007), Berendt et al. (2002), and affected consumer decisions in AOL and HMI. Finally, Chapter 6 concludes this dissertation.

CHAPTER 2: THEORY AND HYPOTHESES

The alleged privacy paradox says decision-makers report high values for personal privacy, while at the same time these same decision-makers report behaviors that would seem to contradict having high privacy values. Three behavioral explanations hypothesized to rationalize reported behavior are: Savage's subjective expected utility (Syverson 2003), aversion to uncertainty (Acquisti and Grossklags 2004), and time inconsistent preferences (Acquisti 2004). In the sequel, I test Syverson's (2003) hypothesis that the pattern of observed privacy behaviors is consistent with Savage's (1954) subjective expected utility (SEU) model. Uncertainty aversion is a more general model, where the decision-maker holds multiple uncertain prior beliefs for the risks associated with privacy behavior. Because of its close relation to subjective beliefs, the time inconsistencies explanation is not studied here.

2.1 Subjective Expected Utility

Savage (1954) shows that if the decision-maker behaves according to a set of axioms he will behave *as if* maximizing a preference functional give by

$$V(\mathbf{z}) = \sum_{j \in J} p_j \cdot v(z_j), \tag{1}$$

where z_j are consequences of act Z, dependent on which state $j \in J$ occurs, p_j is a probability measure (subjectively) known to the decision-maker, and $v(\cdot)$ is the state independent utility function. To show how SEU preferences explain privacy behavior, consider the canonical "loyalty card" example discussed by Acquisti and Grossklags (2005a). A majority of survey respondents (89.2%) reported having a high concern for privacy. However, those same respondents admit to routinely placing themselves in privacy-sensitive situations. For example, 87.5% of respondents with a high concern for privacy have signed up for loyalty cards using real identifying information.

A high privacy concern is taken to be synonymous with a high dollar value of private information. Thus, the paradoxical privacy behavior is represented by the decision to not make a *direct-sale* of information to someone who would potentially do harm, while at the same time make an *indirect-sale* of the same personal information to someone who will not do direct harm but may reveal the information to the same person who would potentially do harm. Acquisti and Grossklags (2005a), among others, would claim this behavior represents a dichotomy between stated privacy concerns and stated behavior.

Consider this numerical example of the "loyalty card" problem. Assume the decision-maker has an initial wealth level given by w (e.g., $w = \$100$) and, in exchange for identifying information, he is offered some positive amount of money y (e.g., $y = \$20$). If the decision-maker is successfully defrauded, he will lose some portion of his wealth. For simplicity, assume he loses $1-\delta$ percent, retaining either δw or $\delta\left[w+y\right]$ following a successful fraud attempt. Specifically, let $\delta = 0.5$, $\delta w = \$50$ and $\delta\left[w+y\right] = \$60$. Finally, let $J = \left(\text{cg}, \text{cb}, \text{ng}, \text{nb}\right)$ be the events (good (g) conditional of confidential (c), bad (d) conditional on confidentiality, etc.) considered by the decision-maker.

For the direct sale the decision-maker compares the lottery between good and bad events conditional on confidentiality, against the alternative lottery for good and bad events conditional on non-confidentiality *and* payment for his identifying information.

Assume these beliefs are given by $\left(p_{\text{g|c}}, p_{\text{b|c}}, p_{\text{g|n}}, p_{\text{b|n}}\right) = (0.65, 0.35, 0.35, 0.65)$ with $\left(p_{\text{c}}, p_{\text{n}}\right) = (0.50, 0.50)$. When his identifying information is confidential, the decision-maker believes there is a lower risk of being defrauded.

Defining $v(x) = \sqrt{x}$, SEU preferences imply that if the decision-maker makes the direct sale he expects utility

$$V\left(\mathbf{z}|\text{direct sale}\right) = 0.35 \cdot \sqrt{120} + 0.65 \cdot \sqrt{60} = 8.869,$$

and if he does not make the direct sale he expects utility

$$V\left(\mathbf{z}|\text{no direct sale}\right) = 0.65 \cdot \sqrt{100} + 0.35 \cdot \sqrt{50} = 8.975.$$

The decision-maker decides not to make the direct sale. However, when confronted with the same offer of $20 for an indirect sale, the decision-maker agrees to the transaction because he believes there is a 50 percent chance his personal information remains confidential. For the indirect sale, the decision-maker expects utilities

$$V\left(\mathbf{z}|\text{indirect sale}\right) = 0.5 \cdot \left[0.35 \cdot \sqrt{120} + 0.65 \cdot \sqrt{60}\right]$$

$$+0.5 \cdot \left[0.65 \cdot \sqrt{120} + 0.35 \cdot \sqrt{60}\right] = 9.350, \text{ and}$$

$$V\left(\mathbf{z}|\text{no indirect sale}\right) = 0.65 \cdot \sqrt{100} + 0.35 \cdot \sqrt{50} = 8.975 = V\left(\mathbf{z}|\text{no direct sale}\right).$$

As this example demonstrates, exotic non-SEU preference functions are unnecessary to explain privacy behaviors. However, for ambiguous events, decision-makers appear to exhibit aversion to uncertain mean preserving spreads (Camerer and Weber 1992). Halevy (2007) reports on an experiment where approximately 30% are characterized by *ambiguity aversion*. The uncertain priors (UP) model (Neilson 1993, 2009; and Klibanoff, Marinacci, and Mukerji 2005) is used to behaviorally allow for attitudes towards uncertain privacy events.

The canonical concept of uncertainty aversion is introduced with Ellsberg's (1961, p. 650) two-color problem. The same UP model also explains Ellsberg's three-color problem (see Appendix B).

2.2 Uncertainty Aversion: Ellsberg's Paradox

Consider the following Ellsberg (1961, p. 650) example. There are two urns, and each is filled with red and black balls. Urn 1 contains 100 balls, split evenly between red and black. Balls drawn from urn 1 are labeled "R" for red and "B" for black. Urn 2 also contains 100 balls. However, the mix of balls is unknown. Balls drawn from urn 2 are labeled "r" for red and "b" for black.

Table 1. Ellsberg's Two Urn Problem

Outcomes	L_1	L_2	L_3	L_4
Rr	\$100	\$0	\$100	\$0
Rb	\$100	\$100	\$0	\$0
Br	\$0	\$0	\$100	\$100
Bb	\$0	\$100	\$0	\$100

Table 1 shows four lotteries (L_1, L_2, L_3, and L_4), with prizes \$0 or \$100 defined over the unique outcomes from drawing one ball from urn 1, and then a second ball from urn 2. Ellsberg (1961) hypothesized that subjects would exhibit preference relations given by $L_1 \sim L_4$, $L_2 \sim L_3$, $L_1 \succ L_2$, and $L_4 \succ L_3$. These hypotheses are the result of a thought experiment by Ellsberg, in the sense defined by Harrison and List (2004). He did pose these choices hypothetically to several prominent economists, including Savage. But the key "empirical hypothesis" here derives from intuition, not observed choices in the sense that modern experimental economics would suggest.

Remember, L_2 and L_3 are each filled with 100 balls in unknown proportions of red and black balls. Had our Ellsberg decision-maker believed either event red or black was more likely to occur, he would have preferred to a bet paying on that color to indifference. By stating indifference, he is revealing to us his prior uniform belief. By this same logic, preferences for L_1 over L_2 and for L_4 over L_3 implies (Savage's (1954) SEU) that subjects believe the likelihood of drawing red and black balls from urn 2 are less than $\frac{1}{2}$, hence the paradox. The UP model (Neilson 1993, 2009; and Klibanoff, Marinacci, and Mukerji 2005) rationalizes these preferences by applying Savage's (1954) axioms to second-order beliefs.

2.2.1 The Uncertain Priors Model

Using the terminology of Anscombe and Aumann (1963), let there be $j = 1,...,J$ (uncertain) horse lotteries and $k = 1,...,K$ (certain) roulette lotteries. The decision-maker holds $i = 1,...,I$ prior distributions over each horse's ability to win the race – the outcome of the uncertain process U. Denote the probability over these priors as $\boldsymbol{\rho} = (\rho_1,...,\rho_I)$. The set $(U_{i1},...,U_{iJ})$ is the set of uncertain processes with unknown probabilities for each of the J horses winning the race. Define a set $(C_1,...,C_K)$ as the set of certain processes with known probabilities over each of the K roulette lotteries.

Let $(\sigma_{ij1},...,\sigma_{ijK})$ define the subjective conditional probabilities assigned to j^{th} horse winning and the k^{th} roulette lottery outcome under each prior i. The decision-maker's overall evaluation of his preference for the race is

$$W(\mathbf{z}) = \sum_{i=1}^{I} \rho_i u\left(\sum_{j=1}^{J} \sum_{k=1}^{K} \sigma_{ijk} v\left(z_{jk} \right) \right), \quad (2)$$

where $W(\mathbf{z})$ is the evaluation of all I priors that the decision-maker holds, and $\sigma_{ijk} \equiv \pi_{ij}^{U} \pi_{k}^{C}$ with π_{ij}^{U} defined as the probabilistic belief of each horse j winning and π_{k}^{C} the known probability of the k^{th} certain event. The function $v(\cdot)$ measures utility over final payoffs z_{jk}, and $u(\cdot)$ is the evaluation of the decision-maker's subjective expected utility over final payoffs from the certain roulette lotteries. The curvature of $u(\cdot)$ measures uncertainty associated with the priors $i = 1,...,I$. To illustrate how the UP model is able to account for the preferences depicted in Ellsberg's example, I recreate the numerical example found in Andersen, Harrison, Fountain, and Rutström (2009).

For some argument x, define $v(x) = \sqrt{x}$ and $u(x) = x^{0.9}$. Define balls drawn from urns 1 and 2 as belonging to the sets $k = \{\text{R}, \text{B}\}$ and $j = \{\text{r}, \text{b}\}$, respectively. Further assume the decision-maker holds three priors over the distribution of balls in urn 2. That is, $(\rho_1, \rho_2, \rho_3) = (0.6, 0.2, 0.2)$, with $(\pi_{1\text{r}}^{U}, \pi_{1\text{b}}^{U}) = (0.5, 0.5)$, $(\pi_{2\text{r}}^{U}, \pi_{2\text{b}}^{U}) = (0.4, 0.6)$, and $(\pi_{3\text{r}}^{U}, \pi_{3\text{b}}^{U}) = (0.6, 0.4)$. For each of these priors, the decision-maker evaluates $\sigma_{ijk} = \pi_{ij}^{U} \pi_{k}^{C}$ as $(\pi_{1\text{r}}^{U}\pi_{\text{R}}^{C}, \pi_{1\text{b}}^{U}\pi_{\text{R}}^{C}, \pi_{1\text{r}}^{U}\pi_{\text{B}}^{C}, \pi_{1\text{b}}^{U}\pi_{\text{B}}^{C}) = (0.25, 0.25, 0.25, 0.25)$ for his first prior set of probabilistic beliefs, $(\pi_{2\text{r}}^{U}\pi_{\text{R}}^{C}, \pi_{2\text{b}}^{U}\pi_{\text{R}}^{C}, \pi_{2\text{r}}^{U}\pi_{\text{B}}^{C}, \pi_{2\text{b}}^{U}\pi_{\text{B}}^{C}) = (0.2, 0.3, 0.2, 0.3)$ for his second set of prior beliefs, and finally for his third set of priors the decision-maker believes

$\left(\pi^U_{3r}\pi^C_{R}, \pi^U_{3b}\pi^C_{R}, \pi^U_{3r}\pi^C_{B}, \pi^U_{3b}\pi^C_{B}\right) = \left(0.3, 0.2, 0.3, 0.2\right)$. For each of these priors, the evaluation of $\sum_{j=1}^{J}\sum_{k=1}^{K}\sigma_{ijk}v\left(z_{jk}\right)$ for lottery L_1 (see Table **1**) is then given by

$$L_1: \quad 0.25\cdot 10 + 0.25\cdot 10 + 0.25\cdot 0 + 0.25\cdot 0 = 5,$$

under prior 1,

$$L_1: \quad 0.20\cdot 10 + 0.30\cdot 10 + 0.20\cdot 0 + 0.30\cdot 0 = 5,$$

under prior 2, and

$$L_1: \quad 0.30\cdot 10 + 0.20\cdot 10 + 0.30\cdot 0 + 0.20\cdot 0 = 5,$$

under prior 3. Similar calculations are made for lotteries L_2, L_3, and L_4. Evaluating preferences for each lottery,

$$W\left(L_1\right) = 0.6\cdot 5^{0.9} + 0.2\cdot 5^{0.9} + 0.2\cdot 5^{0.9} = 4.257,$$

$$W\left(L_2\right) = 0.6\cdot 5^{0.9} + 0.2\cdot 6^{0.9} + 0.2\cdot 4^{0.9} = 4.254,$$

$$W\left(L_3\right) = 0.6\cdot 5^{0.9} + 0.2\cdot 4^{0.9} + 0.2\cdot 6^{0.9} = 4.254,$$

$$W\left(L_4\right) = 0.6\cdot 5^{0.9} + 0.2\cdot 5^{0.9} + 0.2\cdot 5^{0.9} = 4.257.$$

For this numerical example, $W\left(L_1\right) = W\left(L_4\right)$, $W\left(L_2\right) = W\left(L_3\right)$, $W\left(L_1\right) > W\left(L_2\right)$, and $W\left(L_4\right) > W\left(L_3\right)$, which explains the hypothesized pattern of preferences in Ellsberg's example. It is easy to see that, if there is no aversion to uncertainty, such that $u\left(x\right) = x$ apart from arbitrary normalizations, then $W\left(L_1\right) = W\left(L_2\right) = W\left(L_3\right) = W\left(L_4\right)$. This is the prediction of conventional subjective expected utility theory.

Although the hypothesis that individuals exhibit uncertainty aversion has been studied extensively (Camerer and Webber 1992), prior investigations of the uncertainty aversion hypothesis failed to verify the background assumption: the decision-maker believes that the realization of events is equally likely for both the known and unknown urns. Given this gap in the existing literature, the first hypothesis to be tested is:

HYPOTHESIS 1: In Ellsberg's (1961) 2-color problem (p. 650), subjects behave *as if* the realization of each uncertain event is equally likely as each certain event *and* bets on certain events are preferred to bets on uncertain events.

Smith (1969, p. 329) conjectured that Ellsberg's (1961) pattern of preferences would also be observable for bets where the distribution of balls in the ambiguous urn was determined by a uniform random integer 0-100. Since then, experimentalists (Sarin and Weber 1993; Harrison 2009) have considered compound lotteries as attractive tools for inducing uncertainty in laboratory settings. Because Smith's (1969) conjecture remains *untested*, the following two hypotheses emerge as important methodological inquiries:

HYPOTHESIS 2: The proportion UP/SEU consistent choices are equal for both the Ellsberg (1961) and Smith (1969) treatments.

HYPOTHESIS 3: Attitudes towards uncertainty are equivalent for both the Ellsberg (1961) and Smith (1969) lotteries.

The remainder of this chapter presents the UP model in the context of privacy. Finally, the analysis is extended to include two uncertain processes.

2.3 Explaining Privacy Behavior with the Uncertain Priors Model

The Ellsberg (1961) example(s) and the UP model (Neilson 1993, 2009; and Klibanoff, Marinacci, and Mukerji 2005) demonstrate how the uncertainty averse individual, will discount more heavily those processes which are described as "more uncertain." The utility spread for L_2 and L_3 are greater than that of L_1 and L_4.

The "loyalty card" problem is used as to illustrate the role of uncertain priors in privacy decisions. This behavior can occur in any privacy decision. The acts of confession or being an "anonymous source" are other examples of the privacy paradox.

Redefine $k = \{\mathrm{g}, \mathrm{b}\}$ for the good and bad outcomes. Let the J uncertain events be given by $j = \{\mathrm{c}, \mathrm{n}\}$ for when the vendor has upheld the confidentiality of the decision-maker and when confidentiality was violated. The following example shows that the UP model with only one uncertain process explains the alleged privacy paradox when the objective probabilities of experiencing either a good or bad events are conditional on the decision-maker's state of confidentiality.

Assume the decision-maker has an initial wealth level given by w (e.g., $w = \$100$) and, in exchange for identifying information, he is offered some positive amount of money y (e.g., $y = \$20$). Unconditional on the decision to sell information, if the decision-maker is successfully defrauded, he will lose some portion of his wealth. For simplicity, assume he loses $1-\delta$ percent, retaining either δw or $\delta[w+y]$. Specifically, let $\delta = 0.5$, $\delta w = \$50$ and $\delta[w+y] = \$60$. Assume the decision-maker holds 2 priors $\boldsymbol{\rho} = (0.5, 0.5)$ for the uncertainty that the decision-maker's confidentiality is violated. For each of these priors, let the distribution of events $j = \{\mathrm{c}, \mathrm{n}\}$ be $(\pi^U_{1\mathrm{c}}, \pi^U_{1\mathrm{n}}) = (0.7, 0.3)$ and $(\pi^U_{2\mathrm{c}}, \pi^U_{2\mathrm{n}}) = (0.3, 0.7)$. These beliefs assume the decision-maker has joined the loyalty card program. If the decision-maker does not make an indirect sale, then he forms a set of degenerate beliefs $\left(\pi_{1c}^{U},\pi_{1n}^{U}\right)=\left(\pi_{2c}^{U},\pi_{2n}^{U}\right)=\left(0,1\right)$.

Let the objectively-known probabilities of a bad event conditional on a privacy breach be $\left(\pi_{g|c}^{C},\pi_{b|c}^{C}\right)=\left(0.65,0.35\right)$ and $\left(\pi_{g|n}^{C},\pi_{b|n}^{C}\right)=\left(0.35,0.65\right)$. For prior one the decision-maker holds subjective probabilistic belief given by $\left(\sigma_{1cb},\sigma_{1nb},\sigma_{1cg},\sigma_{1ng}\right)=\left(0.245,0.195,0.455,0.105\right)$, and for prior two his beliefs are given by $\left(\sigma_{2cb},\sigma_{2nb},\sigma_{2cg},\sigma_{2ng}\right)=\left(0.105,0.455,0.195,0.245\right)$. Defining $v\left(x\right)=\sqrt{x}$ and $u\left(x\right)=x^{0.7}$, equation (2) implies that if the decision-maker makes an indirect sale, he expects utility

$$W\left(\mathbf{z}|\text{indirect sale}\right)=0.5\cdot\left[0.245\cdot\sqrt{60}+0.195\cdot\sqrt{60}+0.455\cdot\sqrt{120}+0.105\cdot\sqrt{120}\right]^{0.7}$$

$$+0.5\cdot\left[0.105\cdot\sqrt{60}+0.455\cdot\sqrt{60}+0.195\cdot\sqrt{120}+0.245\cdot\sqrt{120}\right]^{0.7}=4.781.$$

If he does not make an indirect sale, the decision-maker's information remains confidential and he forms beliefs $\left(\pi_{1c}^{U},\pi_{1n}^{U}\right)=\left(\pi_{2c}^{U},\pi_{2n}^{U}\right)=\left(1,0\right)$, which imply that $\left(\sigma_{2cb},\sigma_{2nb},\sigma_{2cg},\sigma_{2ng}\right)=\left(\sigma_{1cb},\sigma_{1nb},\sigma_{1cg},\sigma_{1ng}\right)=\left(0.35,0,0.65,0\right)$, and

$$W(\mathbf{z}|\text{no indirect sale})=\left[0.35\cdot\sqrt{50}+0.65\cdot\sqrt{100}\right]^{0.7}=4.646<W\left(\mathbf{z}|\text{indirect sale}\right),$$

and the decision-maker decides to make the indirect sale because he expects a higher utility.

Calculating utilities for the direct sale part of the alleged paradox is similar to the first part of the example. The direct sale decision removes the uncertainty from the decision-maker's problem. He forms one of two degenerate beliefs, 100% or 0%

confidentiality. By not directly selling his information, the decision-maker forms the degenerate belief $\left(\pi_{1c}^{U},\pi_{1n}^{U}\right)=\left(\pi_{2c}^{U},\pi_{2n}^{U}\right)=\left(1,0\right)$. Thus,

$$W(\mathbf{z}|\text{no direct sale})=\left[0.35\cdot\sqrt{50}+0.65\cdot\sqrt{100}\right]^{0.7}=W(\mathbf{z}|\text{no indirect sale}).$$

By directly selling his personal information, the decision-maker holds beliefs $\left(\pi_{1c}^{U},\pi_{1n}^{U}\right)=\left(\pi_{2c}^{U},\pi_{2n}^{U}\right)=\left(0,1\right)$, such that his beliefs are *objectively* given by $\left(\sigma_{2cb},\sigma_{2nb},\sigma_{2cg},\sigma_{2ng}\right)=\left(\sigma_{1cb},\sigma_{1nb},\sigma_{1cg},\sigma_{1ng}\right)=\left(0,0.65,0,0.35\right)$, and so

$$W(\mathbf{z}|\text{direct sale})=\left[0.65\cdot\sqrt{60}+0.35\cdot\sqrt{120}\right]^{0.7}=4.608<W(\mathbf{z}|\text{no direct sale}).$$

With the objective probabilities of either a bad or good event occurring conditioned on confidentiality of the decision-maker's information, we see how decision-makers evaluate uncertainty in privacy decisions. Extending the UP model to include two uncertain processes is a straightforward exercise.

2.4 Explaining the Privacy Paradox with Two Uncertain Processes

Extending the UP model to account for subjective belies for both a privacy breach and the consequences of such a breach is a conceptually straightforward exercise, although it does impose some notational burden. Consider the preference function

$$W\left(\mathbf{z}\right)=\sum_{i^1=1^1}^{I^1}\sum_{i^2=1^2}^{I^2}\rho_{i^1}\theta_{i^2}u\left(\sum_{j^1=\{c,n\}}\sum_{j^2=\{g,b\}}\pi_{i^1j^1}^{1}\pi_{j^1i^2j^2}^{2}v\left(z_{j^2}\right)\right). \tag{3}$$

In addition to his first I^1 priors for his identifying information remaining confidential, the decision-maker has now formed the additional I^2 prior probabilistic beliefs of a bad event, conditioned on the $j^1=\{c,n\}$ events. This formulation of the UP model assumes ROCL applies between the two uncertain processes. Beliefs represented by $\pi^2_{j^1 i^2 j^2}$, and $\sigma_{i^1 i^2 j^1 j^2} \equiv \pi^1_{i^1 j^1}\pi^2_{j^1 i^2 j^2}$ are the decision-maker's beliefs of realizing the events $j^1 = \{\mathrm{c},\mathrm{n}\}$ *and* $j^2 = \{\mathrm{g},\mathrm{b}\}$. Finally, θ_{i^2} are the probabilities over the I^2 priors.

In equation (3), curvature of $u(x)$ at the point x measures the decision-maker's aversion to his $I^1 \times I^2$ uncertain beliefs of the $J^1 \times J^2$ events. To show how equation (3) explains privacy behavior, use the same payoffs and functions before. Denote the subjective beliefs of good or bad events by $\left(\pi^2_{1^2\,\mathrm{g|c}}, \pi^2_{1^2\,\mathrm{b|c}}, \pi^2_{1^2\,\mathrm{g|n}}, \pi^2_{1^2\,\mathrm{b|n}}\right) = (0.7, 0.3, 0.3, 0.7)$ and $\left(\pi^2_{2^2\,\mathrm{g|c}}, \pi^2_{2^2\,\mathrm{b|c}}, \pi^2_{2^2\,\mathrm{g|n}}, \pi^2_{2^2\,\mathrm{b|n}}\right) = (0.6, 0.4, 0.4, 0.6)$ which are his beliefs of bad and good events under each prior, conditional on his state of confidentiality.

Define $SEU_{i^1 i^2} \equiv \sum_{j^1=\{\mathrm{c},\mathrm{n}\}} \sum_{j^2=\{\mathrm{g},\mathrm{b}\}} \pi^1_{i^1 j^1}\pi^2_{j^1 i^2 j^2} v\left(\mathrm{z}_{j^2}\right)$ as the decision-maker's prior subjective expected utilities over the final outcomes g *or* b, conditioned on c *or* n. Beliefs of having his identifying information remain confidential after engaging in an indirect sale are given by $\left(\pi^1_{1^1\,\mathrm{c}}, \pi^1_{1^1\,\mathrm{n}}, \pi^1_{2^1\,\mathrm{c}}, \pi^1_{2^1\,\mathrm{n}}\right) = (0.7, 0.3, 0.3, 0.7)$

If the decision-maker indirectly sells his information

$$SEU_{1^1 1^2} = 0.58\sqrt{120} + 0.42\sqrt{60} = 9.607\,,$$

$$SEU_{1^1 2^2} = 0.42\sqrt{120} + 0.58\sqrt{60} = 9.094\,,$$

$$SEU_{2^1 1^2} = 0.54\sqrt{120} + 0.46\sqrt{60} = 9.479\,,\text{ and}$$

$$SEU_{1^1 2^2} = 0.46\sqrt{120} + 0.54\sqrt{60} = 9.222\,.$$

The decision-maker expects *final* utility

$$W(\mathbf{z}\,|\,\text{indirect sale}) = 0.25 \cdot [9.607]^{0.7} + 0.25 \cdot [9.094]^{0.7}$$

$$+0.25\cdot[9.479]^{0.7}+0.25\cdot[9.222]^{0.7}=4.781.$$

If the decision-maker decides not to make the indirect sale, then he recognizes that he will be in a confidential state with certainty, and he forms the degenerate prior conditional probability distributions $\boldsymbol{\pi}^1=\left(\pi^1_{1^1\text{c}},\pi^1_{1^1\text{n}},\pi^1_{2^1\text{c}},\pi^1_{2^1\text{n}}\right)=(1,0,1,0)$, which implies

$$SEU_{1^11^2}=SEU_{1^12^2}=0.70\sqrt{100}+0.30\sqrt{50}=9.992\text{, and}$$

$$SEU_{2^11^2}=SEU_{1^12^2}=0.60\sqrt{100}+0.40\sqrt{50}=9.671.$$

By deciding not to make the indirect sale, the decision-maker expects final utility

$$W(\mathbf{z}\,|\,\text{no indirect sale})=0.5\cdot[9.992]^{0.7}+0.5\cdot[9.671]^{0.7}=4.646<W(\mathbf{z}\,|\,\text{indirect sale}).$$

The decision-maker will make the indirect sale because he expects to be better-off.

Not making a direct sale is equivalent to not making an indirect sale of identifying information. Thus, $W(\mathbf{z}\,|\,\text{no direct sale})=W(\mathbf{z}\,|\,\text{no indirect sale})=4.646$. Making the direct sale, the decision-maker forms the degenerate beliefs $\boldsymbol{\pi}^1=\left(\pi^1_{1^1\text{c}},\pi^1_{1^1\text{n}},\pi^1_{2^1\text{c}},\pi^1_{2^1\text{n}}\right)=(0,1,0,1)$ by recognizing that he will be in a non-confidential state. Hence,

$$SEU_{1^11^2}=SEU_{1^12^2}=0.30\sqrt{100}+0.70\sqrt{50}=8.709\text{, and}$$

$$SEU_{2^11^2}=SEU_{1^12^2}=0.40\sqrt{100}+0.60\sqrt{50}=9.029.$$

By deciding not to make the direct sale, the decision-maker expects final utility

$$W(\mathbf{z}\,|\,\text{direct sale})=0.5\cdot[8.709]^{0.7}+0.5\cdot[9.029]^{0.7}=4.607<W(\mathbf{z}\,|\,\text{no direct sale}),$$

and the decision-maker decides not to sell his information.

These numerical examples have shown how uncertainty aversion is incorporated into reported privacy behavior. The two-process UP model specified by equation (3) has two alternative interpretations. First, the decision-maker cognitively differentiates between the probabilities he assigns to his I^1 and I^2 priors (Kramer and Budescu 2002), and his preferences are given by

$$W(\mathbf{z}) = \sum_{i^1=1^1}^{I^1} \rho_{i^1} u^1 \left(\sum_{i^2=1^2}^{I^2} \theta_{i^2} u^2 \left(\sum_{j^1=\{\mathrm{c,n}\}} \sum_{j^2=\{\mathrm{g,b}\}} \pi^1_{i^1 j^1} \pi^2_{j^1 i^2 j^2} v\left(z_{j^2}\right) \right) \right), \tag{4}$$

which is consistent with the interpretation that the decision-maker believes the uncertain confidentiality process determines the fraud process, which finally determines his payoff (Nielson's 1993, 2009). The second (re)interpretation says the resolution of the fraud event determines the uncertain confidentiality process which determines confidentiality, and preference are given by

$$W(\mathbf{z}) = \sum_{i^2=1^2}^{I^2} \theta_{i^2} u^2 \left(\sum_{i^1=1^1}^{I^1} \rho_{i^1} u^1 \left(\sum_{j^1=\{\mathrm{c,n}\}} \sum_{j^2=\{\mathrm{g,b}\}} \pi^1_{i^1 j^1} \pi^2_{j^1 i^2 j^2} v\left(z_{j^2}\right) \right) \right). \tag{5}$$

Each of these last two models reduces to equation (3) when the decision-maker's attitudes are neutral towards the uncertainty of his priors over confidentiality or fraud, respectively. Chapter 4 introduces the experimental instrument used to vary each uncertainty, confidentiality breach and consequences, to identify the model (equation (3), (4),or (5)) which best describes individual privacy behaviors.

Chapter 4 also accomplishes two objectives. First, the analysis is extended to identify attitudes towards commodity identification. The experimental design of Heath and Tversky (1991), which elicits preferences for probabilistically equivalent certain and uncertain lottery pairs, is adapted to Harrsion, List, and Towe (2007) which elicits preferences for lotteries paying with a field commodity rather than cash. The experiment is used to demonstrate that separate attitudes towards different uncertain processes are identifiable. And, these estimates are behaviorally meaningful. The primary hypothesis tested is:

HYPOTHESIS 4: Subjects cognitively differentiate between different uncertain processes.

Chapter 5 collects all of these concepts together and offers the first true test for uncertainty aversion in the context of privacy decisions. The main hypotheses to be tested are:

HYPOTHESIS 5: Subjects' willingness-to-accept confidentiality loss is lower when making indirect sales of information to a party that does not have a direct mechanism to harm the subject.

HYPOTHESIS 6: Subjects cognitively differentiates between uncertain confidentiality breach and consequences.

Full information maximum likelihood (FIML) techniques were used to estimates the structural parameters of the SEU and UP models presented in the preceding discussion.

CHAPTER 3: TESTING ELLSBERG'S PARADOX & SMITH'S HYPOTHESIS

This chapter presents a study of uncertainty aversion in individual decision-making. This study is a methodological inquiry to replicate Ellsberg's (1961) two-color thought experiment using real monetary rewards in a controlled laboratory environment. Although experimental evidence has been offered suggesting uncertainty aversion is a good description of individual decision-making (Becker and Brownson 1964; Yates and Zukowski 1976; Chow and Sarin 2002; Halevy 2007), verification of symmetric beliefs for both the known and unknown urns, necessary for uncertainty aversion, have not been verified. Ellsberg's (1961, p. 653) three-color problem has been replicated by Ford and Ghose (1998) and Schmidt and Neugebauer (2003).

The three-color problems, as well as supporting arguments for the two-color problem (Ellsberg's 1961, p. 651 fn. 1), offer inappropriate support for uncertainty aversion. This argument has been previously recognized by Wakker (2001, p. 1040) and Tversky and Kahneman (1992, §1.3). Like the Allais paradox, multi-color and single-urn problems are also explained without reference to uncertainty attitudes. As a result, single-urn problems do not isolate uncertainty aversion, a violation of simple ordering[9], from violations of independence or the sure-thing principle, or even a systematic resolution of indifference (see Appendix B).[10] Neilson (1993, 2009) and Klibanoff, Marinacci, and Mukerji (2005), as well as other multiple-prior models (e.g., maxmin EU of Gilboa and

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[9] Cox and Epstein (1989) found that preference reversals were the result of violations of the completeness axiom, rather than violations the sure-thing principle.

[10] It must also be recognized that direct replication of the three-color problem, as in the case of Ford and Ghose (1998), omits the possibility of indifference which allows for an explanation of the preference reversal as (possibly) the result of a systematic resolution of indifference (see Appendix B). Those decision-maker's choices should not be considered significant (Savage 1954, p. 17).

Schmeidler (1989) and anticipated utility of Segal (1987)), capture the essence of UA, as describing attitudes towards expectations of expectations.

The closest replication of Ellsberg's (1961) two-color problem was offered by Chow and Sarin (2002).[11] In their experiments, an unopened bag of M&Ms was used to simulate Ellsberg's unknown urn. Chow and Sarin (1976, p. 135) report that "…there was virtually no difference in the mean prices…" for bets on red, blue, or orange and bets on green, brown, or yellow. The M&Ms test reveals the most compelling evidence in favor of uncertainty aversion. Lacking statistical verification of symmetric probabilistic beliefs, certainty equivalents reported in Chow and Sarin (2002) are consistent with both aversion to acts with uncertain or ambiguous probabilities, and the formation of asymmetric beliefs. Consider the following example.

Chow and Sarin (2002) asked subjects to report their willingness-to-pay for a bet that the color of a candy drawn from an M&M's bag. The first bets paid if the color candy was red, blue, or orange. The second paid if the color was green, brown, or yellow. On average subjects were willing to pay $11.95 when the true distribution of color groups was known to be 50-50. Assuming EUT applied, the mean report is consistent with moderate risk aversion crra≈0.326, assuming also the utility function $u \equiv x^{crra}$. For an unknown distribution of candies, average willingness-to-pay decreased $5.57 to $6.38. This value is consistent with either the belief that a favorable outcome is ≈41% and there is no uncertainty, or the subject has many uncertain priors and attitudes towards their uncertainty.

[11] Halevy (2007, p. 516, footnote 14) notes that the background assumption that subjective beliefs for the composition of the unknown urn needs to be 50-50 for either color. However, he offers no test of the assumption.

Halevy (2007) used four urns, with varying degrees of ambiguity, to extend Yates and Zukowski (1976). Each urn contained ten balls with distributions either known with certainty or determined using Smith's (1969) compound objective lottery. Values of each lottery were elicited using the Becker-DeGroot-Marschak (1964) (BDM) mechanism. There was considerable heterogeneity between elicited values which were shown to be consistent with three popular decision theories: SEU, rank dependent utility, and the less popular uncertain priors model. Use of the BDM mechanism to elicit incentive compatible values has come into question, however; especially when preferences violate reduction of compound lotteries (Segal 1987; Holt 1986; and Karni and Safra 1987).

Approximately 35% of subjects revealed values consistent with the UP model, another 35% were consistent with a recursive rank dependent utility specification (Segal 1987), and the last 30% exhibited preferences consistent with SEU. In principle, had the mechanism worked properly and subjects were known to assign 50-50 probabilities to the uncertain events, this discussion would be mute. Criticisms raised by Segal (1987) (as well as Holt (1986) and Karni and Safra (1987)) would validate Halevy's (2007) conclusions. However, unknown subjective beliefs raise behavioral doubts and question the validity of Halevy's design.

These criticisms point to the need to control for subjective beliefs in order to properly identify attitudes towards uncertainty. Heath and Tversky (1991) addressed control of beliefs by eliciting probabilistic reports for the occurrence of a series of uncertain events. Reports were subsequently used to present subjects with paired lottery choices between the status quo uncertain prospect and an equivalent objective lottery with probabilities equal to subjects' reports. The crux of the problem with the Heath and

Tversky (1991) design is that unless reports are honest in the sense of Myerson (1981), arguments in favor or against the presence of uncertainty aversion are confounded. It is well known that reports elicited without properly aligned incentives are biased by attitudes towards risk and/or uncertainty. Or, maybe, because it was costless to do so, subjects simply felt like misrepresenting their true belief (Harrison 1994), which is why the experimental design presented in the sequel used a large stakes belief elicitation task. Beliefs were elicited and symmetry tested by using a mechanism such as a scoring rule (Andersen et al. 2009a).

To identify uncertainty attitudes, a design using paired lotteries is capable of alleviating the criticisms of previous experimental designs. Structural estimation of the UP model's parameters and the identification of attitudes towards uncertainty do not suffer from the criticisms of the BDM procedure. By eliciting beliefs and using a binary choice mechanism to control risk attitudes, testing the uncertainty aversion hypothesis in Ellsberg's (1961) thought experiment becomes practical from both theoretical and empirical perspectives.

Replicating Ellsberg's two-color problem with simple binary choice tasks allows for the identification of attitudes towards uncertainty as explanations of choice behavior when probabilities may not be well formed. The two-color problem using compound objective lotteries was also replicated to test Smith's (1969) hypothesis that behavior similar to the predictions of Ellsberg (1961) would be observed using compound objective lotteries to induce second-order distributions.

3.1 Experimental Design

Subjects were recruited from the student population at the University of Central Florida in the spring 2010 semester. In total 167 subjects participated in 10 different sessions during the spring 2010 semester. The experimental instruments were designed to test for uncertainty aversion and the validity of Smith's (1969) hypothesis[12] on a between subject basis. Ellsberg's (1961) two-color problem is tested on a between subject basis.[13] The exact instructions used for these experiments are reproduced in Appendix D.

Subjects were confronted with two bingo cages which were used in place of Ellsberg's urns. One of these cages remained covered until a ball was drawn from it at the end of the session. The covered cage represented Ellsberg's (1961) unknown urn. Half of the designs were used for the Ellsberg treatment and the other half for the Smith treatment. To save space the remainder of this section will focus on the Ellsberg's two-color problem. Smith's choice problem is comprised of the same three variations, the difference was the randomization devices.

To control for the range hypothesis, the number of balls in the visible cage were set to 30 or 50. Half (51%) of subjects participated in each treatment. To control for potential center effects, the distributions of orange balls were set to 50% or 20%.

[12] Smith's (1969) hypothesis sates that similar choice patterns from Ellsberg's two-color problem are observed when the unknown urn is replaced with an objective compound lottery.

[13]To the best of my knowledge, there are no presentations of individual decisions that support the hypothesis that subjects believe the draw of red or black from the Ellsberg's unknown urn is 50-50. Becker and Brownson (1964, p. 66) claim "…subjects given a choice of colors … are typically indifferent…", however, no statistical evidence to support the 50-50 background assumption is presented. Chow and Sarin (1988 p. 134) acknowledge subjects having 50-50 beliefs for the colors of M&M candies in a bag (their unknown urn), yet they offer no test statistics. The background assumption of 50-50 beliefs for the distribution of balls in Ellsberg's uncertain urn is a necessary condition for any Ellsberg test. Ellsberg (1961) was aware of this fundamental issue. However, Kadane (1992) shows that Ellsberg's pattern of preferences is possible without 50-50 beliefs provided the subjects distrust the experimenter. Kadane's model is nearly untestable hypothesis tantamount to a faith based argument.

Following the preference elicitation task subjects participated in a belief elicitation task that paid according to a linear scoring rule (LSR). To identify and control for anchoring biases in reporting, approximately half of the subjects in each session were exposed to each skew frame of the LSR. Section 3.1.2 explains the LSR and skew frames in detail. Table 2 summarizes the full experimental design which was used.

Table 2. Ellsberg/Smith Experimental Design

Session Number	Ellsberg / Smith Urns	Probability Range (Balls)	Probability Center (Orange)	LSR Anchoring (Skew)	Subjects
1	Ellsberg	50	50%	High	13
				Low	12
2	Smith	50	50%	High	9
				Low	8
3	Ellsberg	30	20%	High	8
				Low	8
4	Smith	30	20%	High	12
				Low	11
5	Ellsberg	30	50%	High	12
				Low	10
6	Smith	30	50%	High	13
				Low	12
7	Ellsberg	50	20%	High	11
				Low	10
8	Smith	50	20%	High	11
				Low	7

3.1.1 Preference Elicitation Tasks

3.1.1.1 Ellsberg's Treatment

The two bingo cages used to represent Ellsberg's urns were labeled "cage I" and "cage II." Cage I represented the known urn with a verified number and distribution of orange and white balls. The number of balls in cage I were counted and verified prior to the end of the session, when one of its balls was randomly drawn. Cage II also remained covered until one of its balls was randomly drawn at the end of the session. Reproductions of the decision sheets presented to subjects can be found in Appendix D.

To avoid potential contamination from portfolio effects, one row was selected at random from each subject's decision sheet to be played for real rewards. Each bet paid either $10 or $0.

3.1.1.2 Smith's Treatment

For the Smith treatment the distribution of balls in cage II was determined by the number 0 to 30 of a ball drawn from a third bingo cage, cage III. To operationalize cage III, each ball was labeled with a number 0, 1, 2, …, 30 to indicate the distribution of orange balls that would be used to play each bet. For the 50-ball frame, cage III was filled with balls numbered 0, 1, 2, …, 50.

At the end of the session, when all bets had been finalized, one subject selected at random drew a ball from cage III. Cage II was then filled with orange balls in the amount of the number written on the ball drawn from the cage III. The remaining balls were white.[14] A research assistant then drew one ball from both cage I and cage II, and all bets were paid accordingly.

3.1.1.3 Controlling for Risk Attitudes

Risk attitudes were controlled using subject responses to a series of 45 random lottery pairs, consistent with the classic Hey and Orme (1994) experiments. All bets were in the gain domain with payments of $0, $15, $35, and $50. An example screen shot of the computer interface used to elicit preferences is in Appendix D.

3.1.2 Elicitation of Beliefs

Beliefs regarding the distribution of balls in cage II, the covered bingo cage were elicited using a LSR. The design of Holt and Laury (2002) was adopted to avoid portfolio

[14] For example, if the ball drawn from cage III was labeled "13," then cage II would be filled with 13 orange balls and 17 white balls, for the 30-ball frame. In the 50-ball frame, the remaining 37 balls in cage II would be white.

effects. Once subjects completed the individual choice task and knew which option of which row they would be paid from, the LSR betting task was introduced. Subjects were informed about the belief task with the following statement:

> [E]ach of you have [sic] the chance to make another choice, with much higher potential payoffs. Our research assistants are passing around the decision sheets for this task. If you choose to participate in this task, we will not pay you for the decision that you just made. You have the choice which decision we will pay you for: the one you just completed, or the new one we are offering you now.

When deciding whether or not to participate in the LSR bet, subjects evaluated their original Ellsberg/Smith choice, which pays at most $10, with giving up that choice to participate in the LSR betting task. The range of LSR bets were from $0 to $50, with a "safe" bet paying $25 for sure. With the $25 safe bet, there was at least one LSR bet which strictly dominated all Ellsberg/Smith bets. As expected, all subjects gave up their previous choice to participate in the belief elicitation task. Table 3 shows an example of the LSR betting sheet used in the experiment.

Table 3. Example Betting Sheet for Linear Scoring Rule

Choice	**Payment if Ball Drawn from Cage #2 is Orange**	**Payment if Ball Drawn from Cage #2 is White**
1	$0.00	$50.00
2	$2.00	$48.00
3	$4.00	$46.00
⋮	⋮	⋮
12	$23.00	$27.00
13	$25.00	$25.00
14	$25.50	$24.50
⋮	⋮	⋮
49	$48.50	$1.50
50	$49.50	$0.50
51	$50.00	$0.00

For report λ^*, that an orange ball occurs, the LSR was defined as payment $S\left(\lambda^*|\text{Orange occurs}\right)=50-50\left[1-\lambda^*\right]$ and $S\left(\lambda^*|\text{White occurs}\right)=50-50\left[\lambda^*\right]$. As the subject becomes more confident that cage II is filled entirely with orange (white) balls, he should choose a lower (higher) numbered choice. Row "1" is consistent with the belief that cage II is entirely filled with white balls. Row "51" is consistent with a belief that cage II is entirely filled with orange balls. These two reports, respectively, pay $0 and $50 if orange occurs. Row "13" is the "safe" bet with a guaranteed payoff of $25. The risk neutral subject should choose 1 (51) for any belief greater than 50% that white (orange) will occur and 13 if his beliefs are exactly 50%. As this representative subject becomes more risk averse, his optimal bet will move closer towards row 13, the safe bet.

The LSR was administered using paper and pencil. To control and identify anchoring biases, an anchoring treatment varied the skewness of the payoffs (and their implicit probabilities). For the skew low treatment, the safe bet occurred at row 13 of the betting sheet. The safe bet occurred at row 39 in the skew high frame. As a result, anchoring would have a positive reporting bias in the skew low treatment and a negative bias in the skew high treatment. Appendix D contains copies of the actual scoring rules that were included with the subject instructions.

3.2 Econometric Model

3.2.1 Controlling Risk Attitudes

Risk attitudes were controlled assuming the utility over risky choices is given by an expo-power utility function[15] of the form

[15] The two parameter expo-power form is chosen due to its empirical consistency over a wide range of real payoffs (Holt and Laury 2001).

$$v(x) = \left[1 - \exp\left(-\alpha x^{1-r}\right)\right] / \alpha, \quad (6)$$

where $\alpha \neq 0$ and $r \neq 1$ are parameters to be estimated, and x is income from observed lottery choices. The Arrow-Pratt measure of relative risk aversion is given by $r + \alpha[1-r]x^{1-r}$, which is increasing (decreasing) as $\alpha > 0$ ($\alpha < 0$). Moreover, constant absolute risk aversion and constant relative risk aversion are nested special cases as $r \to 0$ and $\alpha \to 0$, respectively.

With observed lottery choices, equation (6) is estimated using structural maximum likelihood techniques, assuming some latent structural model of choice such as EUT. For Ω outcomes in each of the two paired Hey-Orme lotteries,

$$EU_1 = \sum_{\ell \in \Omega} p_{1\ell} v(x_\ell) \text{ and } EU_2 = \sum_{\ell \in \Omega} p_{2\ell} v(x_\ell),$$

where $p_{1\ell}$ and $p_{2\ell}$ are the known, certain, chances of winning prize x_ℓ from each lottery, 1 and 2.

Assuming the *link function* between choices and the maximum likelihood procedure is represented by logistic distribution, the probability that the subject chooses the lottery 1 is given by the index function

$$\nabla EU = \frac{\exp\left(\mathrm{eu}_1(\alpha, r)/\mu_0\right)}{\exp\left(\mathrm{eu}_1(\alpha, r)/\mu_0\right) + \exp\left(\mathrm{eu}_2(\alpha, r)/\mu_0\right)}. \quad (7)$$

Equation (7) adopts Wilcox's (2009) contextual error specification[16] where $\mathrm{eu}_i(\alpha, r) = EU_i(\alpha, r)/\xi_0$, with $\xi_0 \equiv \overline{v} - \underline{v}$ defined as the difference between the highest and lowest possible utility obtainable in the lottery pair. EU_1 and EU_2 are the vNM

[16] Contextual utility theory applies an adjustment to the Fechner error term, defined by the difference in value between maximum and minimum prizes in each choice context. Wilcox (2009) shows that without such normalization risk aversion does not imply probabilistically more risk averse.

utilities of lotteries 1 and 2, and μ_0 is a noise parameter which is proportional to the standard deviation of the decision-maker's perceptual (or computational) error, conditional on the assumed logistic distribution. As $\mu_0 \to 0$ subject responses become more precise and the probability of choosing the utility maximizing choice converges to one. For noisier responses, as $\mu_0 \to 0$ choice probabilities are random and not explained by utility differences.

Dropping indifference, the log-likelihood to be maximized is written as

$$\ln L\left(r,\alpha,\mu_0;y,\mathbf{X}\right)=\sum_{t=1}^{T}\left\{y_t \ln \nabla EU+\left[1-y_t\right]\ln\left[1-\nabla EU\right]\right\},\ \alpha \neq 0\ \ r \neq 1, \tag{8}$$

where $y_t = 1(0)$ indicates the t^{th} choice of lottery 1(2), and $\mathbf{X}$ is data pertaining to the choice tasks and/or subject characteristics.

3.2.2 Identifying Subjective Beliefs and Uncertainty Attitudes

Subjective beliefs and attitudes towards uncertainty were identified from responses to the LSR bets and choices in the individual choice task.

For the LSR betting task, the contents of the bingo cage with the known distribution *a priori* does not enter the subjects' UP preference functions. Subjects are asserted to maximize

$$W\left(\mathbf{z}\right)=\sum_{i=0}^{I}\rho_i u\left(\sum_{j=\{\text{o},\text{w}\}}\pi_{ij}^{U} v\left(z_j \mid \text{report}\lambda\right)\right), \tag{9}$$

where I = 30 and 50 for each range treatment, and utility over final prizes are identified by $v(\cdot)$ from equation (6). The subjective priors $\left(\pi_{i\text{o}}^{U},\pi_{i\text{w}}^{U}\right)$ for the distribution of orange and white balls in the covered (unknown) bingo cage are given by $\left(i/I, 1-i/I\right)$. Second-order utilities are assumed to be characterized by constant relative uncertainty aversion where

$$u(x) \equiv x^{1-\phi} / [1-\phi]. \tag{10}$$

For a given report λ^*, the *multinomial* logistic link functions is written as

$$\nabla W_1 = \frac{\exp\left(\mathrm{w}_{\lambda^*}(\boldsymbol{\rho}, \boldsymbol{\pi}, \phi; \alpha, r)/\mu_1\right)}{\sum_{\lambda \in \Lambda} \exp\left(\mathrm{w}_{\lambda}(\boldsymbol{\rho}, \boldsymbol{\pi}, \phi; \alpha, r)/\mu_1\right)}, \tag{11}$$

where $\mathrm{w}_{\lambda}(\boldsymbol{\rho}, \boldsymbol{\pi}, \phi; \alpha, r) = W_{\lambda}(\boldsymbol{\rho}, \boldsymbol{\pi}, \phi; \alpha, r)/\xi_1$ with $\xi_1 \equiv u(v(50)) - u(v(0))$ is the contextual error specification for the UP values, analogous to equation (7). The log-likelihood function is

$$\ln L(\boldsymbol{\rho}, \boldsymbol{\pi}, \phi, \mu_1; y, \mathbf{X}, \alpha, r) = \sum_{t=1}^{T} \left\{ y_t \ln \nabla W + [1-y_t] \ln [1-\nabla W] \right\}, \alpha \neq 0,\ r \neq 1, \tag{12}$$

where $y_t = 1$ for the report λ^* and $y_t = 0$ for all other $\lambda \in \Lambda$.

For the Ellsberg/Smith choice tasks subjects' UP preferences are given by equation (2) in chapter 2.

$$W(\mathbf{z}) = \sum_{i=1}^{I} \rho_i u\left(\sum_{j=1}^{J} \sum_{k=1}^{K} \sigma_{ijk} v(z_{jk}) \right), \tag{2}$$

where $\sigma_{ijk} \equiv \pi_{ij}^U \pi_k^C$ and $\Pi_{\mathrm{j}} = \sum_{i \in I} \rho_i \pi_{ij}$ are the subject's weighted average beliefs for each of the *J* events – draw an orange ball and draw a white ball from cage II. The π_k^C terms are known to be 0.5 for both orange and white balls drawn from cage I.

For the logistic link function, the probability of each subject choosing option A is

$$\nabla W_2 = \frac{\exp\left(\mathrm{w}_{\mathrm{A}}(\boldsymbol{\rho}, \boldsymbol{\pi}, \phi; \alpha, r)/\mu_2\right)}{\exp\left(\mathrm{w}_{\mathrm{A}}(\boldsymbol{\rho}, \boldsymbol{\pi}, \phi; \alpha, r)/\mu_2\right) + \exp\left(\mathrm{w}_{\mathrm{B}}(\boldsymbol{\rho}, \boldsymbol{\pi}, \phi; \alpha, r)/\mu_2\right)}, \tag{13}$$

where $\mathrm{w}_{\cdot}\left(\boldsymbol{\rho},\boldsymbol{\pi},\phi;\alpha,r\right)=W_{\cdot}\left(\boldsymbol{\rho},\boldsymbol{\pi},\phi;\alpha,r\right)/\xi_2$ with $\xi_2\equiv u\left(v(10)\right)-u\left(v(0)\right)$ is the contextual error specification. The log likelihood function is

$$\ln L\left(\boldsymbol{\rho},\boldsymbol{\pi},\phi,\mu_2;y,\mathbf{X},\alpha,r\right)=\sum_{t=1}^{T}\left\{y_t\ln\nabla W_2+\left[1-y_t\right]\ln\left[1-\nabla W_2\right]\right\},\alpha\neq 0,\ r\neq 1, \quad (14)$$

where $y_t=1$ for a choice of option A and $y_t=0$ for a choice of option B.

3.3 Data and Results

Chapter 2 identified three behavioral hypotheses for Ellsberg's (1961) two-color problem.

HYPOTHESIS 1: In Ellsberg's (1961) two-color problem (p. 650), subjects behave *as if* the realization of each uncertain event is equally likely as each certain event *and* bets on certain events are preferred to bets on uncertain events.

HYPOTHESIS 2: The proportions of UP and SEU consistent choices are equal for both the Ellsberg (1961) and Smith (1969) lotteries.

HYPOTHESIS 3: Attitudes towards uncertainty are equivalent for both the Ellsberg (1691) and Smith (1969) treatments.

Before reporting the tests of Hypotheses 1 and 3, analysis of the raw choices in the Ellsberg/Smith task supports hypothesis 2. Smith's conjecture "choice behavior" is unchanged if the contents of the ambiguous urn is determined by the draw of a random integer. Table 4 reports the raw classifications of choices in the Ellsberg and Smith tasks when each bet on orange or white from cage I had a known 50% chance of paying. The *p*-value for the Fisher exact probability test is 0.398 and the null that there is no difference in the distributions is not rejected.

Table 4. Raw Classification of Choices in Ellsberg & Smith Tasks

Treatment	Neither	SEU	Uncertainty Averse	Uncertainty Seeking
Ellsberg	43	4	0	0
Smith	37	3	2	0
Total	80	7	2	0

Note: Subject choices are pooled across range treatments (see Table 2). With a *p*-value of 0.85, the Fisher exact test rejected the null of range effects.

In Table 4, subjects were classified as SEU if their choice pattern was: 1) bets on orange I ~ white I, orange II ~ white II, orange I ~ orange II, and white I ~ white II; 2) bets on orange I ~ white I, orange II $\succ$ white II, orange I $\prec$ orange II, and white I $\succ$ white II; or 3) bets on orange I ~ white I, orange II $\prec$ white II, orange I $\succ$ orange II, and white I $\prec$ white II. Uncertainty averse behavior was classified according to Ellsberg's predicted pattern of preferences. No subjects exhibited uncertainty seeking behavior, in their raw choices.

The distribution of responses in Table 4 presents evidence against Ellsberg's (1961) hypothesis while supporting Smith's (1969) conjecture. Eighty out of 89 subjects' choices were not consistent with either SEU or Ellsberg's uncertainty aversion. A subject was classified as "Neither" when his preferences for bets on orange from cage I or cage II and white from cage I or cage II contradicted his preference (and implied belief) from his bet of orange or white cage II. For example, a subjects reporting preferences orange I ~ white I, orange II $\succ$ white II, orange I $\succ$ orange II, and white I $\succ$ white II would be classified as "Neither." His preference orange II $\succ$ white II implies a belief that orange is more than 50% likely in cage II and contradicts the preference orange I $\succ$ orange II. Uncertainty aversion cannot be claimed here because his preference white I $\succ$ white II and orange I ~ white I are consistent with SEU.

The parametric structural FIML model simultaneously controls for risk attitudes and (possibly) asymmetric beliefs when estimating the degree of relative uncertainty aversion and, as such, is superior to the nonparametric test from Table 4 for identifying non-neutral attitudes towards uncertainty. The remainder of this chapter will report the results of parametric structural UP, SDRA, and SEU likelihood models derived from equations (8), (12), and (14).

3.3.1 Risk Attitudes Alone

The lottery choice data identified risk attitudes. Assuming subjects made decisions under risk according to the mandates of EUT, the average relative risk aversion of the subject pool over prizes x = ($0, $15, $35, and $50) was estimated from the CRRA utility function $v(x) \equiv x^{(1-r)} / (1-r)$. Table 5 shows the estimate of average relative risk aversion. Over the domain of prizes, the subject pool exhibited an average relative risk aversion $\hat{r} = 0.4422$, with a p-value less than 0.0001.

Table 5. Estimated Parameters from CRRA Utility Function

Variable	Description	Coefficient	Standard Error	p-value	Lower 95% CI	Upper 95% CI
r	CRRA coefficient	0.4422	0.0602	<0.0001	0.3242	0.5601
μ_0	RLP Fechner error	0.0926	0.0078	<0.0001	0.0773	0.1079
Pseudo log-likelihood = -4921.5341 Observations = 7261						

Coefficient estimates from the expo-power specification (equation (6)) are shown in Table **6**. Estimates $\hat{r}$ and $\hat{\alpha}$ are highly significant. The estimated degree of relative risk aversion

$$\text{RRA} = \hat{r} + \hat{\alpha}\left[1-\hat{r}\right]x^{1-\hat{r}}, \ \hat{r} \neq 1 \tag{15}$$

is increasing when $\hat{\alpha} > 0$, decreasing for $\hat{\alpha} < 0$, and remains constant if $\hat{\alpha} = 0$. Choices exhibit risk aversion for low stakes gambles ($\hat{r} = 0.7265$), which decreases as lottery prizes increase to $50 ($\hat{\alpha} = -0.7082$).

Table 6. Estimated Parameters from Expo-Power Utility Function

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.7265	0.0236	<0.0001	0.6802	0.7727
α	Positive income RRA normalization	-0.7082	0.0567	<0.0001	-0.8194	-0.597
μ_0	RLP Fechner error	0.0742	0.0053	<0.0001	0.0638	0.0845
Pseudo log-likelihood = -4872.891 Observations = 7261						

3.3.1 The Uncertain Priors Model

The maximum likelihood estimator shows evidence of decreasing relative risk aversion, with relatively high risk aversion at low stakes. In the absence of uncertainty, estimated risk attitudes imply raw bets in the belief elicitation task are substantially closer to the safe 50-50 bet that true beliefs. A large number of subjects placed bets at the 50-50 mark, ensuring a payoff of $25. Note, however with evidence of significant treatment effects. Subjects in the low skew treatment tended to place larger bets than in the high skew treatment. The largest difference in bets between low and high treatments is 30 percentage points, which is significant that the 0.001 level. However, there does not appear to be evidence of lower bets for subjects in the high skew treatment.

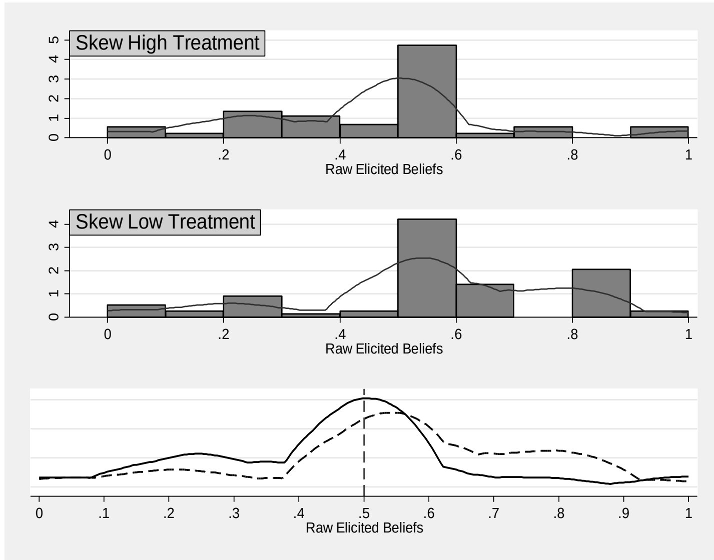

Figure 1. Raw LSR Bets for Color Ball Drawn From Cage II

For each possible set of beliefs $\left(\boldsymbol{\pi}_{\text{o}}^{U}, \boldsymbol{\pi}_{\text{w}}^{U}\right) = \left(\frac{0}{30}, \frac{30}{30}; \frac{1}{30}, \frac{29}{30}; \ldots; \frac{30}{30}, \frac{0}{30}\right)$ when there are 30 balls in each cage and $\left(\boldsymbol{\pi}_{\text{o}}^{U}, \boldsymbol{\pi}_{\text{w}}^{U}\right) = \left(\frac{0}{50}, \frac{50}{50}; \frac{1}{50}, \frac{49}{50}; \ldots; \frac{50}{50}, \frac{0}{50}\right)$ when there are 50 balls in each cage, prior weights, $\boldsymbol{\rho}$, were modeled using a Beta function with probability mass function

$$f\left(\pi_{\text{io}}; a, b\right) = \frac{\pi_{\text{io}}^{a-1}\left(1-\pi_{\text{io}}\right)^{b-1}}{\sum_{i=0}^{1} \pi_{\text{io}}^{a-1}\left(1-\pi_{\text{io}}\right)^{b-1}}, \text{ for } \pi_{\text{io}} \in (0,1). \tag{16}$$

To obtain mass at the beliefs $\left(\pi_{0\text{o}}, \pi_{1\text{o}}\right) = (0,1)$, $f\left(\pi_{1\text{o}}; a, b\right)$ and $f\left(\pi_{0\text{o}}; a, b\right)$ were calculated using the approximation $\left(\pi_{0\text{o}}, \pi_{1\text{o}}\right) = (0.0001, 0.9999)$. Figure 2, illustrates the prior weights given estimated shape parameters, $\hat{a} = 0.0065$ and $\hat{b} = 0.0052$.

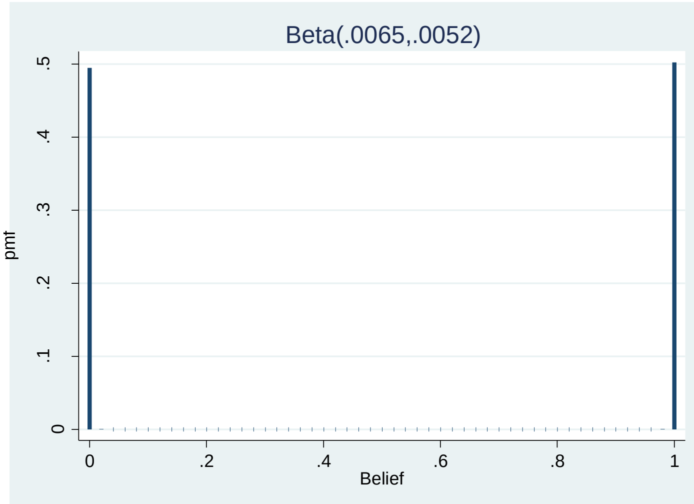

Figure 2. Estimated Beta Mass Function for Prior Weights

Coefficent estimates from the UP model (equation (2)) are shown in Table 7. The risk coefficients have the expected signs and magnitudes, $\hat{r} = 0.7233$ and $\hat{\alpha} = -0.6895$. Estimated shape parameters imply subjects behaved *as if* the experiment were almost surely "rigged" and believed there was a 49.5% chance the unknown cage was filled entirely with white balls and a 50.3% chance it was filled entirely with orange balls. While the shape parameters imply a SDRA consistent belief structure, the estimated coefficient of relative uncertainty aversion, $\hat{\phi} = 0.1007$, is significant at the 10.9% level, suggesting that SEU may be a better predictor of behavior than the UP model.[17]

[17] Contrary to previous estimates of uncertainty aversion presented in Anderson et al. (2009b) who found evidence of moderate uncertainty seeking, here small insignificant amounts of uncertainty aversion with a *p*-value of 0.109 were estimated. These differences warrant further analysis and replication to test a new hypothesis: in unfamiliar ambiguous choice situations subjects revert to SEU preferences assigning equal weight to the degenerate outcomes and willing to trade bets for a certain 50% chance at the high payoff.

Table 7. Coefficient Estimates for Uncertain Priors Model

Variable	Description	Coefficient	Standard Error	p-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.7233	0.0237	<0.0001	0.6768	0.7698
α	Positive income RRA normalization	-0.6895	0.0572	<0.0001	-0.8015	-0.5774
μ_0	RLP Fechner error	0.0742	0.0053	<0.0001	0.0639	0.0846
a	Shape parameter for prior weights $\boldsymbol{\rho}$	0.0065	0.0145	0.6540	-0.0220	0.0350
b	Shape parameter for prior weights $\boldsymbol{\rho}$	0.0052	0.0107	0.6310	-0.0159	0.0262
ϕ	CRUA coefficient	0.1007	0.0628	0.1090	-0.0224	0.2238
μ_1	LSR Fechner error	0.1631	0.1167	0.1620	-0.0656	0.3918
μ_2	Ellsberg Fechner error	0.1938	0.0230	<0.0001	0.1487	0.2390

Pseudo log-likelihood = -5853.4699
Observations = 8026

Table 8 shows the coefficient estimates from the SDRA model. As expected, prior weights, $\boldsymbol{\rho}$, are approximately evenly distributed, with cage II containing all orange balls with probability $\hat{\rho} = 0.5039$. With a standard error of 0.0158, $\hat{\rho}$ is equal to 50.3 at the 5% level. The estimated coefficient of relative uncertainty aversion $\hat{\phi} = 0.1006$ is significant at the 10.9% level.

Table 8. Coefficient Estimates for Source-Dependant Risk Attitudes Model

Variable	Description	Coefficient	Standard Error	p-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.7233	0.0237	<0.0001	0.6768	0.7698
α	Positive income RRA normalization	-0.6895	0.0572	<0.0001	-0.8015	-0.5774
μ_0	RLP Fechner error	0.0742	0.0053	<0.0001	0.0639	0.0846
ρ	Prior weight for cage II all orange	0.5039	0.0158	<0.0001	0.4730	0.5349
ϕ	CRUA coefficient	0.1006	0.0627	0.1090	-0.0223	0.2236
μ_1	LSR Fechner error	0.1631	0.1167	0.1620	-0.0656	0.3918
μ_2	Ellsberg Fechner error	0.1938	0.0230	<0.0001	0.1487	0.2390

Pseudo log-likelihood = -5853.4695
Observations = 8026

I used the Clarke (2003, 2006) paired sign test of the log-likelihood ratios to test the auxiliary hypotheses: SDRA explains behavior better than UP. The other well-known test for non-nested models was developed by Vuong's (1989) and is only appropriate when likelihood ratios are normally distributed (Clarke 2006). The Shaprio-Wilk test fails to reject normality at the 5% level, W = 0.898 n = 765.[18] Figure 3 graphically depicts the distribution of likelihood ratios.

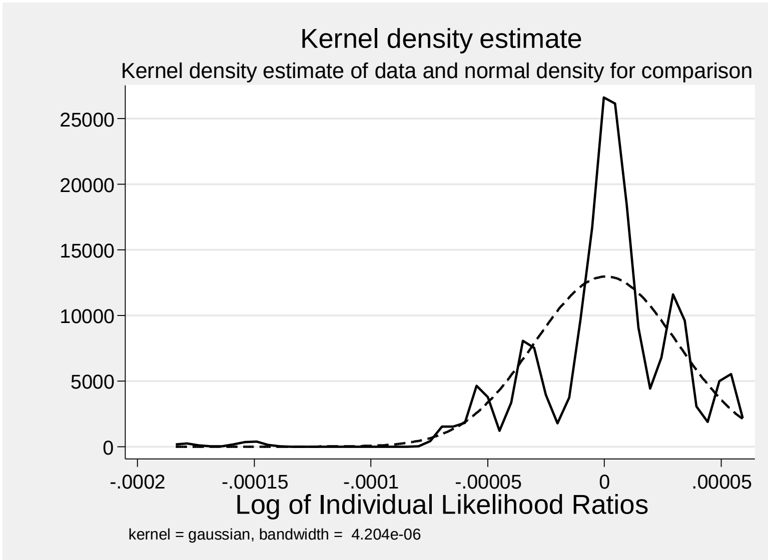

Figure 3. Likelihood Ratio Distribution

The SDRA model yields higher likelihood values for 437 out of 762 non-zero differences. The sign test rejects equality of the models in favor of SDRA with a *p*-value < 0.0001.[19] Coupled with a coefficient of relative risk aversion $\hat{\phi} > 0$ significant at the 10.9% level and $\hat{\rho} = 0.50$ with $\chi_1^2 = 815.26$, the SDRA model without accounting for treatment effects presents evidence in favor of hypothesis 1.

In Table 9, treatment variables are added to the SDRA model. Each treatment variable is a binary indicator. The treatment variable *Smith* takes on a value of 1 if uncertainty was facilitated by cage III, which determined the distribution of orange and white balls in cage II. The Smith variable equals 0 for sessions where subjects were confronted with Ellsberg's original problem. Hypothesis 3, that uncertainty is not

[18] The 7261 observations from the random lottery pair task were dropped from the model selection test. The Clarke statistics are calculated using only the 765 decisions from the Ellsberg/Smith and LSR tasks, those decisions the latent choice models are dependent on purely subjective beliefs.
[19] The Vuong statistic is 0.5384 which is less than 1.96, the critical value from the standard normal distribution.

affected by the generating mechanism and predicts the coefficient of *smith* is insignificantly different from zero.

Center equals to 1 when the distribution of balls in the known cage was 50% orange and 0 when the distribution was 20% orange. *Range* indicates the number of bingo balls used in cages I and II. Range equals 1 when 50 bingo balls were used and 0 when 30 bingo balls were used. If the range hypothesis of Becker and Brownson (1964) is correct, subjects' attitudes towards uncertainty covary with the ranges of second-order probabilities. The null is that range has no effect on estimated uncertain aversion.

Finally, *Skew* controls for anchoring biases in the LSR betting task, and varies within each session. Skew is set to 1 for subjects in the "high" treatment, where the safe bet was lower on the betting sheet. Skew is 0 for subjects in the "low" treatment, when the safe bet was higher on the betting sheet.

Estimates of the SDRA model controlling for treatment effects are presented in Table 9. Estimates for *Range* and *Smith*, treatments on the coefficient of RUA, are both insignificant. The coefficient for the range treatment $\hat{\phi}_{Range} = 0.0037$ is highly insignificant, with a *p*-value = 0.975. There are no differences in uncertainty attitudes between subjects in the 50 ball and 30 ball treatments. The point estimate for the smith treatment variable is $\hat{\phi}_{Smith} = -0.0198$ with *p*-value = 0.907.

Conditional on SDRA preferences, the coefficient $\hat{\phi}_{Range}$ does not support the range hypothesis (Becker and Brownson 1964). Subjects' attitudes towards uncertainty do not covary with the ranges of second-order probabilities. There is evidence in support of Smith's (1969) conjecture, hypothesis 3. With $\hat{\phi}_{Smith} = 0$, attitudes towards uncertainty are not affected by the uncertainty generating mechanism.

Table 9. SDRA Model Estimates with Treatment Variables Added

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.7233	0.0240	<0.0001	0.6764	0.7703
α	Positive income RRA normalization	-0.6895	0.0580	<0.0001	-0.8033	-0.5758
μ_0	RLP Fechner error	0.0742	0.0053	<0.0001	0.0639	0.0846
ρ	Prior weight for cage II all orange					
Constant		0.4615	0.0210	<0.0001	0.4204	0.5026
Center	Known probability center effect	0.0495	0.0269	0.0660	-0.0033	0.1023
Skew	Anchoring effect	0.1513	0.0942	0.1080	-0.0333	0.3359
ϕ	CRUA coefficient					
Constant		0.0753	0.0777	0.3330	-0.0771	0.2277
Smith	Compound objective lottery effect	0.0249	0.1133	0.8260	-0.1972	0.2471
Range	Probability range effect	0.0092	0.1022	0.9280	-0.1910	0.2095
μ_1	LSR Fechner error	0.1465	0.0953	0.1240	-0.0403	0.3333
μ_2	Ellsberg Fechner error	0.1774	0.0206	<0.0001	0.1371	0.2177

Pseudo log-likelihood = -5845.1253
Observations = 8026

3.3.3 The Subjective Expected Utility Model

The final model estimated was Savage's (1954) SEU theory. The coefficient for subjective beliefs that an orange ball is drawn from cage II, $\hat{\pi} = 0.5052$, is highly significant (Table 10). Subjects believed the contents of the covered cage II were approximately evenly distributed between orange and white ping-pong balls.

Table 10. Coefficient Estimates for Subjective Expected Utility Model

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.7232	0.0236	<0.0001	0.6770	0.7694
α	Positive income RRA normalization	-0.6871	-0.0570	<0.0001	-0.7988	-0.5753
μ_0	RLP Fechner error	0.0742	0.0053	<0.0001	0.0639	0.0845
π	Subjective belief of orange cage II	0.5052	0.0154	<0.0001	0.4751	0.5353
μ_1	LSR Fechner error	0.1299	0.0791	0.1000	-0.0251	0.2848
μ_2	Ellsberg Fechner error	0.2020	0.0239	<0.0001	0.1550	0.2489

Pseudo log-likelihood = -5854.3914
Observations = 8026

Adding treatment variables to control for center and anchoring affects, coefficient estimates reported in Table 11 demonstrate that beliefs regarding the unknown urn are conditioned on the known probabilities. Subjects in the low center treatment, where the known urn had a 20% of yielding an orange ball, held beliefs only 4.88% lower than subjects in Ellsberg's original 50/50 treatment.

Table 11. SEU Model Estimates with Treatment Variables Added

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.7231	0.0238	<0.0001	0.6764	0.7698
α	Positive income RRA normalization	-0.6871	0.0577	<0.0001	-0.8003	-0.5739
μ_0	RLP Fechner error	0.0742	0.0053	<0.0001	0.0639	0.0845
π	Subjective belief of orange cage II					
Constant		0.4599	0.0203	<0.0001	0.4200	0.4998
Center	Known probability center effect	0.0489	0.0265	0.0650	-0.0031	0.1008
Skew	Anchoring effect	0.1222	0.0599	0.0410	0.0049	0.2396
μ_1	LSR Fechner error	0.1188	0.0621	0.0560	-0.0030	0.2406
μ_2	Ellsberg Fechner error	0.1841	0.0216	<0.0001	0.1418	0.2264

Pseudo log-likelihood = -5846.0054
Observations = 8026

The chi-square test clearly rejects the null that all treatment effects are jointly zero ($\chi_2^2 = 7.72$). Testing the distinction between SDRA (Table **8**) and SEU (Table 11) is accomplished by testing the hypothesis that $\hat{\phi}_{Constant} = \hat{\phi}_{Smith} = \hat{\phi}_{Range} = 0$ from Table 9. The SEU model with covariates is a nested special case of the SDRA model with covariates. The likelihood ratio statistic $\chi_3^2 = 2.77$ with *p*-value = 0.429 fails to reject the null that subjects behave as if maximizing SEU as estimated in Table 11. As such, this experiment reports evidence that contradicts Ellsberg's thought experiment.

3.4 Experiment Summary

In Ellsberg's two-color urn experiment, subjects behave as if the realization of each uncertain event is equally likely. However, bets on certain events are not preferred to bets on uncertain events. The data does not support hypothesis 1, Ellsberg's predicted preferences.

Hypothesis 2 and 3 are supported. The nonparametric test of the distributions of preferences between subjects failed to reject the null of hypothesis 2. Choices were unaffected by the mechanism used to generate uncertainty. Econometric estimates fail to reject both hypothesis 3 and neutral attitudes towards uncertainty. Smith was right. Using a compound objective lottery instead of Ellsberg's urn would elicit the same preferences, although in entirely different way than intended.

CHAPTER 4: QUALITY, IDENTIFICATION, AND UNCERTAINTY

The previous chapter tested the Ellsberg's (1961) two-color problem using the uncertain priors model (Neilson 1993, 2009; KMM 2005) and tested the model's key assumption, uncertainty aversion. Attitudes towards risk and uncertainty, along with beliefs were jointly estimated using a structural econometric model. Estimates in chapter 3 demonstrated that (for subjects participating in experiment) behavior is best characterized by Savage's (1954) subjective expected utility.

Here, I build upon the chapter 3 and develop an experimental instrument to identify attitudes towards uncertainty under less abstract conditions and test for separate attitudes towards two separate uncertain processes. To facilitate the identification of separate attitudes, subjects completed a series of binary choices using a multiple price list (MPL) format (Holt and Laury 2002) paying in a *branded* commodity where information possessed by the decision-maker was noisy.

To understand how uncertain processes are at work when evaluating graded commodities such as online security (Spiekerman, Grossklags, and Berendt (2002), Berendt, Günther, and Spiekerman (2005)), food products (Heyes, Shogren, Shin, and Kliebenstein 1995), or even gem stones, a two-uncertain process UP model is developed sequentially from the expected utility model. Consider the comparison of two bets, I and II. Bet I is a bet on receiving one of two commodities B or C, with *known* certified (i.e., branded) quality (e.g., security) $g', g'' \in G$ where $g' \succ g'$ and objective chances of winning given by $\Pr(B)$ and $\Pr(C)$. The second bet, bet II, is a bet on receiving one of two otherwise identical certified commodities A and D, with objective probabilities

$\Pr(\text{A})$ and $\Pr(\text{D})$. When deciding between which bet to choose, the EU decision-maker evaluates each according to the expected utilities

$$EU(\text{B},\text{C}) = \Pr(\text{B})v(\text{B}_{\text{g}'}) + \Pr(\text{C})v(\text{C}_{\text{g}''}), \tag{17}$$

for bet I and

$$EU(\text{A},\text{D}) = \Pr(\text{A})v(\text{A}_{\text{g}'}) + \Pr(\text{D})v(\text{D}_{\text{g}''}). \tag{18}$$

for bet II.

If the commodity qualities are *unknown* (i.e., generic or not branded), the Savage (1954) consistent decision-maker evaluates the likelihood each commodity, A, B, C, and D, belong to the class of commodities with qualities g' and g''.[20] Given beliefs regarding each commodity's quality, preferences would be evaluated by

$$SEU(\text{B},\text{C}) = \Pr(\text{B})\left[\pi_{\text{Bg}'}v(\text{B}_{\text{g}'}) + \pi_{\text{Bg}''}v(\text{B}_{\text{g}''})\right]$$

$$+\Pr(\text{C})\left[\pi_{\text{Cg}'}v(\text{C}_{\text{g}'}) + \pi_{\text{Cg}''}v(\text{C}_{\text{g}''})\right], \text{ and} \tag{19}$$

$$SEU(\text{A},\text{D}) = \Pr(\text{A})\left[\pi_{\text{Ag}'}v(\text{A}_{\text{g}'}) + \pi_{\text{Ag}''}v(\text{A}_{\text{g}''})\right]$$

$$+\Pr(\text{D})\left[\pi_{\text{Dg}'}v(\text{D}_{\text{g}'}) + \pi_{\text{Dg}''}v(\text{D}_{\text{g}''})\right], \tag{20}$$

where the $\boldsymbol{\pi}$ are the subjective beliefs that A, B, C, and D are either g' or g''.

When the decision-maker is unsure of his beliefs, he may form a sets of I_A subjective distributions that A is g' or g''. Denote the i^{th} prior belief $\boldsymbol{\pi}_{\text{A}i} = (\pi_{\text{A}i\text{g}'}, \pi_{\text{A}i\text{g}''})$ and the probabilities over all the I_A priors $\boldsymbol{\rho}_\text{A} = (\rho_{\text{A}1}, ..., \rho_{\text{A}I_\text{A}})$. Similarly, for B, C, and D, the decision-maker has prior beliefs $\boldsymbol{\pi}_{\text{B}i}$ $\boldsymbol{\pi}_{\text{C}i}$, and $\boldsymbol{\pi}_{\text{C}i}$ with respective weights $\boldsymbol{\rho}_\text{B}$, $\boldsymbol{\rho}_\text{C}$,

[20] The experiment designed below uses Coke and Pepsi, "familiar" products, as the experimental metaphor for more general economic concepts of differentiation.

and $\boldsymbol{\rho}_{\mathrm{D}}$. Extending equations (19) and (20) to account for these prior beliefs, preference for the Neilson consistent decision-maker are given by

$$UP(\mathrm{B},\mathrm{C}) = \sum_{i\in I} \rho_i u\left(\sum_{k\in\{\mathrm{g}',\mathrm{g}''\}} \pi_{\mathrm{B}i_{\mathrm{B}}k} \Pr(\mathrm{B}) v(\mathrm{B}_k) + \pi_{\mathrm{C}i_{\mathrm{C}}k} \Pr(\mathrm{C}) v(\mathrm{C}_k)\right), \text{ and} \quad (21)$$

$$UP(\mathrm{A},\mathrm{D}) = \sum_{i\in I} \rho_i u\left(\sum_{k\in\{\mathrm{g}',\mathrm{g}''\}} \pi_{\mathrm{A}i_{\mathrm{A}}k} \Pr(\mathrm{A}) v(\mathrm{A}_k) + \pi_{\mathrm{D}i_{\mathrm{D}}k} \Pr(\mathrm{D}) v(\mathrm{D}_k)\right), \quad (22)$$

with $I \equiv I_{\mathrm{A}} \times I_{\mathrm{B}} \times I_{\mathrm{C}} \times I_{\mathrm{D}}$ and $\boldsymbol{\rho} \equiv \left(\rho_{\mathrm{A}1}\rho_{\mathrm{B}1}\rho_{\mathrm{C}1}\rho_{\mathrm{D}1}, \ldots \rho_{\mathrm{A}i_{\mathrm{A}}}\rho_{\mathrm{B}i_{\mathrm{B}}}\rho_{\mathrm{C}i_{\mathrm{C}}}\rho_{\mathrm{D}i_{\mathrm{D}}}, \ldots, \rho_{\mathrm{A}I_{\mathrm{A}}}\rho_{\mathrm{B}I_{\mathrm{B}}}\rho_{\mathrm{C}I_{\mathrm{B}}}\rho_{\mathrm{D}I_{\mathrm{D}}}\right)$.

In many instances however, commodities are accompanied by noisy quality signals. To better understand how noisy reports “change” the UP model in equations (21) and (22), consider once again the Savage consumer. With such a noisy signal, preferences can be separated into two component parts: EU if signal is accurate and the SEU given an inaccurate signal. Assuming the signal that B is g' and C is g'', equation (19) is rewritten

$$SEU(\mathrm{B},\mathrm{C}) = [1-\pi_{\mathrm{w}}]\left[\Pr(\mathrm{B})v(\mathrm{B}_{\mathrm{g}'}) + \Pr(\mathrm{C})v(\mathrm{C}_{\mathrm{g}''})\right]$$

$$+\pi_{\mathrm{W}}\left[\Pr(\mathrm{B})\left[\pi_{\mathrm{Bg}'|\mathrm{w}}v(\mathrm{B}_{\mathrm{g}'}) + \pi_{\mathrm{Bg}''|\mathrm{w}}v(\mathrm{B}_{\mathrm{g}''})\right] + \Pr(\mathrm{C})\left[\pi_{\mathrm{Cg}'|\mathrm{w}}v(\mathrm{C}_{\mathrm{g}'}) + \pi_{\mathrm{Cg}''|\mathrm{w}}v(\mathrm{C}_{\mathrm{g}''})\right]\right], \quad (23)$$

where π_{w} is the belief that the signal is wrong (inaccurate) and thus $\pi_{\cdot\mathrm{g}'|\mathrm{w}}$ and $\pi_{\cdot\mathrm{g}''|\mathrm{w}}$ are beliefs that B and C are g' or g'' give inaccuracy. For the personal belief that the signal was wrong, the Savage consumer's beliefs are $\pi_{\mathrm{Bg}'|\mathrm{w}} = 1-\pi_{\mathrm{Bg}'}$ and $\pi_{\mathrm{Cg}''|\mathrm{w}} = 1-\pi_{\mathrm{Cg}''}$, the consumer's unconditional beliefs that each brand is not those of the signal, g' for B and g' for C. Equation (20) then becomes

$$SEU(\mathrm{A},\mathrm{C}) = [1-\pi_{\mathrm{w}}]\left[\Pr(\mathrm{A})v(\mathrm{A}_{\mathrm{g}'}) + \Pr(\mathrm{D})v(\mathrm{D}_{\mathrm{g}''})\right]$$

$$+\pi_{\mathrm{w}}\left[\Pr(\mathrm{A})\left[\pi_{\mathrm{Ag}'|\mathrm{w}}v(\mathrm{A}_{\mathrm{g}'}) + \pi_{\mathrm{Ag}''|\mathrm{w}}v(\mathrm{A}_{\mathrm{g}''})\right]\right]$$

$$+\Pr(\mathrm{D})\Big[\pi_{\mathrm{Dg'|w}} v\big(\mathrm{D_{g'}}\big) + \pi_{\mathrm{Dg''|w}} v\big(\mathrm{D_{g''}}\big)\Big]\Big], \tag{24}$$

with conditional beliefs $\pi_{\mathrm{Ag'|w}} = 1 - \pi_{\mathrm{Ag'}}$ and $\pi_{\mathrm{Dg''|w}} = 1 - \pi_{\mathrm{Dg''}}$ for the quality of A and D, given an inaccurate signal. Equations (23) and (24) can also be extended to account for uncertain beliefs for signal accuracy. Define a set of priors J for the belief that the prediction is wrong, $\pi_{j\mathrm{W}}$, with probabilistic weights $\boldsymbol{\theta} = (\theta_1, ..., \theta_J)$.

Allowing for J signal accuracy beliefs and I quality beliefs, the two processes at work in the Nielson subject's preference function can be modeled as

$$UP(\mathrm{B,C}) = \sum_{\substack{i\in I \\ j\in J}} \rho_i \theta_j u\Big(\pi_{j\mathrm{W}}\Big[\sum_{k\in\{\mathrm{g',g''}\}}[1-\pi_{\mathrm{B}ik}]\Pr(\mathrm{B})v(\mathrm{B}_k) + [1-\pi_{\mathrm{C}ik}]\Pr(\mathrm{C})v(\mathrm{C}_k)\Big]$$

$$+\big[1-\pi_{j\mathrm{W}}\big]\Big[\Pr(\mathrm{B})v\big(\mathrm{B_{g'}}\big) + \Pr(\mathrm{C})v\big(\mathrm{C_{g''}}\big)\Big]\Big), \tag{25}$$

$$UP(\mathrm{A,D}) = \sum_{\substack{i\in I \\ j\in J}} \rho_i \theta_j u\Big(\pi_{j\mathrm{w}}\Big[\sum_{k\in\{\mathrm{g',g''}\}}[1-\pi_{\mathrm{A}ik}]\Pr(\mathrm{A})v(\mathrm{A}_k) + [1-\pi_{\mathrm{D}ik}]\Pr(\mathrm{D})v(\mathrm{D}_k)\Big]$$

$$+\big[1-\pi_{j\mathrm{w}}\big]\Big[\Pr(\mathrm{A})v\big(\mathrm{A_{g'}}\big) + \Pr(\mathrm{D})v\big(\mathrm{D_{g''}}\big)\Big]\Big), \tag{26}$$

where A and B are predicted to be quality $\mathrm{g'}$, and C and D are predicted to be quality $\mathrm{g''}$ (Model 1). The UP preferences assumed in equations (25) and (26) are analogous to the preferences given by equation (3) in chapter 2. Alternative specifications given by equations (27) and (28), Model 2:

$$UP(\mathrm{B,C}) = \sum_{i\in I} \rho_i u^I\Big(\sum_{j\in J} \theta_j u^J\Big(\pi_{j\mathrm{W}}\Big[\sum_{k\in\{\mathrm{g',g''}\}}[1-\pi_{\mathrm{B}ik}]\Pr(\mathrm{B})v(\mathrm{B}_k)$$

$$+[1-\pi_{\mathrm{C}ik}]\Pr(\mathrm{C})v(\mathrm{C}_k)\Big] + \big[1-\pi_{j\mathrm{W}}\big]\Big[\Pr(\mathrm{B})v\big(\mathrm{B_{g'}}\big) + \Pr(\mathrm{C})v\big(\mathrm{C_{g''}}\big)\Big]\Big)\Big), \tag{27}$$

$$UP(\mathrm{A,D}) = \sum_{i\in I} \rho_i u^I\Big(\sum_{j\in J} \theta_j u^J\Big(\pi_{j\mathrm{w}}\Big[\sum_{k\in\{\mathrm{g',g''}\}}[1-\pi_{\mathrm{A}ik}]\Pr(\mathrm{A})v(\mathrm{A}_k)$$

$$+\left[1-\pi_{\mathrm{D}ik}\right]\Pr(\mathrm{D})v(\mathrm{D}_k)\Big]+\Big[1-\pi_{j\mathrm{w}}\Big]\Big[\Pr(\mathrm{A})v(\mathrm{A}_{g'})+\Pr(\mathrm{D})v(\mathrm{D}_{g''})\Big]\Big)\Big), \tag{28}$$

and equations (29) and (30), Model 3:

$$UP(\mathrm{B,C})=\sum_{j\in J}\theta_j u^J\left(\sum_{i\in I}\rho_i u^I\left(\pi_{j\mathrm{W}}\left[\sum_{k\in\{\mathrm{g}',\mathrm{g}''\}}\left[1-\pi_{\mathrm{B}ik}\right]\Pr(\mathrm{B})v(\mathrm{B}_k)\right.\right.\right.$$

$$\left.\left.\left.+\left[1-\pi_{\mathrm{C}ik}\right]\Pr(\mathrm{C})v(\mathrm{C}_k)\right]+\left[1-\pi_{j\mathrm{W}}\right]\left[\Pr(\mathrm{B})v(\mathrm{B}_{\mathrm{g}'})+\Pr(\mathrm{C})v(\mathrm{C}_{\mathrm{g}''})\right]\right)\right), \tag{29}$$

$$UP(\mathrm{A,D})=\sum_{j\in J}\theta_j u^J\left(\sum_{i\in I}\rho_i u^I\left(\pi_{j\mathrm{w}}\left[\sum_{k\in\{\mathrm{g}',\mathrm{g}''\}}\left[1-\pi_{\mathrm{A}ik}\right]\Pr(\mathrm{A})v(\mathrm{A}_k)\right.\right.\right.$$

$$\left.\left.\left.+\left[1-\pi_{\mathrm{D}ik}\right]\Pr(\mathrm{D})v(\mathrm{D}_k)\right]+\left[1-\pi_{j\mathrm{w}}\right]\left[\Pr(\mathrm{A})v(\mathrm{A}_{g'})+\Pr(\mathrm{D})v(\mathrm{D}_{g''})\right]\right)\right), \tag{30}$$

where the concavity of $u^I(\cdot)$ and $u^J(\cdot)$ capture aversion to uncertainty over the I and J subsets of prior beliefs.

The experimental design integrates the equivalent lottery pair procedure of Heath and Tversky (1991) with a linear scoring rule used to identify subjective beliefs to test hypothesis 4 and identify which UP preference specification describes behavior, Model 1, 2, or 3. The remainder of Chapter 4 is devoted to the experimental design used to test hypothesis 4 and the results of said test.

4.1 Experimental Design

Appendix E contains detailed instructions for the experimental sessions used to identify uncertainty aversion and test the hypothesis that subjects form separate sets of uncertain beliefs and attitudes towards distinctly uncertainty processes, hypothesis 4.

HYPOTHESIS 4: Subjects cognitively differentiate between different uncertain processes.

In summary, four individual choice tasks were employed to identify preferences for uncertain lotteries, control for risk attitudes, elicitation of beliefs, and control for uncertainty. Each of these tasks is discussed in turn. In total, 82 subjects took part in four sessions over a one month period at the University of Central Florida. Table 12 summarizes the experimental design used to test hypotheses 4.

Table 12. Experiment Design

Session	Commodity Information	LSR Bets on Commodities	LSR Anchoring (Skew)	MPL Anchoring (Skew)	Subjects
1	Branded	N/A	N/A	High	13
				Low	12
2	Ungraded	Brand of Commodity won in MPL	High	High	6
				Low	7
			Low	High	6
				Low	6
3	Graded	Brand of Commodity won in MPL	High	High	2
				Low	0
			Low	High	0
				Low	3
		"Grade" prediction Accuracy	High	High	0
				Low	3
			High	High	3
				Low	0
4	Graded	"Grade" prediction Accuracy	High	High	5
				Low	6
			Low	High	5
				Low	5

4.1.1 Eliciting Preferences

Elicitation of preferences for the experimental graded commodity was conducted using a multiple price list instrument with twenty paired choices. Soft drinks were chosen as the experimental commodity, with their brand representing quality due to constraints of using student research subjects. Students can be reasonably expected to be familiar with taste differences between Coke and Pepsi. To control the ranking of utilities over these brands, subjects were instructed:

> Each of these letters A, B, C, and D labels one of the sodas on the table in the front of the room. If the soda you win is a Coke, we will pay you $10. If the soda you win is Pepsi we will pay you $0…
>
> At the conclusion of this session you can have either a Coke or a Pepsi, which ever you prefer. You should not let the fact that you like to drink one soda brand over the other influence the 20 choices you make. You can have whichever soda you prefer at the end of the session.

An example of the MPL is shown here.

Table 13. Example Decision Sheet

Option I	Option II	Decision	
5/100 of C, 95/100 of B	5/100 of D, 95/100 of A	I	II
10/100 of C, 90/100 of B	10/100 of D, 90/100 of A	I	II
15/100 of C, 85/100 of B	15/100 of D, 85/100 of A	I	II
⋮	⋮	⋮	⋮

Commodities used in the experiment were labeled A, B, C, and D to match the price list. Ambiguity was controlled in three treatment frames: branded (certified), graded (uncertified), and ungraded. Each of these is discussed below in more detail. To detect anchoring of subject responses towards the middle their decision sheets, the decision sheet used two treatment frames, skew low and skew high.

4.1.1.1 Ungraded Commodity

For the ungraded treatment, subjects *a priori* did not know which soda brand, Coke and Pepsi, was associated with each label A, B, C, and D . Sodas were entirely covered with two to three layers of colored masking tape to completely conceal identifying brand characteristics.

Prior to placing their bets, subjects were allowed to taste approximately 1 ounce from each soda. By taste testing, subjects were able to form a set of beliefs for each of the four commodities brands.

4.1.1.2 Graded Commodity

In the graded treatment, a signal in the form of a brand prediction was added prior to subjects making their decisions. One volunteer subject was selected to taste each soda and report, to other subjects in the room, a binary prediction for each sodas correct brand. To incentivize the volunteer to report truthfully, a $10 reward was added for correctly predicting the brand of each soda A, B, C, and D.

Finally, before making their choices subjects were once again invited to taste each soda to form their own sets of beliefs.

4.1.1.3 Certified Commodity

In the certified treatment, subjects knew in advance of betting that labels A and B were applied to cans of Coke, and C and D were applied to cans of Pepsi. To keep things equal subjects were invited to taste each soda prior to making their decisions – all subjects declined.

4.1.1.4 Controlling for Risk Attitudes

Risk attitudes were controlled by using reciprocal probabilities in options I and II. This means for the certified commodity treatment, excluding errors, subjects should have choosen option I up to the row there each option has 50-50 probabilities and then choose option II for the remaining rows of the MPL. Deviations in the switch point are assumed to be explained by asymmetric subjective beliefs for the brand of each commodity, or calculation errors.

4.1.2 Elicitation of Beliefs

Subjects' beliefs for the correct brand of the soda they won and the accuracy of the volunteer's report for both sodas in their chosen option were elicited using a LSR.

Subjects were assigned to only one of these two treatment frames. The LSR frame was varied within-session for the graded commodity treatment. Only the grade frame of the LSR was used in the ungraded commodity treatments.

To operationalize the LSR, each subject placed their bets on the uncertain events by circling the appropriate row number on their decision sheets. Copies of the decision sheets and instructions can be found in Appendix E. The first six rows of a decision sheet used for the *brand frame* are shown in Table 14. To detect anchoring biases, two versions of the scoring rule varied the payoffs to determine if subjects anchor their choices in the center of the decision sheet.

Table 14. Example Betting Sheet for Linear Scoring rule

Row	**Payment if the correct brand for the soda you won is Coke**	**Payment if the correct brand for the soda you won is Pepsi**
0%	$0.00	$50.00
4%	$2.00	$48.00
8%	$4.00	$46.00
12%	$6.00	$44.00
15%	$7.50	$42.50
19%	$9.50	$40.50

Subjects placed their bets by circling the row number corresponding to the bet they preferred. For the decision sheet here selecting row 19% would pay $9.50 if the brand for the soda possessed by the subject was a Coke and $40.50 if the brand was Pepsi. These prize amounts correspond directly to a report of λ% report in the LSR given by $S(\lambda|\text{Coke}) = 50 - 50[1-\lambda]$ if Coke and $S(\lambda|\text{Pepsi}) = 50 - 50[\lambda]$ if Pepsi.[21]

[21] At least one subjects recognized the relationship between their implied beliefs and the row numbering.

4.1.2.1 Equivalent Lottery Pairs: Controlling Uncertainty

The equivalent lottery pair (ELP) choice was the final decision subjects made. After subjects placed their bets for either brand or accuracy, each one was given the choice to either keep their bet, conditional on the uncertain event, or trade their bet for an equivalent objective bet. Prior to making their choices subjects were given examples, for betting row 19% and 77%. A subject who chose row 19% could either keep the bet or replace the uncertainty with the spin of a bingo cage. If a number between 0 and 19 was drawn the subject won the $9.50 prize. He would receive $40.50 for drawing a number between 20 and 100. For a bet on row 77%, if a number between 0 and 77 was drawn, he would receive $38.50. Numbers between 78 and 100 paid $11.50.

Assuming subjects have multiple prior probabilistic beliefs for each event; those who are averse to the uncertainty associated with their bet would prefer to "swap" for the equivalent objective bet. Uncertainty seeking subject would strictly prefer to keep their bet from the belief elicitation task. For subjects who expressed indifference, a 6-sided die was used to determine if they kept their uncertain bet or swapped the equivalent objective lottery.

For the *accuracy frame*, indifference suggests reduction and preferences are given by Model 2, equations (27) and (28) with $u^J(x) \equiv x$ or Model 1, equation (25) and (26) with $u(x) \equiv x$. Preferences for the certain (uncertain) bet imply $u^I(\cdot)$ (or $u(\cdot)$) is concave (convex) and the subject are uncertainty aversion (loving). Indifference in the *brand* frame of the ELP suggests that reduction applies for the uncertain brand process and UP preferences are of the form given by Model 3, equations (29) and (30) with $u^I(x) \equiv x$ or Model 1, equation (25) and (26) with $u(x) \equiv x$.

4.1.2.2 Controlling for Risk Attitudes

Risk attitudes were controlled using subject responses to a series of random lottery pair choices consistent with the classic Hey and Orme (1994) experiments. All bets were in the gain domain and in the range of $0 to $50. An example screen shot of the computer interface used to elicit preferences is in Appendix D.

4.2 Econometric Model

4.2.1 Controlling Risk Attitudes

Risk attitudes were controlled assuming the expo-power utility function

$$v(x) = \left[1 - \exp\left(-\alpha x^{1-r}\right)\right] \big/ \alpha \,, \tag{6}$$

where $\alpha \neq 0$ and $r \neq 1$ are parameters to be estimated, and x is income from observed lottery choices, \$0, \$15, \$35, and \$50. With many of the same subjects who participated in the Ellsberg experiment reported in Chapter 3, I expected to find evidence of decreasing relative risk aversion. Equation (6) was estimated using maximum likelihood techniques, assuming EUT.

As in Chapter 3, the *link function* was assumed to be the logistic distribution. The probability that the subject chooses lottery 1 was modeled with the index function

$$\nabla EU = \frac{\exp\left(\mathrm{eu}_1(\alpha, r)/\mu_0\right)}{\exp\left(\mathrm{eu}_1(\alpha, r)/\mu_0\right) + \exp\left(\mathrm{eu}_2(\alpha, r)/\mu_0\right)} \,. \tag{7}$$

where $\mathrm{eu}_i(\alpha, r) = EU_i(\alpha, r) \big/ \xi_0$ with ξ_0 the contextual norm, and μ_0 the Fechner error parameter. Maximizing the log-likelihood, equation (8) in chapter 3, I found evidence that subjects exhibited decreasing relative risk aversion as predicted, with $\hat{r} = 0.7336$ and $\hat{\alpha} = -0.7256$.

4.2.2 Identifying Subjective Beliefs and Uncertainty Attitudes

Beliefs and attitudes towards uncertainty were identified from choices made in the MPL bets paying in the simulated commodity, LSR bets for the “quality” of the experimental commodity, and the ELP task where subjects are able to swap uncertainty for objectivity.

From the MPL task, subjects made choices between pairs of uncertain lotteries. To simplify the discussion, I will only use the UP preference function defined in Model 1, equations (25) and (26). The utility of option I is evaluated by

$$UP(\mathrm{B},\mathrm{C}) = \sum_{\substack{i\in I\\ j\in J}} \rho_i \theta_j u\Big(\pi_{j\mathrm{w}}\Big[\sum_{k\in\{\mathrm{g}',\mathrm{g}''\}}[1-\pi_{\mathrm{B}ik}]\Pr(\mathrm{B})v(\mathrm{B}_k)+[1-\pi_{\mathrm{C}ik}]\Pr(\mathrm{C})v(\mathrm{C}_k)\Big]$$

$$+[1-\pi_{j\mathrm{w}}]\Big[\Pr(\mathrm{B})v(\mathrm{B}_{\mathrm{g}'})+\Pr(\mathrm{C})v(\mathrm{C}_{\mathrm{g}''})\Big]\Big),$$

and option II by

$$UP(\mathrm{A},\mathrm{D}) = \sum_{\substack{i\in I\\ j\in J}} \rho_i \theta_j u\Big(\pi_{j\mathrm{w}}\Big[\sum_{k\in\{\mathrm{g}',\mathrm{g}''\}}[1-\pi_{\mathrm{A}ik}]\Pr(\mathrm{A})v(\mathrm{A}_k)+[1-\pi_{\mathrm{D}ik}]\Pr(\mathrm{D})v(\mathrm{D}_k)\Big]$$

$$+[1-\pi_{j\mathrm{w}}]\Big[\Pr(\mathrm{A})v(\mathrm{A}_{\mathrm{g}'})+\Pr(\mathrm{D})v(\mathrm{D}_{\mathrm{g}''})\Big]\Big).$$

Second-order utilities were assumed characterized by constant relative uncertainty aversion, $u(x) \equiv x^{1-\phi}/[1-\phi]$. The latent index was modeled using the logistic function

$$\nabla UP = \frac{\exp\big(\mathrm{up}_{\mathrm{II}}(\phi,\boldsymbol{\pi}_{\mathrm{w}},\boldsymbol{\pi}_{\mathrm{A}},\boldsymbol{\pi}_{\mathrm{D}};\alpha,r)/\mu_1\big)}{\exp\big(\mathrm{up}_{\mathrm{I}}(\phi,\boldsymbol{\pi}_{\mathrm{w}},\boldsymbol{\pi}_{\mathrm{B}},\boldsymbol{\pi}_{\mathrm{C}};\alpha,r)/\mu_1\big)+\exp\big(\mathrm{up}_{\mathrm{II}}(\phi,\boldsymbol{\pi}_{\mathrm{w}},\boldsymbol{\pi}_{\mathrm{A}},\boldsymbol{\pi}_{\mathrm{D}};\alpha,r)/\mu_1\big)}, \quad (31)$$

with log-likelihood

$$\ln L(\phi,\boldsymbol{\pi},\mu_1;y,\mathbf{X},\alpha,r) = \sum_{t=1}^{T}\{y_t \ln \nabla UP + [1-y_t]\ln[1-\nabla UP]\}, \alpha \neq 0,\ r \neq 1, \quad (32)$$

where $y_t = 1(0)$ indicates the t^{th} choice of lottery II(I), and $\mathbf{X}$ is data pertaining to the choice tasks and/or subject characteristics. To supplement identification of μ_1, the Fechner error for MPL choices, deviations in the switching point for the "branded" commodity treatment are only explained by errors, μ_1.

Beliefs $\boldsymbol{\pi}_{\mathrm{w}}$, $\boldsymbol{\pi}_{\mathrm{A}}$, $\boldsymbol{\pi}_{\mathrm{B}}$, $\boldsymbol{\pi}_{\mathrm{C}}$, and $\boldsymbol{\pi}_{\mathrm{D}}$ were identified using a linear scoring rule, where subjects place bets that either the can they won was Coke or Pepsi, or both cans in their chosen option were correctly grade ("branded") by the motivated volunteer.[22] All 25 subjects in the *ungraded* sessions and 5 subjects in the first *graded* session made bets for the brand of the experimental commodity they won.

For each belief, bets with the LSR were placed using identical experimental procedures. To save space and avoid overly repetitive discussion, description of the LSR component(s) of the FIML model will focus on bets contingent on the brand of commodity A. In such an instance, subjects behave as if maximizing

$$UP_{\lambda}\left(\mathrm{A}\right)=\sum_{i=0}^{I}\rho_{\mathrm{A}i}u\left(\sum_{g=\{\mathrm{Coke,Pepsi}\}}\pi_{\mathrm{A}ig}v\left(\mathrm{A}_{g}\mid\text{report }\lambda\right)\right). \tag{33}$$

For a given report λ^*, the multinomial logistic link functions is written as

$$\nabla W=\frac{\exp\left(\mathrm{UP}_{\lambda^*}\left(\phi,\boldsymbol{\pi}_{\mathrm{A}},\boldsymbol{\rho}_{\mathrm{A}};\alpha,r\right)/\mu_1\right)}{\sum_{\lambda\in\Lambda}\exp\left(\mathrm{UP}_{\lambda}\left(\phi,\boldsymbol{\pi}_{\mathrm{A}},\boldsymbol{\rho}_{\mathrm{A}};\alpha,r\right)/\mu_1\right)}, \tag{34}$$

where $\mathrm{UP}_{\lambda}\left(\phi,\boldsymbol{\pi}_{\mathrm{A}},\boldsymbol{\rho}_{\mathrm{A}};\alpha,r\right)=UP_{\lambda}\left(\phi,\boldsymbol{\pi}_{\mathrm{A}},\boldsymbol{\rho}_{\mathrm{A}};\alpha,r\right)/\xi_1$ is the contextual error specification for the UP values, analogous to equation (7). The log-likelihood function is

$$\ln L\left(\phi,\boldsymbol{\pi}_{\mathrm{A}},\boldsymbol{\rho}_{\mathrm{A}};y,\mathbf{X},\alpha,r\right)=\sum_{t=1}^{T}\left\{y_t\ln\nabla W+\left[1-y_t\right]\ln\left[1-\nabla W\right]\right\},\alpha\neq 0,\ r\neq 1, \tag{35}$$

where $y_t=1$ for the report λ^* and $y_t=0$ for all other $\lambda\in\Lambda$. (The likelihood functions for those subjects betting on the brands of the other commodities are identical, except subscripts "A" in equations (33), (34), and (35) are replaced by either B, C, or D.)

In the final task, the ELP task, the subject in possession of commodity A and having placed a bet λ^* was afforded the opportunity to swap his uncertain bet, in

[22] The motivated volunteer was given an incentive of $10 extra if he correctly identified the brand for each soda can in options I and II. The volunteer for each "graded" session was randomly chosen from a pool of multiple volunteers.

exchange for a bet defined by the objective probability $P_L = \left[100\pi^*_{\text{ACoke}}\left(\lambda^*\right)+1\right]\big/101$ and $P_R = 100\left[1-\pi^*_{\text{ACoke}}\left(\lambda^*\right)\right]\big/101$ that he receive payment from the left (L) or right (R) hand columns of Table 14, where $\boldsymbol{\pi}^*_{\text{A}}\left(\lambda^*\right)$ is the implicit raw subjective belief given report λ^*. Subjects evaluated their objective

$$EU = P_L v\left(z_L\right) + P_R v\left(z_R\right), \tag{36}$$

of making the swap, with their ambiguous

$$UP_{\lambda^*}\left(\text{A}\right) = \sum_{i=0}^{I} \rho_{\text{A}i} u\left(\sum_{g=\{\text{Coke,Pepsi}\}} \pi_{\text{A}ig} v\left(\text{A}_g \mid \lambda^*\right)\right), \tag{33}$$

of keeping their LSR bet.

With these the preferences, ELP choices were assumed logistically distributed, with probability of replacing the uncertain bet given by

$$\nabla W = \frac{\exp\left(\text{eu}\left(P_L, P_R; \alpha, r\right)/\mu_1\right)}{\exp\left(\text{eu}\left(P_L, P_R; \alpha, r\right)/\mu_1\right) + \exp\left(\text{up}\left(\phi, \boldsymbol{\pi}_{\text{A}}, \boldsymbol{\rho}_{\text{A}}; \alpha, r\right)/\mu_1\right)}, \tag{37}$$

where $\text{eu}(\cdot)$ and $\text{up}(\cdot)$ are the contextual normalizations of equation (36) and (33). The log-likelihood is

$$\ln L\left(\phi, \boldsymbol{\pi}_{\text{A}}, \boldsymbol{\rho}_{\text{A}}, \mu_1; y, P_L, P_R, \alpha, r, \mathbf{X}\right) = \sum_{t=1}^{T} \left\{ y_t \ln \nabla W + \left[1-y_t\right] \ln\left[1-\nabla W\right] \right\},$$

$$\alpha \neq 0,\ r \neq 1, \tag{38}$$

where $y_t = 1(0)$ indicates the t^{th} subject's choice of replacing (keeping) his uncertain LSR bet, and $\mathbf{X}$ is data pertaining to the choice tasks and/or subject characteristics.

<u>4.3 Data and Results</u>

Hypothesis 4, identified in chapter 2, extends the economic concept of uncertainty aversion and multiple priors to multiple uncertain processes. For each process, the subject may have different sets of prior beliefs and attitudes towards each uncertainty embodied in those sets.

HYPOTHESIS 4: Subjects cognitively differentiate between different uncertain processes.

Hypothesis 4 is tested as follows. Section 4.3.2 estimates risk attitudes alone, assuming EUT. Section 4.3.3 estimates three models of uncertain priors. First, both brand beliefs for each commodity as well as signal (prediction) accuracy of a volunteer "grader" is assumed uncertain with multiple beliefs (Model 1), equation (25) and (26). Second, subjects are assumed uncertainty neutral[23] with respect to prediction accuracy (Model 2), equations (27) and (28) with $u^J(x) \equiv x$. Third, subjects are assumed uncertainty neutral with respect to brand and UP preferences with respect to brand beliefs (Model 3), equations (29) and (30) with $u^I(x) \equiv x$. These preference specifications are tested using Clarke's (2003, 2006) sign test.[24] Finally, an estimated "SEU model", where subjects were assumed to be uncertainty neutral over both brand and prediction accuracy is compared to the better model out of Model 1, 2, or 3.

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[23] I purposely avoid describing uncertainty neutral preferences as SEU. In the context of Ellsberg's (1961) two-color problem SEU implies subjects believe balls are *only* distributed 50-50 (or some other distribution), for example. However, in the context of a soda's brand, the single belief interpretation appears to be inappropriate. There are *only* two possibilities: the commodity is either Coke, not Pepsi, *or* it is Pepsi, not Coke. Sodas are not 50% Coke and 50% Pepsi. The subject logically weights these two possibilities. But this interpretation is clearly not the same as SEU preferences in an "Ellsberg" context.

[24] Vuong's (1989) non-nested test was inappropriate. The Shapiro-Wilk test rejected the null that the likelihood ratios for each model comparison were normally distributed.

4.3.2 Estimating Risk Attitudes Alone

Before estimating the expo-power utility function (equation (6)), average relative risk aversion of the subject-pool was estimated using the CRRA utility function, $v(x) \equiv x^{(1-r)} / (1-r)$, over the domain of RLP prizes used to calibrate risk attitudes ($0, $15, $35, and $50). On average, subjects were moderately risk averse over the prize domain, $\hat{r} = 0.4587$ (Table 15).

Table 15. Coefficient Estimates for Risk Attitudes from CRRA Utility

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.4587	0.0791	<0.0001	0.3037	0.6136
μ_0	RLP Fechner error	0.0881	0.0098	<0.0001	0.069	0.1073

Pseudo log-likelihood = -2479.5339
Observations =3667

Table 16 reports coefficient estimates assuming an expo-power utility specification. The expo-power specifications allows relative risk aversion to either increase, decrease, or remain constant over the domain of prizes ($0, $15, $35, and $50). The degree of relative risk aversion is

$$\text{RRA} = r + \alpha [1-r] x^{1-r}, \tag{15}$$

which is increasing when $\alpha > 0$, decrease for $\alpha < 0$, and remain constant if $\alpha = 0$. From Table 16, $\hat{\alpha}$ is highly significant and CRRA is rejected. Choices exhibit risk aversion for low stakes gambles ($\hat{r} = 0.7336$), which decreases as lottery prizes increase to $50 ($\hat{\alpha} = -0.7256$).

Table 16. Coefficient Estimates for Risk Attitudes from Expo-Power Utility

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.7336	0.0317	<0.0001	0.6714	0.7957
α	Positive income RRA normalization	-0.7256	0.0783	<0.0001	-0.8790	-0.5722
μ_0	RLP Fechner error	0.0712	0.0067	<0.0001	0.0581	0.0843
Pseudo log-likelihood = -2455.1592 Observations =3667						

4.3.3 The Uncertain Priors Model

For the unbranded and graded treatments, where each commodity was not known with certainty, 15 subjects won commodity A and 5 placed LSR bets on the commodity's brand. The average report was 0.616, with a median of 0.58 and each bet was: 0, 0.5 0.58 and 1. The left hand column of Figure 4 graphically depicts these bets for each anchoring treatment, high and low. The kernel density of each bet is shown in the last row. The Kolmogorov-Smirnov test failed to reject the null hypotheses of no anchoring biases for LSR bets placed on the correct brand of commodities A (*p*-value = 0.20, n = 5). Anchoring bias is also rejected for commodities B, C, and D.

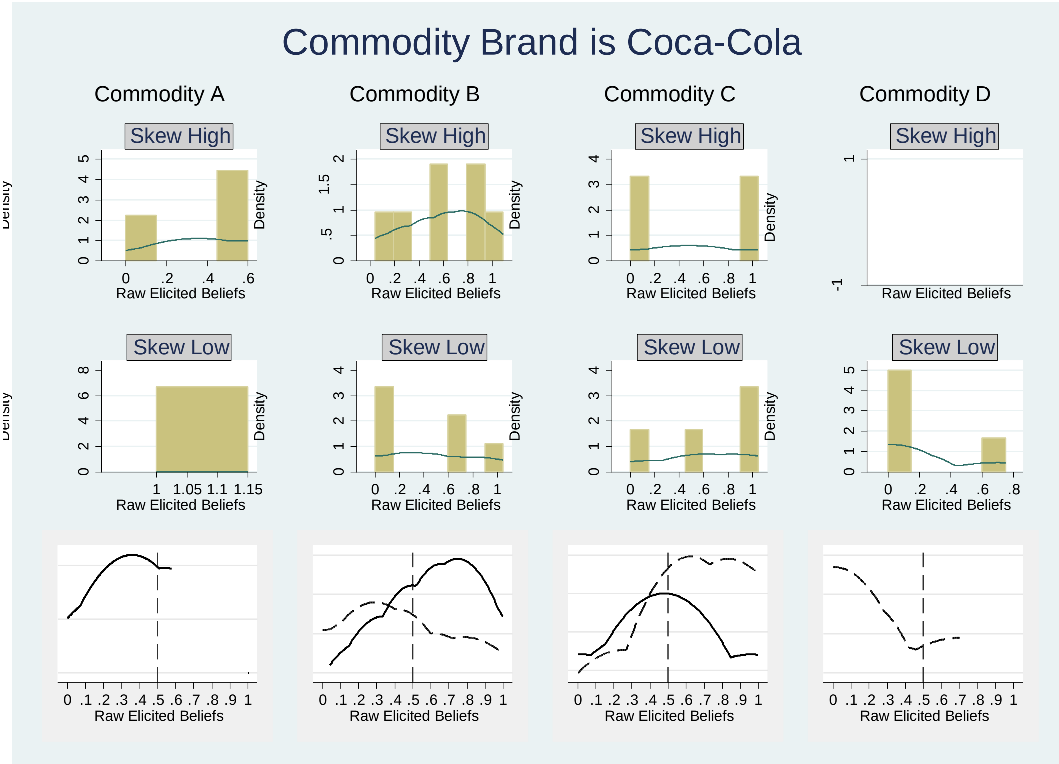


Figure 4. Raw Elicited Brand Beliefs

Thirteen out of 23 subjects winning commodity B placed LSR bets on the commodities brand. The average report was 0.495, with median 0.62 and 2 bets that B was Pepsi for sure and 2 bets that B was Coke for sure. Bets for commodity C's brand were similar. Eight out of 12 subjects who won commodity C in the MPL task placed bets on its brand. The mean report was 0.486, with median 0.71. Reports from the 4 subjects betting on the brand of commodity D were similar to those of commodity A. There was a low number of subjects placing bets (4 out of 7 possible). Three of the 4 subjects placed bets consistent with risk and uncertainty neutral preferences. Two subjects were certain commodity D was Pepsi and one was certain it was Coke. The last subject bet 0.4, consistent with a belief it was more likely commodity D was Pepsi than Coke.

The remaining 27 subjects participating in the ungraded and graded treatment placed LSR bets on the accuracy of their chosen option in the MPL task. Subjects who chose option I placed their bets that commodities B and C were correctly identified by the financially motivated volunteer.[25]

The majority of subjects betting each option were more than 50% sure the volunteers' predictions were correct. The median reports were 0.81 for option I and 0.905 for option II. The 25th percentile for each set of reports was greater than or equal to 0.5. Figure **5** shows these reports graphically. The Kolmogorov-Smirnov two-sample test failed to reject the null hypotheses of no anchoring biases for LSR bets placed on the accuracy of brand signal for each MPL option I (*p*-value = 0.898, n = 15) and II (*p*-value = 0.990, n = 12).

[25] The volunteers in each graded session made the same prediction. Commodities A and B were predicted to be Coke, B and C were predicted to be Pepsi.

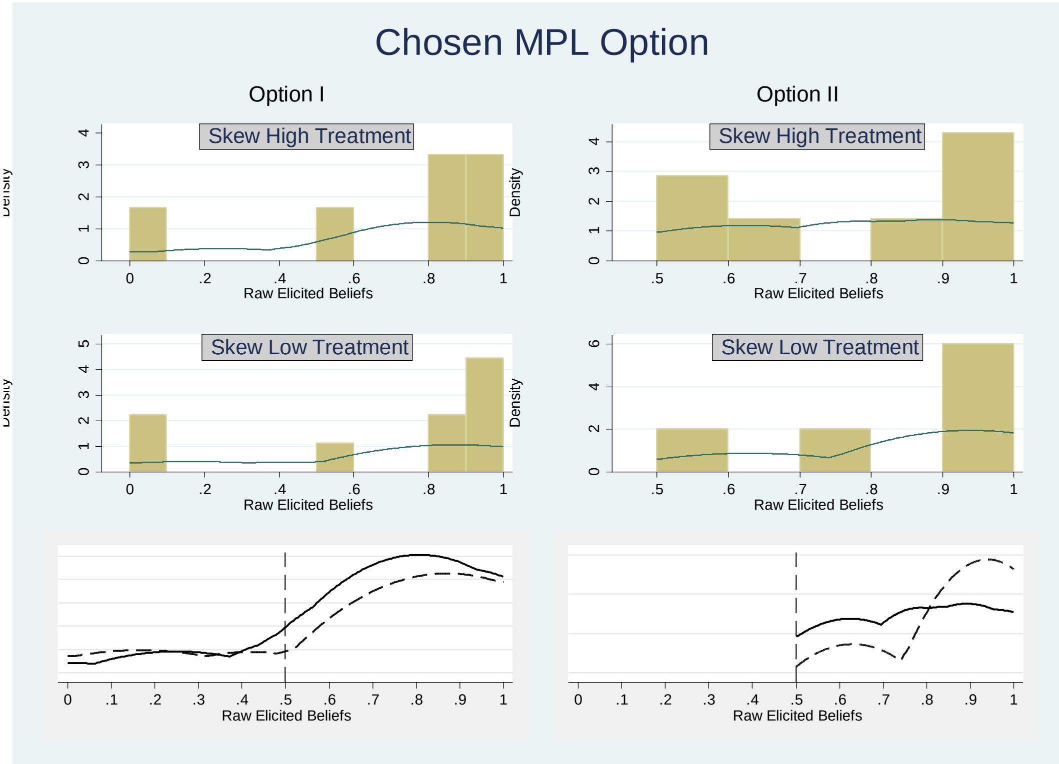


Figure 5. Raw Elicited Signal (Prediction) Accuracy Beliefs

Coefficient estimates for the UP model with brand and prediction uncertainty are shown in Table 17. The identifying assumption that subjects' preferences are SDRA with respect to individual commodity brand beliefs and prediction accuracy of the volunteer was made. Specifically, $I_A = I_B = I_C = I_D = 2$. Economically, the SDRA assumption is based on the argument that subjects believe either the commodity is all Coke or all Pepsi and weight these priors by their subjective probability that each outcome will occur.

This interpretation is distinctly different from that of the UP model as it was applied to the Ellsberg problem in chapter 3. In chapter 3, it was reasonably assumed that subjects believed the priors were equal to the possible distributions of colored balls in the unknown bingo cage. Prior weights then represented the subjective belief that the experimenter filled the cage with a particular distribution of bingo-balls. Here, there is no such set of possibilities. Each commodity is either one brand or the other. The same argument applies for the assumption of SDRA with respect to the volunteer's prediction accuracy. Table 17 reports the coefficient estimates for Model 1, the UP model given by equations (25) and (26). Subjects were very confident that commodity A was coke, $\hat{\rho}_{\mathrm{A}} = 0.7223$. Subjects were also more confident that commodity C was Coke ($\hat{\rho}_{\mathrm{C}} = 0.6421$), than they were for commodities B ($\hat{\rho}_{\mathrm{B}} = 0.3390$) and D ($\hat{\rho}_{\mathrm{D}} = 0.2255$) which was insignificant at conventional levels. A contradiction to the raw LSR reports in Figure 5, Model 1 estimates that subjects were very confident the volunteer's prediction was incorrect, $\hat{\rho}_{\mathrm{W}} = 0.6513$ with *p*-value = 0.003.

Table 17. Model 1: Brands & Prediction Accuracy

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.716	0.0209	<0.0001	0.675	0.757
α	Positive income RRA normalization	-0.6413	0.0205	<0.0001	-0.6815	-0.6011
μ_0	RLP Fechner error	0.0718	0.0072	<0.0001	0.0578	0.0858
ρ_{W}	Prior weight: brand prediction	0.6513	0.2214	0.0030	0.2174	1.0852
ρ_{A}	Prior weight: soda A Coke	0.7223	0.2110	0.0010	0.3088	1.1358
ρ_{B}	Prior weight: soda B Coke	0.3390	0.1977	0.0860	-0.0485	0.7264
ρ_{C}	Prior weight: soda C Coke	0.6421	0.2210	0.0040	0.2089	1.0752
ρ_{D}	Prior weight: soda D Coke	0.2255	0.1993	0.2580	-0.1650	0.6161
ϕ	CRUA coefficient	-0.1560	0.1399	0.2650	-0.4302	0.1181
μ_1	Fechner error	0.3514	0.0944	<0.0001	0.1665	0.5364

Pseudo log-likelihood = -3608.5548
Observations = 5313

Statistical control for anchoring biases in the MPL decisions are added to the model in Table 18. At the beginning of this section, the Kolmogrov-Smirnov test failed to reject the null of no anchoring biases in LSR bets. Coefficient estimates for $\hat{\boldsymbol{\rho}}_{Anchor}$ are jointly zero at the 0.9733 level ($\chi^2_5 = 0.86$). The model reported in Table 17 is the better model, assuming UP preferences with both brand and prediction uncertainty.

Table 18. Model 1: Brands & Prediction Accuracy with Treatment Effects

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.7172	0.0232	<0.0001	0.6717	0.7626
α	Positive income RRA normalization	-0.6461	0.0864	<0.0001	-0.8154	-0.4767
μ_0	RLP Fechner error	0.0717	0.0071	<0.0001	0.0579	0.0856
ρ_W	Prior weight: brand prediction					
Constant		0.5835	0.2504	0.0200	0.0928	1.0741
Anchor	MPL anchoring treatment	0.2055	0.4238	0.6280	-0.6251	1.036
ρ_A	Prior weight: soda A is Coke					
Constant		0.7059	0.2215	0.0010	0.2718	1.1401
Anchor	MPL anchoring treatment	0.0838	3.3025	0.9800	-6.3890	6.5565
ρ_B	Prior weight: soda B is Coke					
Constant		0.3509	0.2240	0.1170	-0.0882	0.7899
Anchor	MPL anchoring treatment	-0.1827	0.3455	0.5970	-0.8599	0.4946
ρ_C	Prior weight: soda C is Coke					
Constant		0.6434	0.2396	0.0070	0.1737	1.1131
Anchor	MPL anchoring treatment	0.0196	3.3823	0.9950	-6.6096	6.6488
ρ_D	Prior weight: soda D is Coke					
Constant		0.2033	0.2593	0.4330	-0.3049	0.7116
Anchor	MPL anchoring treatment	-0.1780	0.2854	0.5330	-0.7374	0.3814
ϕ	CRUA coefficient	-0.1646	0.1643	0.3160	-0.4866	0.1573
μ_1	Fechner error	0.3570	0.1041	0.0010	0.1531	0.5609
Pseudo log-likelihood = -3607.3399 Observations = 5313						

4.3.3.1 Uncertain Distinctions

Two alternative UP-consistent preference models assume either:

1. Model 2, subjects are uncertainty neutral in the prediction accuracy and uncertainty seeking/averse in the brand domain (equations (27) and (28) with $u^J(x) \equiv x$), or
2. Model 3, subjects are uncertainty seeking/averse in the prediction accuracy domain and uncertainty neutral in the brand domain (equations equations (29) and (30) with $u^I(x) \equiv x$).

Table 19 and Table 20 show the likelihood estimates for Model 2. Anchoring biases are tested in Table 20. The chi-square test fails to reject the null of no bias and all treatment variables are jointly zero at the 0.1122 level, with $\chi_5^2 = 8.92$.

Table 19. Model 2: Uncertainty Neutral in Prediction Domain

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.7240	0.3686	0.0490	0.0016	1.4464
α	Positive income RRA normalization	-0.6842	2.1441	0.7500	-4.8866	3.5182
μ_0	RLP Fechner error	0.0716	0.0079	<0.0001	0.0561	0.0871
ρ_W	Prior weight: brand prediction	0.1876	0.3198	0.5580	-0.4393	0.8144
ρ_A	Prior weight: soda A Coke	0.7964	0.2545	0.0020	0.2976	1.2952
ρ_B	Prior weight: soda B Coke	0.3357	0.2567	0.1910	-0.1675	0.8388
ρ_C	Prior weight: soda C Coke	0.6623	0.2899	0.0220	0.0941	1.2304
ρ_D	Prior weight: soda D Coke	0.1353	0.3254	0.6780	-0.5024	0.7730
ϕ	CRUA coefficient	-0.1155	0.2739	0.6730	-0.6523	0.4213
μ_1	Fechner error	0.3927	0.1911	0.0400	0.0181	0.7674

Pseudo log-likelihood = -3599.637
Observations = 5313

Table 20. Model 2: Uncertainty Neutral in Prediction Domain with Treatment Effects

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.7229	0.0574	<0.0001	0.6105	0.8354
α	Positive income RRA normalization	-0.6772	0.2504	0.0070	-1.1680	-0.1863
μ_0	RLP Fechner error	0.0716	0.0071	<0.0001	0.0578	0.0854
ρ_W	Prior weight: brand prediction					
Constant		0.1633	0.3067	0.5940	-0.4379	0.7645
Anchor	MPL anchoring treatment	0.0546	0.3271	0.8670	-0.5865	0.6957
ρ_A	Prior weight: soda A is Coke					
Constant		0.8012	0.3074	0.0090	0.1988	1.4037
Anchor	MPL anchoring treatment	-0.6249	0.6043	0.3010	-1.8094	0.5596
ρ_B	Prior weight: soda B is Coke					
Constant		0.3726	0.2453	0.1290	-0.1082	0.8535
Anchor	MPL anchoring treatment	0.6133	0.2385	0.0100	0.1458	1.0807
ρ_C	Prior weight: soda C is Coke					
Constant		0.6513	0.3286	0.0470	0.0072	1.2953
Anchor	MPL anchoring treatment	-0.6124	0.5006	0.2210	-1.5934	0.3687
ρ_D	Prior weight: soda D is Coke					
Constant		0.0488	0.4433	0.9120	-0.8200	0.9176
Anchor	MPL anchoring treatment	0.7733	0.5155	0.1340	-0.2371	1.7837
ϕ	CRUA coefficient	-0.1292	0.2907	0.6570	-0.6989	0.4404
μ_1	Fechner error	0.3908	0.1089	<0.0001	0.1773	0.6042

Pseudo log-likelihood = -3598.7185
Observations = 5313

Estimates reported in Table 19 suggests that subjects were highly confident that the volunteer prediction was correct, $\hat{\rho}_W = 0.1876$ with *p*-value = 0.558. This is consistent with the raw reports in Figure 5. Subjects remain confident that commodities A and C are Coke ($\hat{\rho}_{\text{A}} = 0.7964$ and $\hat{\rho}_{\text{C}} = 0.6623$) the coefficient $\hat{\rho}_{\text{B}} = 0.3357$ is now insignificant at the 0.19 level. The coefficient $\hat{\rho}_{\text{D}} = 0.1353$ remains insignificant. The estimated coefficient of relative uncertainty $\hat{\phi} = -0.1155$ in the brand domain is insignificant.

Figure 6 shows the distribution of likelihood ratios comparing Models 1 and 2. The Shapiro-Wilk test clearly rejects the null that the ratios are normally distributed. The Clarke (2003, 2006) sign test is appropriate to discriminate between these two models. The Clarke test rejects equality of the models in favor of Model 2 at the 0.0622 level. There is evidence that the assumption subjects are uncertainty neutral with respect to prediction accuracy explains the data better than Model 1, where subjects are assumed uncertainty seeking / averse for both brand and prediction accuracy.

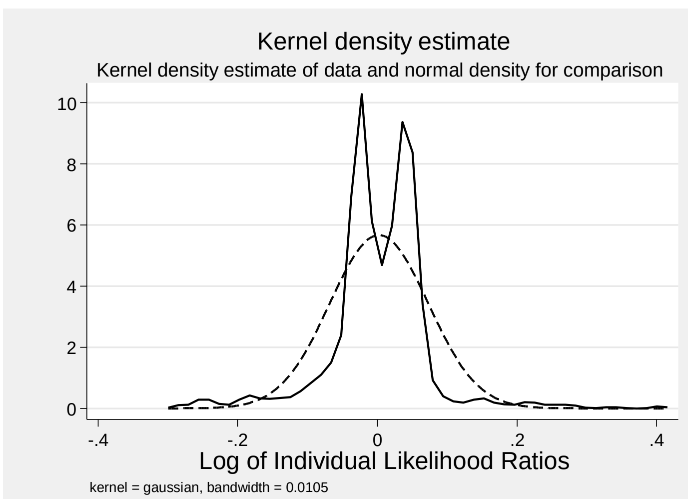


Figure 6. Distribution Likelihood Ratios: Model 1 vs. Model 2

Table 21 reports the likelihood estimates from Model 3, where subjects are assumed uncertainty neutral in the commodity brand domain only. Subjects place more weight on the volunteer prediction was incorrect than correct. The estimated coefficient of relative uncertainty $\hat{\phi} = -0.0404$ in the prediction domain is insignificant. Point estimates of beliefs that each commodity A, B, C and D is coke are consistent with earlier observations, $\hat{\rho}_{\mathrm{A}} = 0.81$ and $\hat{\rho}_{\mathrm{C}} = 0.6728$, while $\hat{\rho}_{\mathrm{B}}$ and $\hat{\rho}_{\mathrm{D}}$ are insignificant. Consistent with raw reports in Figure 5, $\hat{\rho}_{W} = 0.1798$ is insignificant at the 0.479 level. Coefficient estimates reported in Table 22 fail to reject the null of no anchoring biases in the MPL task at the 0.78 level ($\chi_5^2 = 2.47$).

Table 21. Model 3: Uncertainty Neutral in Brand Domain

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.7266	0.0324	<0.0001	0.6631	0.7900
α	Positive income RRA normalization	-0.7014	0.0765	<0.0001	-0.8513	-0.5515
μ_0	RLP Fechner error	0.0716	0.0071	<0.0001	0.0578	0.0855
ρ_{W}	Prior weight: brand prediction	0.1798	0.2540	0.4790	-0.3181	0.6777
ρ_{A}	Prior weight: soda A Coke	0.8100	0.2991	0.0070	0.2236	1.3963
ρ_{B}	Prior weight: soda B Coke	0.3042	0.2748	0.2680	-0.2344	0.8428
ρ_{C}	Prior weight: soda C Coke	0.6728	0.3402	0.0480	0.0061	1.3396
ρ_{D}	Prior weight: soda D Coke	0.0913	0.2825	0.7470	-0.4624	0.6450
ϕ	CRUA coefficient	-0.0404	0.1252	0.7470	-0.2857	0.2049
μ_1	Fechner error	0.3949	0.1065	<0.0001	0.1861	0.6037

Pseudo log-likelihood = -3599.8614
Observations = 5313

Table 22. Model 3: Uncertainty Neutral in Brand Domain with Treatment Effects

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.7273	0.0326	<0.0001	0.6634	0.7912
α	Positive income RRA normalization	-0.7063	0.0795	<0.0001	-0.862	-0.5505
μ_0	RLP Fechner error	0.0716	0.0071	<0.0001	0.0578	0.0855
ρ_W	Prior weight: brand prediction					
Constant		0.1440	0.3034	0.6350	-0.4506	0.7387
Anchor	MPL anchoring treatment	0.0519	0.3456	0.8810	-0.6254	0.7292
ρ_A	Prior weight: soda A is Coke					
Constant		0.8211	0.3012	0.0060	0.2306	1.4115
Anchor	MPL anchoring treatment	0.1524	0.3072	0.6200	-0.4497	0.7545
ρ_B	Prior weight: soda B is Coke					
Constant		0.3541	0.2361	0.1340	-0.1086	0.8168
Anchor	MPL anchoring treatment	-0.1529	0.3559	0.6670	-0.8504	0.5446
ρ_C	Prior weight: soda C is Coke					
Constant		0.6657	0.3446	0.0530	-0.0097	1.3411
Anchor	MPL anchoring treatment	0.1538	0.4635	0.7400	-0.7547	1.0623
ρ_D	Prior weight: soda D is Coke					
Constant		0.0003	0.0120	0.9830	-0.0232	0.0237
Anchor	MPL anchoring treatment	0.0338	0.0413	0.4130	-0.0471	0.1147
ϕ	CRUA coefficient	-0.0151	0.1387	0.9130	-0.2870	0.2568
μ_1	Fechner error	0.3974	0.1069	<0.0001	0.1880	0.6069
Pseudo log-likelihood = -3599.0641 Observations = 5313						

The Shapiro-Wilk test rejects normality of the likelihood ratios between Models 1 and 3 (Figure 7). Clarke's (2003, 2006) test rejects equality of the individual log likelihoods in favor of equations Model 3 at the 0.0988 level. There is a moderate amount of evidence that subjects are uncertainty neutral in the commodity brand domain with $u^I(x) \equiv x$.

The Shapiro-Wilk test rejects the null hypothesis of normality of the likelihood ratios between Model 2 and Model 3. The distribution of likelihood ratios is shown in Figure 8. The Clarke (2003, 2006) test clearly favors Model 3 as the better model to explain subjects' choices when compared to Model 1. More than 63% of non-zero likelihood differences (1049 out of 1629) favor subjects being uncertainty neutral with respect to brand accuracy.

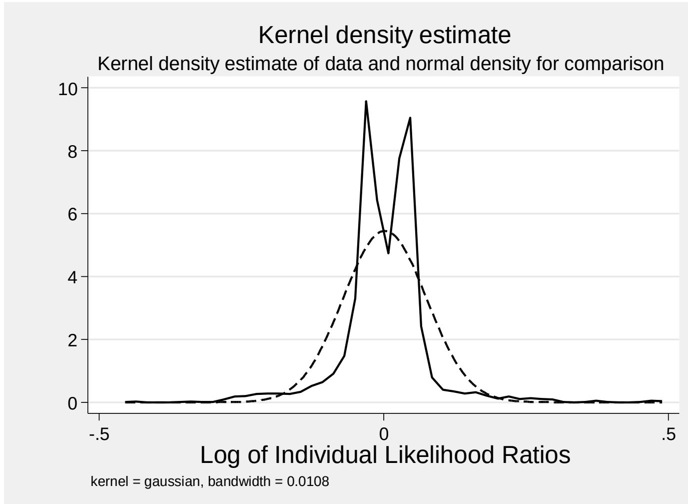


Figure 7. Distribution Likelihood Ratios: Model 1 vs. Model 3

It has been demonstrated that Model 2 (Table 19) and Model 3 (Table 21) both outperform Model 1 (Table 17). As expected, the Shapiro-Wilk test (see Figure 8) rejects normality of the likelihood differences for these two models and the Clarke (2003, 2006) test is appropriate to discriminate between Model 2 and 3. The Clarke test favored Model 3 over Models 2 and 1 (p-value < 0.0001).

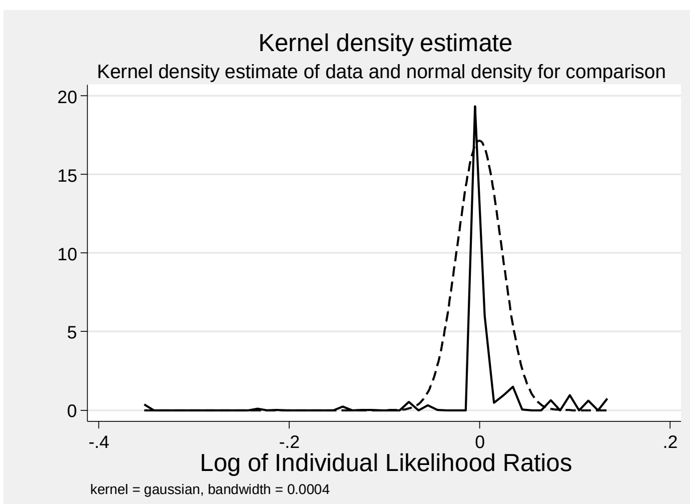


Figure 8. Distribution Likelihood Ratios: Model 2 vs. Model 3

Assuming subjects were uncertainty neutral in both the brand and prediction accuracy domains, point estimates reported in Table 23 describe subjects as believing the volunteer's prediction was correct, $\hat{\rho}_{\mathrm{W}} = 0.166$ is insignificant. Subjects also believed commodities A and C were Coke with $\hat{\rho}_{\mathrm{A}} = 0.8094$ and $\hat{\rho}_{\mathrm{C}} = 0.6722$, respectively. Subjects were very confident commodities B and D were Pepsi, $\hat{\rho}_{\mathrm{B}}$ and $\hat{\rho}_{\mathrm{D}}$ are both insignificant. The point estimates reported in Table 24 fail to reject the null of no anchoring biases at the 0.6055 level, $\chi_5^2 = 3.62$.

Table 23. "SEU" Model: Uncertainty Neutral in Brand and Prediction Domains

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.7276	0.0329	<0.0001	0.6630	0.7921
α	Positive income RRA normalization	-0.7087	0.0794	<0.0001	-0.8642	-0.5531
μ_0	RLP Fechner error	0.0716	0.0071	<0.0001	0.0578	0.0855
ρ_{W}	Prior weight: brand prediction	0.1660	0.2213	0.4530	-0.2677	0.5997
ρ_{A}	Prior weight: soda A Coke	0.8094	0.3000	0.0070	0.2213	1.3974
ρ_{B}	Prior weight: soda B Coke	0.3064	0.2704	0.2570	-0.2234	0.8363
ρ_{C}	Prior weight: soda C Coke	0.6722	0.3376	0.0460	0.0106	1.3339
ρ_{D}	Prior weight: soda D Coke	0.0926	0.2768	0.7380	-0.4500	0.6352
μ_1	Fechner error	0.3981	0.1005	<0.0001	0.2012	0.5951

Pseudo log-likelihood = -3599.9313
Observations = 5313

With $\hat{\phi}$ from Model 3 insignificant (*p*-value = 0.673) and no evidence of treatment effects for the "SEU" model which assumes subjects are uncertainty neutral over both brand and prediction domains, the likelihood ratio test applied to observations from the WTA, LSR, and ELP decision tasks failed to reject the equivalence of Model 2 and the "SEU" mode reported in Table 23 ($\chi_1^2 = 0.5486$).

Table 24. "SEU" Model: Uncertainty Neutral Preferences with Treatment Effects

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.7277	0.0328	<0.0001	0.6634	0.7920
α	Positive income RRA normalization	-0.7091	0.0787	<0.0001	-0.8633	-0.5549
μ_0	RLP Fechner error	0.0716	0.0071	<0.0001	0.0578	0.0855
ρ_W	Prior weight: brand prediction					
Constant		0.1375	0.2552	0.5900	-0.3626	0.6377
Anchor	MPL anchoring treatment	0.0549	0.3349	0.8700	-0.6015	0.7112
ρ_A	Prior weight: soda A is Coke					
Constant		0.8210	0.3006	0.0060	0.2318	1.4101
Anchor	MPL anchoring treatment	0.1652	0.2997	0.5820	-0.4222	0.7525
ρ_B	Prior weight: soda B is Coke					
Constant		0.3561	0.2300	0.1220	-0.0947	0.8069
Anchor	MPL anchoring treatment	-0.1589	0.3499	0.6500	-0.8447	0.5269
ρ_C	Prior weight: soda C is Coke					
Constant		0.6656	0.3431	0.052	-0.0069	1.3381
Anchor	MPL anchoring treatment	0.1671	0.4543	0.713	-0.7233	1.0575
ρ_D	Prior weight: soda D is Coke					
Constant		0.0001	0.0032	0.9830	-0.0062	0.0064
Anchor	MPL anchoring treatment	0.0306	0.0377	0.4160	-0.0432	0.1045
μ_1	Fechner error	0.3986	0.1027	<0.0001	0.1973	0.5999

Pseudo log-likelihood = -3599.0736
Observations = 5313

4.4 Experiment Summary

This chapter set out to develop an experimental design to test the hypothesis that individuals differentiate between different uncertainties.

HYPOTHESIS 4: Subjects cognitively differentiate between different uncertain processes.

To test hypothesis 4, three different specifications of the uncertain priors model were estimated using structural likelihood methods. The first, Model 1 (equation (25) and (26)), assumed attitudes towards uncertainty were singular and subjects did not differentiate between uncertain processes. Model 2 (equations (27) and (28)) assumed subjects had neutral attitudes towards prediction accuracy uncertainty and non-neutral attitudes towards brand uncertainty. Model 3 (equations (29) and (30)) assumed non-neutral attitudes towards prediction accuracy and neutral attitudes towards brand uncertainty. Application of Clarke's (2003, 2006) sign test for non-nested models rejected equality of Models 2 and 3, in favor of Model 2. The Clarke test also rejects equality of Models 1 and 2, in favor of model 2 at the 6.22% level.

Empirical analysis can neither reject nor fail to reject hypothesis 4. Results from the Clarke tests yield evidence in favor of hypothesis 4. There is evidence that one process models, Model 2 (Table 19) and Model 3 (Table 21), explains behavior better than assuming subjects are have attitudes towards uncertainty over both processes. Estimated beliefs from Model 2, Model 3, and the "SEU" model are consistent with each other as well as raw elicited beliefs. Subjects believed the volunteer's prediction was correct. But if he was wrong, subjects believed commodities B and D more likely to be Coke while commodities A and C were more likely to be Pepsi. There is also strong evidence that subjects are uncertainty neutral in both the prediction accuracy and brand domains.

The empirical results are ambiguous.

CHAPTER 5: PRIVACY, IDENTIFICATION, AND UNCERTAINTY

Chapter 3 demonstrated that uncertainty aversion in Ellsberg's (1961) two-color problem only survives a laboratory setting at the 11.7% level. In chapter 4, the Clarke (2003, 2006) test for non-nested model selection favored constraining subjects to have neutral attitudes towards prediction accuracy. The Clarke test supports hypothesis 4. However, the empirical evidence rejected non-neutral attitudes towards quality uncertainty. As a result, the evidence presented in favor of hypothesis 4 is mixed.

The experimental design presented in the sequel retests hypothesis 4 in the context of privacy uncertainties, confidentiality and consequences. The experiment is designed to test hypothesis 5 and 6.

HYPOTHESIS 5: Subjects' willingness-to-accept confidentiality loss is lower when making indirect sales of information to a party that does not have a direct mechanism to harm the subject.

HYPOTHESIS 6: Subjects cognitively differentiates between uncertain confidentiality breach and consequences.

Testing hypothesis 5 and 6 requires that *only* behavior in the laboratory characterizes privacy loss as well as its consequences. To do that, privacy must be salient to the design. There must be a link between subject A's chosen strategy and subject B's valuation of the knowledge of A's strategy. Confounds represented by uncontrolled strategies and interpersonal comparisons outside of the lab must be controlled.

Table 25 lists several well-known games and a lesser known game and tasks that generate private information, which human subjects may value. These include:

- *Social Dilemma Games*, where the payoff to each individual is higher from defecting behavior than those from cooperative behaviors, and all individuals are worse off when cooperation is not unanimous,
- *Bargaining Games,* where common knowledge of otherwise private information is known to change the solution concept (Roth and Malouf 1979),
- *Joy-of-Destruction*, a new game designed to measure "nastiness" towards others, and
- *Lottery Choice Tasks*.

Excluding the Joy-of-Destruction game, introduced by Abbink and Sadrieh (2008) and simple lottery choice tasks, anonymity loss may alter the way subjects play these games (Gächter and Fehr 1999). Anonymity loss may engender other-regarding preferences such as social approval, possibilities for reciprocal actions outside the lab, exhibitionism, or plain old nastiness.

Multiple mechanisms and institutions generate different pieces of information for each subject. Histories of play (actions) are the most salient types of information generated in the games listed in Table 25. Knowing Player A's payoff indirectly informs Player B of Player A's history of play, and vice versa. The qualifying criterion for a candidate experimental design is that actions by Player A map into the payoffs and strategies of Player B, such that Player B's payoffs are partly determined by Player A's chosen strategy. Player A's effect on Player B's payoff, coupled with an appropriate mechanism for reciprocal action would lead Player A to value keeping his history private from Player B.

Consider the joy-of-destruction game. Each player (A or B) can either earn their endowment, or be assigned one at random. Abbink and Sadrieh (2008) used an earnings based mechanism to avoid house *money effects*[26] in their experimental analysis of anonymity and players' willingness to impose financial damage on others. The analysis of Abbink and Sadrieh (2008) focuses on changes to Player A's (the dictator) actions, not his belief regarding possible repercussions, such as the possibility of reciprocal actions from Player B (the victim) knowing Player A's identity. Confounds represented by uncontrolled opportunities for reciprocity that may exist outside the lab makes this particular design inappropriate, since beliefs would not be identifiable and utilities would not be controlled.

Furthermore, Rutström and Williams (2000) concluded that irrespective of the way in which endowments were earned subject behavior may be best described as self-interested. Poorer subjects prefer distributions that increase own payoffs, while richer subjects prefer distributions that leave their payoffs intact. These results suggest that Player A "knowing" Player B's potential payoff would not alter Player A's chosen strategy in the joy-of-destruction in any meaningful way. Player A would rather be nasty, destroying Player B's wealth to maximize the likelihood that he earns at least as much as Player B. In the experimental design of Abbink and Sadrieh (2008), Player B's beliefs for the occurrence of a bad outcome will be unchanged by a loss of privacy over wealth. Player B would have little incentive to be willing to pay to maintain privacy.

Burnham (1997) reported on a series of dictator games where, in one treatment, Player A would receive Player B's photo prior to deciding whether or not to split a $10 endowment between himself and Player B. Burnham (1997) found that receiving player

[26] Thaler and Johnson (1990, p. 643-644) define the house money effect as when "… under some circumstances a prior gain can increase subjects' willingness to accept gambles." Contemporary experimental economics uses the term house money effect to describe behavioral differences between those subjects who earn money in the lab as consequences to choices made and those subjects who are "given" money by the experimenter.

B’s photo does not change the likelihood that Player A chooses to keep the entire $10. However, conditional on Player A already giving Player B a portion of the $10, losing anonymity increases Player A’s giving. These results suggest that the classic dictator game is also an inappropriate design to elicit values of privacy. Both the dictator game and joy-of-destruction game lack mechanisms that would induce dictators to behave in a more self-interested way following the recipients’ loss of confidentiality.

In a series of related experiments, Fehr and Fischbacher (2004), Goette, Huffman, and Meire (2006), Bernhard, Fehr, and Fischbacher (2006), and Chen and Xin Li (2009) measure the effects of induced group identities and real group identities. Using prisoner’s dilemma and dictator games, each analysis measured punishment levels associated with deviations from social norms. Within-group and between-group designs were employed in each experiment. In-group members were robustly found to punish deviation more severely than out-group members, and this finding was statistically significant.

Supporting the saliency of laboratory induced (group) identities to explain the privacy behavior, Fehr and Fischbacher (2004, Fig. 1 and 2) show that subjects form expectations of punishment that increase with violations of social norms. Their results suggest that a dictator game, coupled with the formation of identities and opportunities for reciprocal punishment, may allow subjects to form values of identifying information that are endogenous to the experiment.

The joy-of-destruction and dictator games using *real* subject identities have therefore been eliminated as potential institutions that allow subjective values of privacy to emerge as a result of salient consequences from strategies chosen in the laboratory.

Integrating (repeated) prisoner's dilemma games with punishment opportunities would allow for experimental control of previously identified confounds.

Public goods and common pool resource games with punishment accomplish this task. Consider the simple linear public goods game, where each players' payoff is the sum of the social composition function and the part of their endowment not contributed to the public good. Although full cooperation is the social optimum, as long as the marginal return from own contributions to the public good is less than the marginal private return, Players A, B, and any other subject will completely free-ride. Although the free-rider hypothesis[27] tends to fail one-shot tests, under repeated play behavior tends toward complete free-riding by each player (Camerer 2002, p. 46; Fehr and Gächter 2000). Behavior converges towards full cooperation within a relatively short period of time after the introduction of punishment opportunities, (Fehr and Gächter 2000; Ostrom, Walker, and Gardner 2001).[28]

Observations that punishment opportunities increase contributions to the public good are explainable by a simple subjective expected utility model. Player A evaluates the probability that other players punish him for each possible contribution level. He then chooses the contribution level that maximizes his subjective expected utility. This contribution level would minimize his expected punishment. As punishments are realized, Player A updates his beliefs, and contributions continue to increase towards full cooperation.

[27] The free-rider hypothesis tells us that nonexcludability imparts, on each individual, an incentive to contribute less than his marginal value to the cost of providing a public good.
[28] Ostrom, Walker and Gardner (2001) found that sanctions need not be financial. "Cheap talks" communication is sufficient to substantially reduce over use of the resource.

Players presented with a non-anonymous public goods game with punishment should have a willingness to pay for anonymity that is no more than the amount of money that dissipates all gains from anonymous play. Subjects form beliefs about the likelihood and severity of punishment without anonymity, and then compare these beliefs to their expected utility from anonymous play. This is essentially the same evaluation process that individuals make when evaluating privacy decision similar to the privacy paradox.

From the games discussed above and decision tasks presented in Table 25, public goods games, common pool resource games, and other appropriately designed repeated interaction social dilemma problems appear as natural institutions that may be used to generate individualized histories of play that allow subjects to endogenously value keeping their histories of play private.

In section 5.1, the public goods game is incorporated into an experimental design to elicit subjective beliefs and attitudes towards privacy uncertainties, confidentiality and consequences. The econometric model used to analyze the data is presented in section 5.2. The data analysis results are discussed in section 5.3 and summarized in section 5.4.

Table 25. Candidate Games/Tasks with Private Information

Games/Tasks	Information Generating Process	Stake Holder of Privacy and Payoffs	Saliency of Keeping Privacy
<u>Public Goods</u> Non-rivalrous and non-excludable goods and services.	1) Contributions a) Amount of free-riding behavior. 2) Endowment a) Earned / Random	1) Contributors a) lose money 2) Free-riders gain money	1) Free-riders reduce payoffs to contributors 2) Controlled punishment opportunities *inside* of the lab.
<u>Common Pool Resource</u> Rivalrous and (usually) non-excludable goods, such as grazing lands in the tragedy of the commons.	1) Consumption a) Amount of resource use. 2) Endowment a) Earned / Random	1) Over-users a) Increase payoffs 2) Everyone else a) Relatively lower payoffs	1) Over-users reduce payoffs to all others. 2) Controlled punishment opportunities *inside* the lab.
<u>Dictator Games</u> One person divides a pie between himself and another.	1) Endowment a) Earned / Random 2) Allocation	1) Dictator a) Unilaterally allocates payoffs 2) Receiver a) No laboratory Identity	1) Uncontrolled punishment opportunities *outside* of the lab. 2) Controlled punishment opportunities *inside* of the lab.
<u>Ultimatum Games</u> One person makes an offer to another. The second person may reject the offer, leaving both with zero.	1) Endowment a) Earned / Random 2) Proposal 3) Acceptance / Rejection	1) Proposer a) Offers a payoff 2) Receiver a) Accepts or rejects payoff.	1) Controlled punishment opportunities *inside* of the lab. 2) Uncontrolled punishment opportunities *outside* of the lab.
<u>Prisoner's Dilemma</u> Each player must choose whether to obtain security, to the detriment of the common good.	1) Defection(s) a) One-shot play b) Iterated play	1) Cooperators a) Loose money 2) Defectors a) Gain money	1) Controlled punishment opportunities *inside* of the lab. 2) Uncontrolled punishment opportunities *outside* of the lab.
<u>Joy-of-Destruction</u> Players can mutually destroy each others' wealth.	1) Endowment a) Earned / Random	1) Victim loses money. 2) Nasty player gains no money	1) Privacy (hidden-action) would tend to reduce social distance, increasing players' nastiness to one another.
<u>Lottery Choice tasks</u> Lotteries are randomly presented to subjects, who then state preference for the same lotteries.	1) Randomly determined lottery pairs 2) Randomly determined prizes	1) No laboratory identities	1) Prize differences are random 2) Uncontrolled punishment opportunities *outside* of the lab.

5.1 Experimental Design

Experimental instruments used to elicit privacy values *must* accomplish two things. First, privacy values should emerge endogenously as a result of real choices made by subjects. Second, values should be elicited with incentive compatible mechanisms. A four stage design is sufficient to satisfy these two criteria. In the first stage, subjects play a public goods game. The second stage introduces the prospect of punishment opportunities and uses a BDM mechanism in a bargaining situation where subjects have the opportunity to sell information pertaining to their choices in the public good stage of the experiment. The third stage elicits subjects' beliefs and presents subjects with an ELP choice task to identify UP preferences and attitudes towards uncertainty. Finally, Stage 4 resolves punishment.

Table 26. Experimental Design

	Public Goods			WTA/BDM Interval		LSR Anchoring (Skew)	Sellers, Senders, punishers
Session	Endowment	Private Return	Public Return	Low	High		
1	20	3	1	$0.00	$20.99	High	5, 3, 6
						Low	5, 2, 4
2	30	3	1	$0.00	$20.99	High	4, 1, 3
						Low	2, 2, 3
3	30	3	2	$0.00	$20.99	High	4, 3, 6
						Low	6, 2, 4
4	20	3	2	$0.00	$20.99	High	4, 1, 4
						Low	4, 3, 4
5	30	3	1	$000	$20.99	High	3, 2, 1
						Low	3, 1, 5

5.1.1 Stage 1: The Public Goods Game

In the first stage of the experiment, subjects played a public goods game designed using the V*e*conlab[29] website and software. The game used a 2×2 design where per period endowments were 20 or 30 tokens and the social return was either 1 or 2 cents per

[29] http://veconlab.econ.virginia.edu

token. Private return was a fixed 3 cents per token for each experimental session. Subject endowments and the social return were held fixed for each of the ten rounds played. Ten rounds were played in each session to allow subjects to learn that complete free-riding is in their selfish best interest (Isaac, Walker, and Thomas 1984; Isaac, McCue, and Plott 1985).

At the conclusion of the public goods game, subjects knew only their earnings for that task and the total contributions of the remainder of the group. At this point in the experiment, no subject possessed any information regarding the payoffs of any other subject. The punishment phase was played at the end of each session, after the value elicitation and belief elicitation tasks were completed.

5.1.2 Stage 2: Eliciting Privacy Values

In the value elicitation stage, subjects were randomly assigned to one of three roles: seller, sender, or punisher. Panels A and B of Figure 9 illustrate the bargaining and punishment groups used to simulate the canonical privacy problem. Subject pairings used were direct-sale groups (including a seller and punisher) and indirect-sale groups (including a seller, sender, and punisher).

Panel A depicts the direct-sale groups where sellers trade directly with punishers. To facilitate the transaction, subjects sold their record sheets to the experimenters, who in turn gave the records to the punisher. For the indirect-sale treatment (panel B), the experimenters gave the sold records to senders who then decided to either keep it confidential or pass it to the punisher. The instructions describing these roles to subjects were accompanied with a cartoon used to help privately convey their roles to subjects.

Referring to Figure 10 panel B (indirect-sale), sellers decided whether or not to sell their records. If the seller's records were sold to the experimenter, they were given to the sender with certainty. Records that did not sell stayed secret, with certainty. Senders then decided whether or not to pass the record sheet to a punisher, whom in turn decided whether or not to deduct 50% of the seller's earnings from the public goods game.

Utilizing the public goods game in this way reverses the "good guy" and "bad guy" roles from the loyalty card example. The difference was that in the later, the person responsible for conferring the bad event on the seller wants to defraud the seller in an attempt to better themselves. While in the former, the person conferring the bad event on the seller wants to punish the seller for perceived free-riding behavior. The kernel of reported privacy behavior remains unchanged. Sellers have private information, which if released may incentivize the receiver of that information to harm the *subject* of that information.

Sale of information was facilitated by a (reverse) BDM mechanism. Subjects assigned to the role of seller were instructed to state a price between $0.00 and $20.99 at which they would be willing to sell their record sheet. Their price was then compared to the experimenter's randomly determined bid price. If the seller's asking price was less than or equal to the experimenter's bid, the transaction took place. The seller received the randomly determined bid, and the seller's record sheet was given to his counterpart, a punisher or sender. If the asking price was greater than the random bid, then no transaction took place. The seller's personal information remained private. Consider the following example, illustrating the truth telling properties of the transaction mechanism.

Assume Player A is assigned to the role of seller, and let WTA be his actual willingness-to-accept a privacy loss. With random bid b, his payoff will be $b - WTA \geq 0$ if $WTA \leq b$ and 0 otherwise. Reporting truthfully is a dominant strategy. If Player A reports $WTA^r > WTA > b$, then he is equally well off with either a true or false report. If he reports $WTA^r > b > WTA$, then he loses $b - WTA > 0$ and would have been better off by reporting truthfully. Over-reporting is dominated by reporting honestly. Similarly, if Player A reports $WTA > WTA^r > b$, then he receives 0 with either a true or false report. However, by reporting $WTA > b > WTA^r$, Player A loses $b - WTA < 0$ and would have been better off by reporting truthfully. Under-reporting is dominated by truthful reporting.

5.1.2.1 Maintaining Real-World Privacy

To maintain real-world privacy for the experimental subject, record sheets were purchased from *all* subjects. If a sale did not take place, the earnings information was replaced with "no sale," indicating that the records were not sold. All subjects had no way to know the experimental roles of other subjects. Subjects in the roles of sender and punisher were given an explicit guarantee of confidentiality. Their optimal response to the BDM was a price of $0.[30]

[30] Mean WTA for all senders and punishers was $7.99 with median 7.64, maximum 20.99, and standard deviation 4.98.

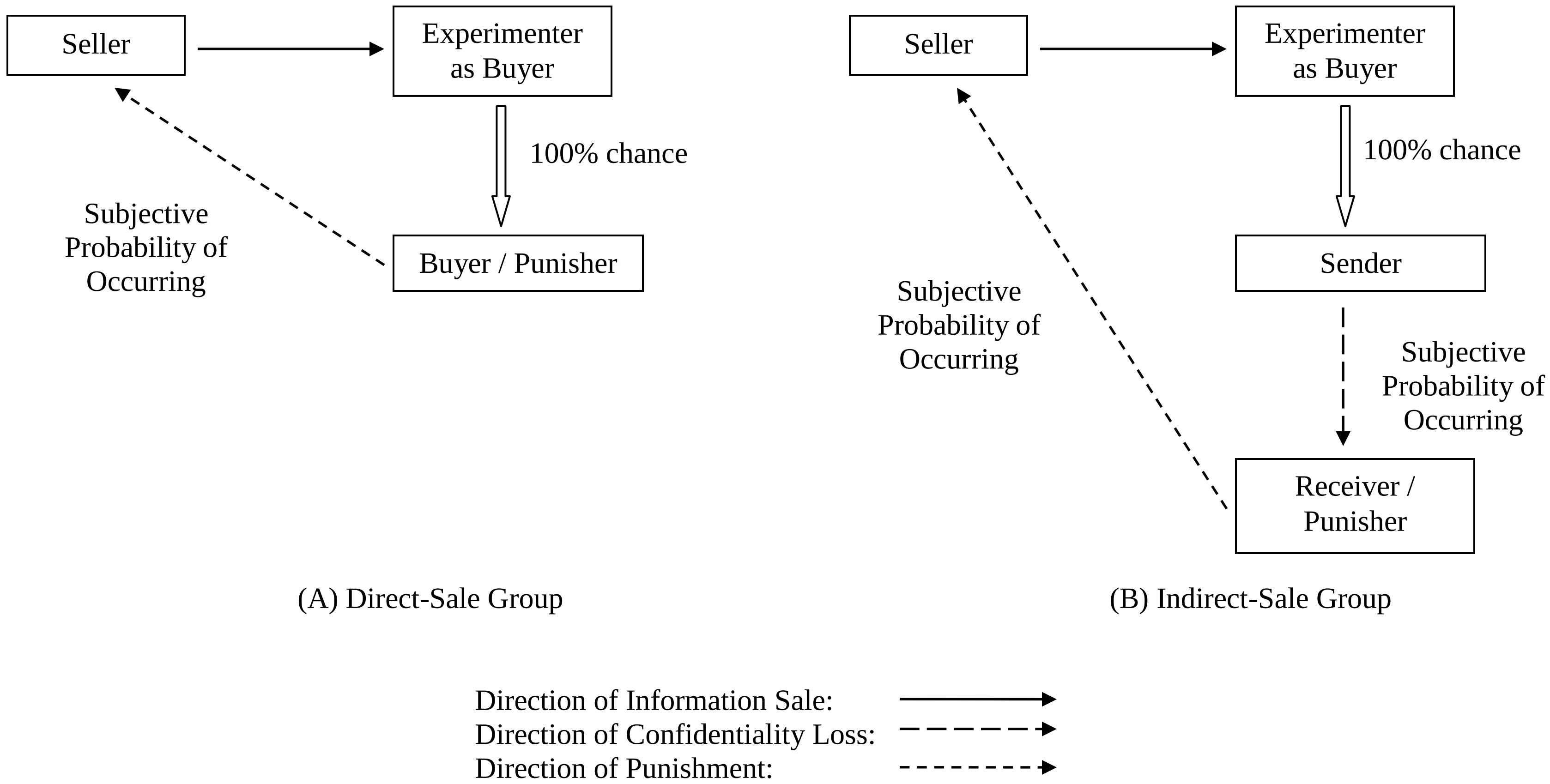
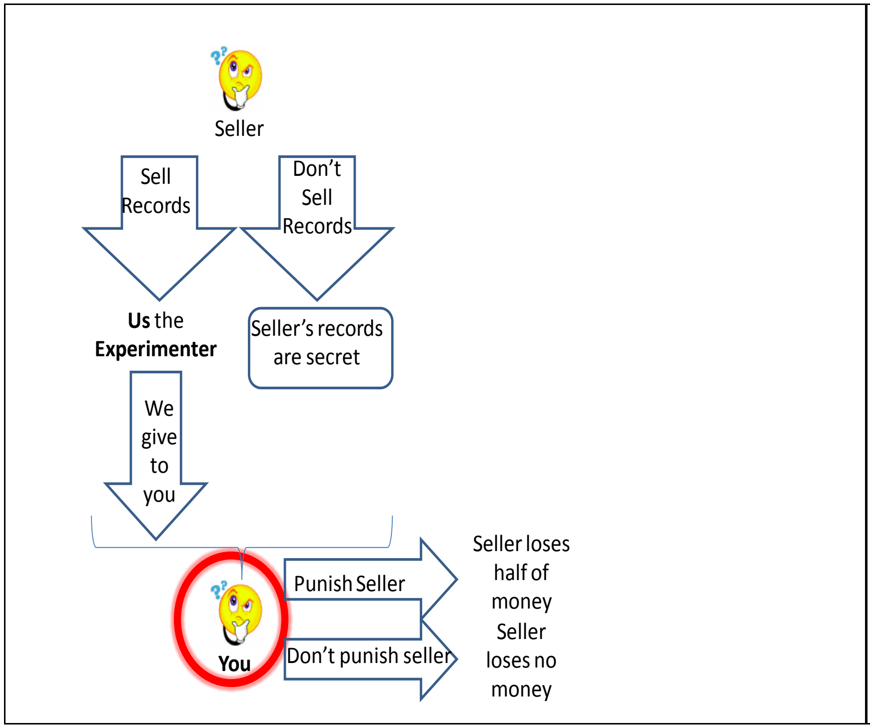
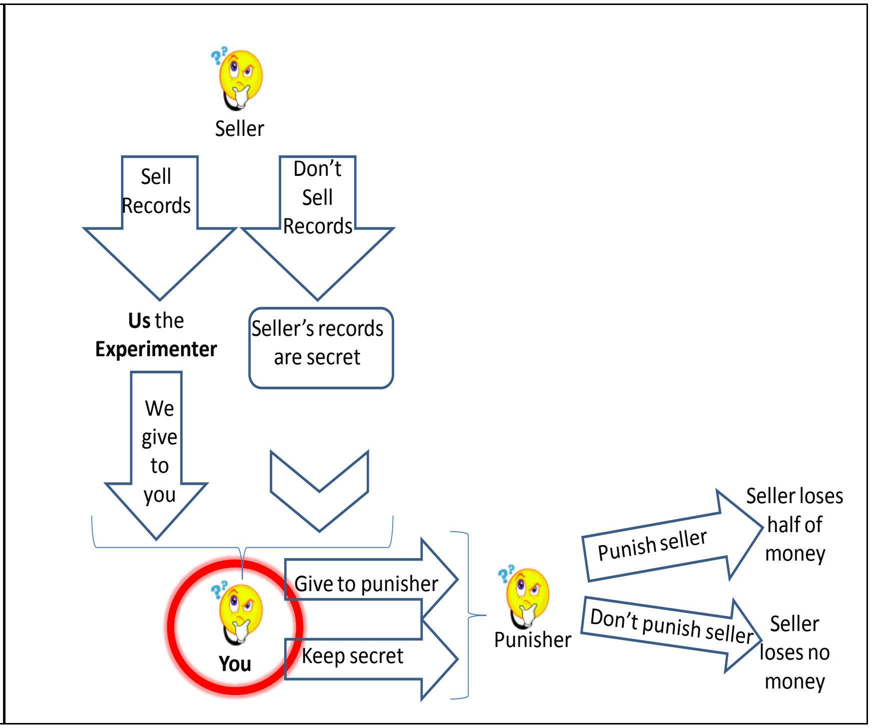


Figure 9. Subject Pairs for (A) Direct-Sale and (B) Indirect-Sale Groups



(A) Punisher in Direct-Sale Group



(B) Sender in Indirect-Sale Group

Figure 10 Instructional Cartoons Depicting Subject Roles and Tasks

5.1.3 Stage 3: Belief Elicitation

Sellers' beliefs for confidentiality loss and consequences were elicited using a LSR. Sellers were assigned to only one of these two treatment frames. The LSR was administered using paper and pencil. Each seller placed bets on the uncertain events by circling the appropriate row number on their decision sheets. Copies of the decision sheets and instructions can be found in Appendix F. The first six rows of a decision sheet used for the *confidentiality frame* are shown here. To detect anchoring biases, two versions of the scoring rule varied the distribution of payoffs to determine if subjects anchor their choices in the center of the decision sheet. In the absence of anchoring biases, reports would be distributed equally across both treatments.

Table 27: Example Betting Sheet for Linear Scoring rule

Row	**Payment if your record sheet <u>is passed</u> to the Punisher**	**Payment if your record sheet *is not passed* to the Punisher**
0%	$0.00	$50.00
4%	$2.00	$48.00
8%	$4.00	$46.00
12%	$6.00	$44.00
15%	$7.50	$42.50
19%	$9.50	$40.50

Sellers placed their bets by circling the row number corresponding to the bet they preferred. For the decision sheet here selecting row 19% would pay $9.50 if the sender passed the seller's record sheet to the punisher and $40.50 otherwise. These prize amounts correspond directly to a report of λ% report in the LSR given by $S(\lambda|\text{passed}) = 50 - 50[1-\lambda]$ and $S(\lambda|\text{not passed}) = 50 - 50[\lambda]$.

5.1.3.1 Maintaining Real-World Privacy

To maintain the real-world privacy of each subject and avoid role identification during the belief elicitation task, senders and punishers place LSR bets that they would receive the record sheet from seller counterpart. Senders place bets that the seller they were paired with would sell his record sheet. Punishers bet on one of two events. Punishers in the direct-sale groups bet that the seller they were paired with would sell his records. Punishers in the indirect-sale bet that the seller sold his records *and* the sender decided to breach the seller's confidentiality.

5.1.3.2 Equivalent Lottery Pairs: Controlling Uncertainty

The ELP choice was the final decision sellers made. After placing their LSR bets, sellers were given the choice to either keep their uncertain bet on confidentiality or consequences, or to trade their bet for an objective bet. Prior to choosing sellers were given examples for bets at row 19% and 77%. A seller who chose row 19% could either keep the bet or replace the uncertainty with the spin of a bingo cage. If a number between 0 and 19 was drawn the subject won the $9.50 prize. He would receive $40.50 for drawing a number between 20 and 100. For a bet on row 77%, if a number between 0 and 77 was drawn, he would receive $38.50. Numbers between 78 and 100 paid $11.50.

Sellers who are averse to the uncertainty associated with their bet would prefer to "swap" for the objective bet. Uncertainty seeking sellers would prefer to keep their bet from the belief elicitation task. For sellers who expressed indifference, whether they kept their uncertain bet or swapped the equivalent objective lottery was randomly determined.

For bets place on consequences, indifference suggests preferences are given by equation (4) with $u^2(x) \equiv x$, Model 2, or equation (3) with $u(x) \equiv x$, Model 1.

Preferences for the certain (uncertain) bet imply $u^2(\cdot)$ (or $u(\cdot)$) is concave (convex) and sellers are uncertainty aversion (loving). Indifference between keeping and swapping bets on confidentiality suggests that reduction applies for the uncertain consequences and UP preferences are of the form given by equation (5) with $u^1(x) \equiv x$, Model 2, or equation (3) with $u(x) \equiv x$, Model 1.

5.1.4 Stage 4: Resolution of Punishment

Confidentiality and punishment were resolved in two steps. First, record sheets for sellers in indirect-sale groups who sold their information were given to those subjects assigned to the role of sender. If a seller in an indirect-sale group did not sell his records, the sender received an indication of "no sale" in place of the seller's earnings from the public goods game. To maintain real-world anonymity for the senders, sellers and punishers were given blank slips of paper. Every subject in the lab received a slip of paper. Subjects could not determine who had been assigned the role of sender. Senders were instructed to make their decisions and all record sheets and blank slips were collected.

Step two resolved the consequences of privacy loss. Records sheets were given to the punishers in accordance with the senders' decision for the indirect-sale groups and the outcome of the BDM mechanism for sellers in the direct-sale groups. Real-world anonymity was maintained by giving blank slips of paper to sellers and senders. Every subject in the lab received a slip of paper, minimizing the chances that subjects could determine who was assigned to what roles. Finally, punishers were instructed to make their decision. Punishment was determined by a binary yes/no (punish/don't punish) choice. Punishment resulted in a fixed 50% loss of earning from the public goods game.

Punishment was proportional to earnings to guarantee non-negative earnings and avoid the possibility of bankruptcy. It is important maintain positive earnings to eliminate the need for house money because its effects have been shown to confound identification of “risky” behavior (Thaler and Johnson 1990).

All earnings from the value and belief elicitation tasks were retained by sellers, regardless of the resolution of punishment. This was made clear to subjects prior to the elicitation of their beliefs in Stage 3.

5.2 Econometric Model

5.2.1 Testing the Privacy Paradox

Sellers in the WTA task reported their minimum willingness-to-accept compensation in exchange for (i) giving their earnings information from the public goods game directly to another subject (a punisher) whom had the option to reduce the seller’s earnings by 50% or (ii) giving their contributions information to a third party (sender) whom may, or may not, pass that information to a punisher. To test hypothesis 5, a hurdle model was estimated to control for the upper payment limit of $20.99 used in the BDM mechanism.

Intuition for the hurdle model is as follows. Upon instruction for the WTA task and assignment to either a direct-sale or indirect-sale group, a seller interrogated himself, determining his minimum WTA loss of privacy. Once the seller mentally calculated his minimum value, he determined if that value is above or below the $20.99 maximum experimenter WTP. If the seller’s WTA was greater than $20.99, he marked some arbitrary value greater than \$20.99.[31] If the seller's WTA was less than or equal to \$20.99, the "hurdle" is crossed and he expressed that value.

Under this framework, likelihood model is given as follows. The probability of stating a WTA less than or equal to \$20.99 is given by

$$\Pr\left(\text{WTA}=y\right)=\begin{cases}\varphi, & y>\$20.99\\ 1-\varphi, & y\le\$20.99\end{cases} \tag{39}$$

Conditional on having a WTA within the bounds of the BDM mechanism, the seller's WTA is given by

$$\text{WTA}=\begin{cases} f\left(\boldsymbol{\beta}^{\mathrm{T}}\mathbf{X}\right), & \text{WTA}\le\$20.99\\ \ge\$21, & \text{otherwise}\end{cases}, \tag{40}$$

where **X** are explanatory variables: earnings in the voluntary contributions game and a dummy variable indicating group membership. Given equations (39) and (40), the unconditional log-likelihood for the seller's WTA privacy loss is

$$\ln L=\begin{cases}\ln\varphi, & \text{WTA}>\$20.99\\ \ln\left\{\left[1-\varphi\right]\phi\left(f\left(\boldsymbol{\beta}^{\mathrm{T}}\mathbf{X}\right)\right)\right\}, & \text{WTA}\le\$20.99\end{cases}, \tag{41}$$

where $\phi(\cdot)$ is the normal density function. Hypothesis 5 predicts the β coefficient for group membership is positive and "large."

5.2.2 Controlling Risk Attitudes

Given the domain of potential experimental payoffs (\$0 to \$50), risk attitudes were controlled using an expo-power utility function

$$v\left(x\right)=\left[1-\exp\left(-\alpha x^{1-r}\right)\right]\big/\alpha, \tag{6}$$

[31] One subject in the direct sale treatment asked \$30 in exchange for his personal information, guaranteeing his information remained private.

where $\alpha \neq 0$ and $r \neq 1$ are parameters to be estimated, and x is income from observed lottery choices. The probability that the subject chooses lottery 1 was modeled with the logistic distribution

$$\nabla EU = \frac{\exp\left(\mathrm{eu}_1(\alpha,r)/\mu_0\right)}{\exp\left(\mathrm{eu}_1(\alpha,r)/\mu_0\right)+\exp\left(\mathrm{eu}_2(\alpha,r)/\mu_0\right)}. \quad (7)$$

where $\mathrm{eu}_i(\alpha,r)$ are the contextually normalized EUs, and μ_0 the Fechner error parameter.

5.2.3 Identification of Subjective Beliefs and Uncertainty Attitudes

Subjective beliefs and attitudes towards uncertainty were identified from subjects' decisions to participate in the belief elicitation task, LSR bets for the events of having confidentiality breached and having earnings reduced (conditional on privacy), and the ELP task where subjects were able to swap their (uncertainty) subjective bets for objective bets with identical payoffs.

Sellers in the direct-sale treatment reported minimum selling price, WTA^r, to equate their UP preferences given that a sale of information has taken place

$$W\left(\mathbf{z}+WTA^r \mid \mathrm{n}\right) = \sum_{i^2=1^2}^{I^2} \theta_{i^2} u\left(\sum_{j^2=\{\mathrm{g,b}\}} \pi^2_{\mathrm{n}i^2 j^2} v\left(z_{j^2}+WTA^r\right)\right), \quad (42)$$

with final voluntary contributions earnings given that no sale takes place

$$W\left(\mathbf{z} \mid \mathrm{c}\right) = \sum_{i^2=1^2}^{I^2} \theta_{i^2} u\left(\sum_{j^2=\{\mathrm{g,b}\}} \pi^2_{\mathrm{c}i^2 j^2} v\left(z_{j^2}\right)\right). \quad (43)$$

$$W\left(\mathbf{z}+WTA^r \mid \mathrm{n}\right) = W\left(\mathbf{z} \mid \mathrm{c}\right), \quad (44)$$

with second-order crra utilities characterized by constant relative uncertainty aversion, $u(x) \equiv x^{1-\phi}/[1-\phi]$. Similarly, sellers in the indirect-sale treatment report WTA^r such that

$$W\left(\mathbf{z}+WTA^{r}\right)=\sum_{i^1=1^1}^{I^1}\sum_{i^2=1^2}^{I^2}\rho_{i^1}\theta_{i^2}u\left(\sum_{j^1=\{\mathrm{c,n}\}}\sum_{j^2=\{\mathrm{g,b}\}}\pi^1_{i^1j^1}\pi^2_{j^1i^2j^2}v\left(z_{j^2}+WTA^{r}\right)\right), \qquad (45)$$

satisfies

$$W\left(\mathbf{z}+WTA^{r}\right)=W\left(\mathbf{z}\,|\,\mathrm{c}\right). \qquad (46)$$

Beliefs and priors $\left(\boldsymbol{\rho},\boldsymbol{\pi}^1\right)$ and $\left(\boldsymbol{\theta},\boldsymbol{\pi}^2\right)$ were isolated by the sellers' LSR bets for either a confidentiality breach or having their earnings reduced by a punisher. Sellers in the indirect-sale treatment bet on confidentiality. Sellers in the direct-sale treatment bet on earnings deduction.

Four sellers decided not to participate in the LSR betting task.[32] Participation decisions were made by comparing the UP preference of not participating in the LSR task to the optimal bet, conditional on deciding to participate. Defining *BDM* as earnings from the BDM mechanism, sellers' UP preferences for not participating are given by

$$W_1\left(\mathbf{z}+BDM \mid j^1=\{\mathrm{c,n}\}\right)=\sum_{i^2=1^2}^{I^2}\theta_{i^2}u\left(\sum_{j^2=\{\mathrm{g,b}\}}\pi^2_{j^1i^2j^2}v\left(z_{j^2}+BDM\right)\right), \qquad (47)$$

for direct-sale groups and

$$W_1\left(\mathbf{z}+BDM\right)=\sum_{i^1=1^1}^{I^1}\sum_{i^2=1^2}^{I^2}\rho_{i^1}\theta_{i^2}u\left(\sum_{j^1=\{\mathrm{c,n}\}}\sum_{j^2=\{\mathrm{g,b}\}}\pi^1_{i^1j^1}\pi^2_{j^1i^2j^2}v\left(z_{j^2}+BDM\right)\right), \qquad (48)$$

for indirect-sale groups.

Conditional on participating in the belief elicitation task, sellers in direct-sale groups placed LSR bets (reports), λ, to maximize

[32] One of the sellers opting out of the LSR bet was in an indirect-sale group. The other three sellers were in direct-sale groups.

$$W_\lambda\left(\mathbf{q}_\lambda \mid j^1=\{\mathrm{c},\mathrm{n}\}\right)=\sum_{i^2=1^2}^{I^2}\theta_{i^2}u\left(\sum_{j^2=\{\mathrm{g},\mathrm{b}\}}\pi^2_{j^1 i^2 j^2}v\left(q_{j^2|\lambda}\right)\right), \tag{49}$$

where $\mathbf{q}_\lambda$ are the LSR payments given report λ. Sellers in the indirect-sale groups placed bets to maximize

$$W_\lambda\left(\mathbf{q}_\lambda\right)=\sum_{i^1=1^1}^{I^1}\sum_{i^2=1^2}^{I^2}\rho_{i^1}\theta_{i^2}u\left(\sum_{j^1=\{\mathrm{c},\mathrm{n}\}}\sum_{j^2=\{\mathrm{g},\mathrm{b}\}}\pi^1_{i^1 j^1}\pi^2_{j^1 i^2 j^2}v\left(q_{j^2|\lambda}\right)\right). \tag{50}$$

The decision to participate in the LSR and optimal report, conditional on participation, were modeled as a simultaneous decision, $\omega=\left\{\lambda^*,1\right\}\in\left(\boldsymbol{\lambda},1\right)$ using the link function

$$\nabla W=\frac{\exp\left(\mathrm{W}_{\omega^*}\left(\phi,\boldsymbol{\theta},\boldsymbol{\pi}^2;\alpha,r\right)/\mu_1\right)}{\sum_{\omega\in\Omega}\exp\left(\mathrm{W}_{\omega}\left(\phi,\boldsymbol{\theta},\boldsymbol{\pi}^2;\alpha,r\right)/\mu_1\right)}, \tag{51}$$

for bets made by sellers in the direct-sale, and

$$\nabla W=\frac{\exp\left(\mathrm{W}_{\omega^*}\left(\phi,\boldsymbol{\rho},\boldsymbol{\pi}^1;\alpha,r,\boldsymbol{\theta},\boldsymbol{\pi}^2\right)/\mu_1\right)}{\sum_{\omega\in\Omega}\exp\left(\mathrm{W}_{\omega}\left(\phi,\boldsymbol{\rho},\boldsymbol{\pi}^1;\alpha,r,\boldsymbol{\theta},\boldsymbol{\pi}^2\right)/\mu_1\right)}, \tag{52}$$

for bets made by sellers in the indirect-sale. $\mathrm{W}_\omega(\cdot)$ is defined as the contextual norm of sellers UP preferences, $W_\omega(\cdot)$. Implicit in equation (52) is the assumption that sellers in the indirect sale have the same priors and beliefs $\left(\boldsymbol{\rho},\boldsymbol{\pi}^1\right)$ as those sellers in the direct sale. The log likelihood function for equations (51) and(52) is

$$\ln L\left(\cdot;y,\mathbf{X},\alpha,r\right)=\sum_{t=1}^{T}\left\{y_t\ln\nabla W+\left[1-y_t\right]\ln\left[1-\nabla W\right]\right\},\ \alpha\neq 0,\ r\neq 1, \tag{53}$$

where $y_t = 1$ for the report ω^* and $y_t = 0$ for all other $\omega \in \Omega$[33].

The ELP task controlled attitudes towards uncertainty and varied probabilities. Sellers opting to participate in the LSR bet were allowed the option of swapping their bets on the uncertain events in exchange for bets defined by

$$\mathrm{P_L} = \left[\omega^* + 1\right] \big/ 101 \text{ and } \mathrm{P_R} = \left[100 - \omega^*\right] \big/ 101 .$$[34]

The objective bets were assumed evaluated as

$$EU = \mathrm{P}_L v\left(z_{\mathrm{L}}\right) + \mathrm{P_R} v\left(z_{\mathrm{R}}\right), \tag{54}$$

and ELP choices were assumed logistically distributed, with the probability

$$\nabla W = \frac{\exp\left(\mathrm{eu}\left(\mathrm{P_L}, \mathrm{P_R}; \alpha, r\right) / \mu_1\right)}{\exp\left(\mathrm{eu}\left(\mathrm{P_L}, \mathrm{P_R}; \alpha, r\right) / \mu_1\right) + \exp\left(\mathrm{W}_{\lambda^*}\left(\phi, \boldsymbol{\rho}, \boldsymbol{\pi}^1; \alpha, r, \boldsymbol{\theta}, \boldsymbol{\pi}^2\right) / \mu_1\right)}, \tag{55}$$

of a seller replacing the uncertain bet on confidentiality and

$$\nabla W = \frac{\exp\left(\mathrm{eu}\left(\mathrm{P_L}, \mathrm{P_R}; \alpha, r\right) / \mu_1\right)}{\exp\left(\mathrm{eu}\left(\mathrm{P_L}, \mathrm{P_R}; \alpha, r\right) / \mu_1\right) + \exp\left(\mathrm{W}_{\lambda^*}\left(\phi, \boldsymbol{\theta}, \boldsymbol{\pi}^2; \alpha, r\right) / \mu_1\right)}, \tag{56}$$

for consequences. The contextual normalizations of equation (54) is given by $\mathrm{eu}(\cdot)$ and μ_1 is a Fechner error parameter. The log-likelihood is

$$\ln L\left(\phi, \boldsymbol{\pi}_{\mathrm{A}}, \mu_1; y, \mathrm{P_L}, \mathrm{P_R}, \alpha, r, \mathbf{X}\right) = \sum_{t=1}^{T} \left\{ y_t \ln \nabla W + \left[1 - y_t\right] \ln\left[1 - \nabla W\right] \right\}, \ \alpha \neq 0, \ r \neq 1,$$

where $y_t = 1(0)$ indicates the t^{th} subject's choice of replacing(keeping) his uncertain LSR bet, and $\mathbf{X}$ is data pertaining to the choice task and/or subject characteristics.

[33] To remove portfolio and wealth effects subject participation in the LSR betting task was voluntary. Four sellers, one in the indirect sale and three in the direct sale treatments, opted not to participate in the LSR betting task. Thus, the set of reports Λ includes the nonparticipation option of keeping their status quo UP following the WTA task.

[34] Sellers opting not to participate in the LSR betting task were not afforded the opportunity to swap their status quo UP preference for the EU bet equation (54). By not participated in the LSR task, probabilities $\mathrm{P_L}$ and $\mathrm{P_R}$ were undefined.

5.3 Data and Results

Data gathered by the experimental design was used to test hypotheses 5 and 6.

HYPOTHESIS 5: Subjects' willingness-to-accept confidentiality loss is lower when making indirect sales of information to a party that does not have a direct mechanism to harm the subject.

HYPOTHESIS 6: Subjects cognitively differentiate between uncertain confidentiality breach and consequences.

Section 5.3.1 reports the estimated hurdle model given by equation (41) to test hypothesis 5, the "privacy paradox." The null is no difference in asking prices for sellers in the direct-sale (DS) and indirect-sale (IS) groups.

$$H5_0: WTA^r_{DS} - WTA^r_{IS} = 0$$

$$H5_A: WTA^r_{DS} - WTA^r_{IS} > 0$$

A positive difference, $H5_A$, supports hypothesis 5. Hypothesis 6 was tested as follows. Section 5.3.2 reports estimated risk attitudes alone, assuming EUT. Section 5.3.3 offers a partial test for hypothesis 6. Three models were estimated. First Model 2, equation (4), assumed subjects were uncertainty neutral in the consequences domain only. Second, Model 3, equation (5), assumed subjects were uncertainty neutral in the confidentiality domain only. Finally, sellers were assumed uncertainty neutral in both the confidentiality and consequences domains and an "SEU" model[35], assuming sellers were uncertainty neutral over both confidentiality and consequences, was estimated. The Clarke (2003,

[35] I purposely avoid describing uncertainty neutral preferences as SEU. In the context of Ellsberg's (1961) two-color problem SEU implies subjects believe balls are *only* distributed 50-50 (or some other distribution), for example. However, in the context of a privacy loss, the single belief interpretation appears to be inappropriate. There are *only* two possibilities: confidentiality is either breached *or* not breached. Seller's arguably do not believe their confidentiality is only partially lost, as the Ellsberg example would imply.

2006) test was used to choose among Models 2, 3, or "SEU" as the specification that explains sellers' privacy preferences.

5.3.1 Testing the Privacy "Paradox"

Average contributions by round for each of the four public goods treatments are shown in Figure 11. In each session, the private return from not investing in the public good was held fixed at 3 cents/tokens. The marginal per capita return (MPCR) from investment was set to 2 cents/tokens for half the sessions and 1 cent/token for the other half. Token endowments were set to 20 or 30 tokens. Comparing the right and left columns of Figure 11, previous empirical observations (Isaac and Walker 1988) were replicated. A higher MPCR results in greater efficiency providing the public goods.

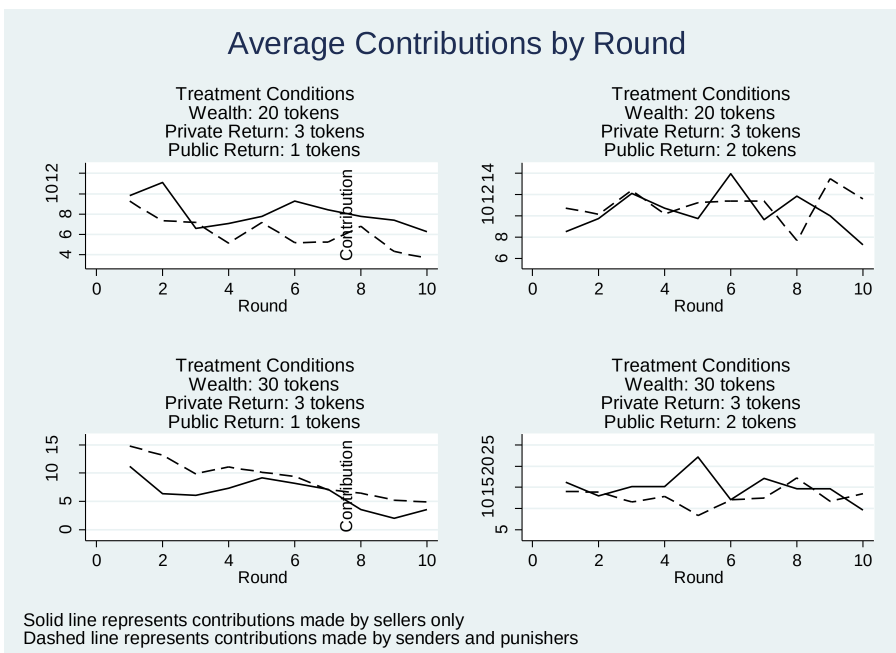


Figure 11. Public Goods Game Contributions

The distributions of raw WTA values for sellers in the direct-sale and indirect-sale groups are shown in Figure 12. The minimum asking price in direct-sale groups was $5, whereas the minimum asking price in indirect-sale groups was $0.01. Mean asking prices in the direct-sale treatment were $3.02 higher than asking prices from seller in indirect-sale groups.

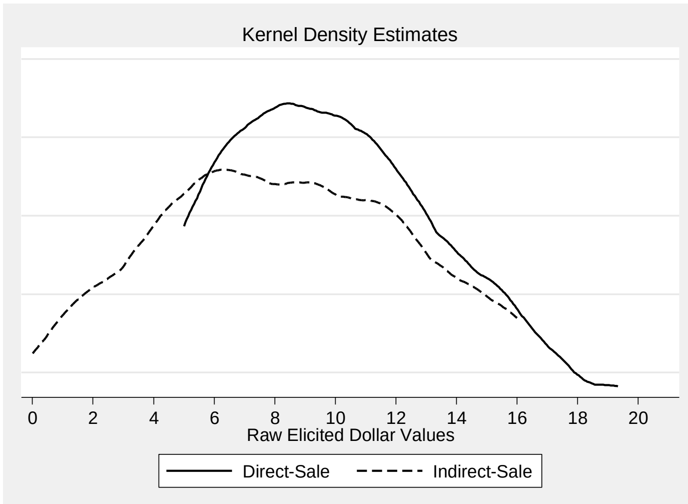


Figure 12. Distribution of WTA Values by Sale Type

The scatter diagram in Figure 13 plots sellers' stated WTA amounts against their earnings from the voluntary contributions game. Bid prices for sellers in the direct sale treatment are shown as blue dots and bids made by sellers in the indirect sale treatment are shown as a red ×. Trend lines for each group are also indicated. Mean asking prices for sellers in direct-sale groups are higher than sellers in indirect-sale groups for all earnings levels from the public goods game.

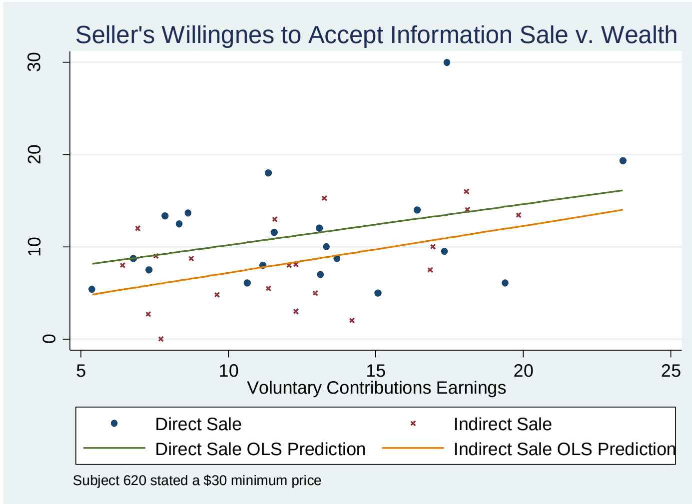


Figure 13. Scatter Plot WTA v. Wealth, by Sale Treatment

Controlling for the $20.99 upper threshold of the BDM mechanism, coefficient estimates from the hurdle model reported in Table 28 provide evidence supporting the "privacy paradox." Controlling for wealth earned in the public goods game, the mean asking price in the indirect-sale groups was $3.98. Asking prices from sellers in the direct-sale groups were significantly higher ($2.00) at the 0.117 level.

After controlling for previously identified experimental confounds, hypothetical bias, other regarding preferences, and deceitful practices, data gathered by the experimental design offer support for previously observed privacy behavior at levels greater than 10%. When selling personal earnings information directly to someone who may harm them, sellers' minimum willingness-to-accept compensation was higher than situations when the buyer did not have a direct mechanism to do harm but could give the information to someone who may do harm.

Table 28. Coefficient Estimates for Hurdle Model Testing the "Privacy Paradox"

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
Participation Equation						
φ	Probability WTA ≤ \$20.99					
Constant		7.4101	158.8722	0.9630	-303.9738	318.7939
PGearn	Voluntary Contribution Earnings	-0.1317	0.1281	0.3040	-0.3827	0.1193
Direct	Direct Sale = 1 Indirect Sale = 0	-3.8115	158.8556	0.9810	-315.1627	307.5397
WTA Bid Equation						
Constant		3.9827	2.0286	0.0500	0.0067	7.9588
PGearn	Voluntary Contribution Earnings	0.3543	0.1495	0.0180	0.0614	0.6473
Direct	Direct Sale = 1 Indirect Sale = 0	1.9973	1.2755	0.1170	-0.5027	4.4973
σ	Standard Error of Regression	3.9813	0.4508	<0.0001	3.0978	4.8648

Pseudo log-likelihood = -112.5437
Observations = 40

5.3.2 Risk Attitudes Alone

Average relative risk aversion for the subject pool was estimated with the CRRA utility function, $v(x) \equiv x^{[1-r]} / [1-r]$. On average, for the domain of RLP prizes (\$0 to \$50), all[36] subjects were risk averse with $\hat{r} = 0.6899$ (Table 29).

Table 29. Coefficient Estimates for Risk Attitudes from CRRA Utility

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
r	CRRA Coefficient	0.6899	0.0725	<0.0001	0.5478	0.8321
μ_0	RLP Fechner error	0.1210	0.0201	<0.0001	0.0815	0.1604

Pseudo log-likelihood = -2803.8896
Observations =4164

Parameter estimates assuming an expo-power utility function reject constant relative risk aversion in favor decreasing relative risk aversion as the prize rises (Table 30). Subjects exhibited risk aversion for low stakes gambles ($\hat{r} = 0.8271$) which is decreasing as lottery prizes increase to \$50 ($\hat{\alpha} = -0.997$). Relative risk aversion,

[36] Risk attitudes were estimated / controlled using RLP choices for all subjects: sellers, senders, and punishers.

$\text{RRA} = r + \alpha[1-r]x^{1-r}$. For the \$15 prize, RRA = 0.552. At \$50, RRA decreases to 0.488.

Table 30. Coefficient Estimates for Risk Attitudes from Expo-Power Utility

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.8271	0.0306	<0.0001	0.7672	0.8870
α	Positive income RRA normalization	-0.9970	0.1032	<0.0001	-1.1992	-0.7947
μ_0	RLP Fechner error	0.0974	0.0124	<0.0001	0.0731	0.1216
Pseudo log-likelihood = -2796.9236 Observations =4164						

5.3.3 The Uncertain Priors Model: Uncertain Distinctions

Figure 14 shows the distributions of raw LSR reports elicited from sellers. Four sellers decided not to participate in the LSR betting task, one from a direct-sale group and three from indirect-sale groups. The left two columns of Figure 14 show raw punishment beliefs for seller in the direct-sale groups. Raw confidentiality beliefs for sellers in indirect-sale groups are shown in the right-hand column. The ten sellers in the indirect-sale groups who did not sell their records were guaranteed privacy and their LSR bets on confidentiality were uninformative and dropped from the remainder of the analysis. Out of the remaining ten sellers in indirect-sale groups who sold their records, only one decided not to participate in the LSR betting task.

Out of twenty sellers in direct-sale groups, ten sold their records and ten did not. The mean report for the seven sellers betting on punishment given non-confidential records was 0.671, with median 0.62 and standard deviation 0.30. The Kolmogorov-Smirnov test rejects anchoring biases at the 0.057 level. For the ten sellers betting on punishment given confidentiality anchoring bias was rejected at the 0.695 level and the mean report was 0.359, with median 0.455 and standard deviation 0.303. For the nine sellers in the indirect-sale groups betting on confidentiality, the mean raw report was 0.393, with median 0.39 and standard deviation 0.24. Anchoring biases are rejected at the 0.556 level.

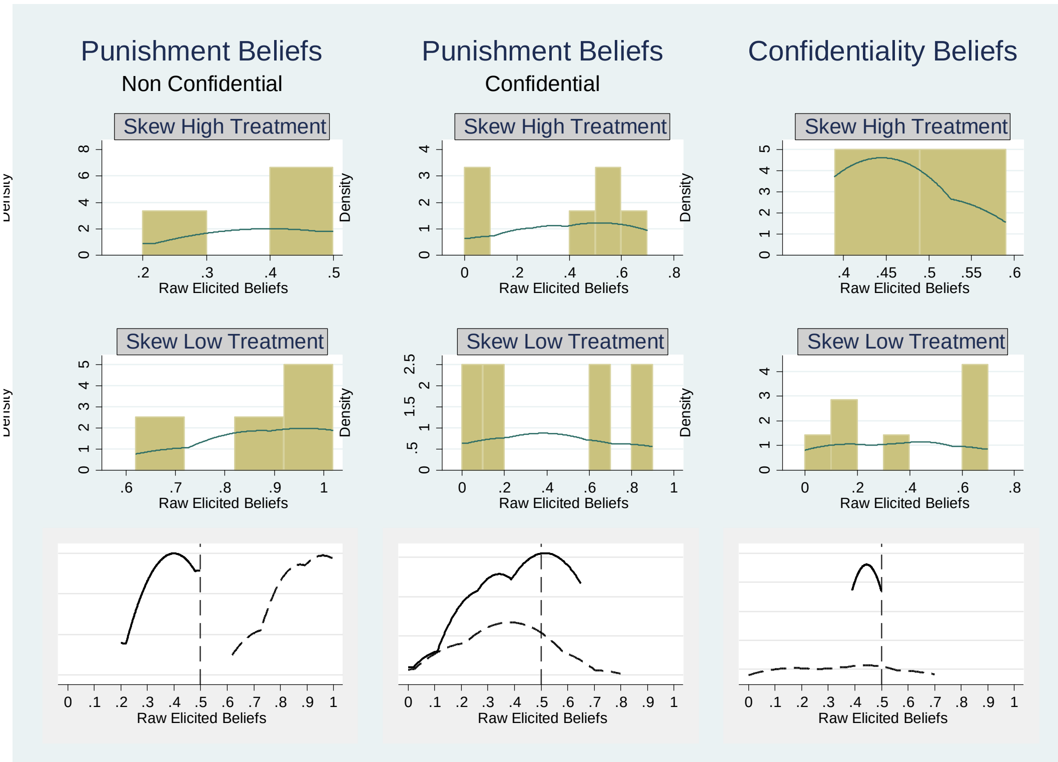


Figure 14. Raw LSR Beliefs

Raw beliefs summarized in Figure 14 suggest that sellers believed confidentiality loss had a low chance of occurring. However, if confidentiality was lost the likelihood of a being punished was substantially larger than when confidentiality was upheld. Controlling for risk and uncertainty attitudes, maximum likelihood estimates confirm these observations.

Likelihood estimates when subjects were assumed uncertainty neutral in the consequences domain (Model 2) are shown in Table 31. Controls for anchoring bias in punishment beliefs given non-confidentiality are shown in Table 32. The variable *Anchor* takes on values of 1 if the sellers' LSR bets were in the skew high treatment when the "safe" bet was at row 39 of the decision sheet, and 0 otherwise. Anchoring bias is rejected at conventional levels, $\hat{\rho}_{\mathrm{b|n}Anchor} = -0.0202$ with p-value = 0.974. Assuming sellers were uncertainty neutral in the consequences domain; estimates reported in Table 31 explain seller beliefs and preferences.

Under Model 2, sellers weight the event of confidentiality loss by $\hat{\rho}_{\mathrm{n}} = 0.2951$ with p-value = 0.031. When records are not confidential, $\hat{\rho}_{\mathrm{b|n}} = 0.8834$ (p-value < 0.0001) and sellers believed there was approximately an 88% chance their earnings from the public goods game would be reduced by the punisher. Sellers place insignificant weight $\hat{\rho}_{\mathrm{b|c}} = 0.1635$ (p-value = 0.202) on being punished when their records were confidential.

Table 31. Model 2: Uncertainty Neutral in Consequences Domain

Variable	Description	Coefficient	Standard Error	p-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.8267	0.0178	<0.0001	0.7919	0.8615
α	Positive income RRA normalization	-0.9964	0.0898	<0.0001	-1.1723	-0.8204
μ_0	RLP Fechner error	0.0971	0.0123	<0.0001	0.0731	0.1212
ρ_{n}	Prior weight: confidentiality	0.2951	0.1369	0.0310	0.0267	0.5636
$\rho_{\mathrm{b\|n}}$	Prior weight: consequence | non-confidential	0.8839	0.2008	<0.0001	0.4903	1.2776
$\rho_{\mathrm{b\|c}}$	Prior weight: consequence | confidential	0.1635	0.1283	0.2030	-0.0880	0.4149
ϕ	CRUA coefficient	-0.4745	0.4278	0.2670	-1.3131	0.3640
μ_1	Fechner error	0.1363	0.0703	0.0520	-0.0014	0.2740

Pseudo log-likelihood = -2926.5533
Observations = 4217

Table 32. Model 2: Uncertainty Neutral in Consequences Domain with Treatment Effects

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.8266	0.0202	<0.0001	0.7871	0.8661
α	Positive income RRA normalization	-0.9951	0.0460	<0.0001	-1.0852	-0.9050
μ_0	RLP Fechner error	0.0971	0.0127	<0.0001	0.0722	0.1220
ρ_n	Prior weight: confidentiality	0.2955	0.1795	0.1000	-0.0562	0.6472
$\rho_{\text{b}\vert\text{n}}$	Prior weight: consequence | non-confidential					
Constant		0.8973	0.3224	0.0050	0.2654	1.5293
Anchor	LSR anchoring treatment	-0.0202	0.6323	0.9740	-1.2594	1.2190
$\rho_{\text{b}\vert\text{c}}$	Prior weight: consequence | confidential	0.1643	0.1316	0.2210	-0.0935	0.4222
ϕ	CRUA coefficient	-0.4715	0.4677	0.3130	-1.3882	0.4451
μ_1	Fechner error	0.1356	0.1039	0.1920	-0.0679	0.3392

Pseudo log-likelihood = -2926.5524
Observations = 4217

Table **33** shows the likelihood estimates from Model 3 where sellers are assumed to be uncertainty neutral in the confidentiality domain. Table **34** estimates Model 3 with a treatment variable to control for anchoring bias in seller beliefs that they will be punished when their information is not held in confidentiality. Controlling for risk and uncertainty attitudes, the *p*-value for $\hat{\rho}_{\text{b}|\text{n}Anchor} = -0.0371$ is large (0.918) and the null of no bias is not rejected.

Estimated prior weights shown in Table **33** suggest that sellers trusted that their confidentiality would be kept by senders in the indirect-sale groups, $\hat{\rho}_\text{n} = 0.186$ with *p*-value = 0.188. This result contrasts with that of Model 2 (Table 31) which estimated that subjects were somewhat distrusting of the senders. Sellers did not place significant weight on the event that confidentiality would be breached and their records would be given to a punisher.

In the event that records were not confidential and punishers knew the earning from the public goods game, sellers weight $\hat{\rho}_{\text{b}|\text{n}} = 0.756$ (*p*-value < 0.001) on the being punished and having their public goods earning reduced by 50%. Sellers place insignificant weight $\hat{\rho}_{b|c} = 0.2852$ (p-value = 0.185) on being punished when their records were confidential. The p-value (0.514) for the coefficient or relative uncertainty $\hat{\phi} = -0.1746$ suggests sellers were uncertainty neutral in the confidentiality domain.

Table 33. Model 3: Uncertainty Neutral in Confidentiality Domain

Variable	Description	Coefficient	Standard Error	p-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.8249	0.0218	<0.0001	0.7821	0.8677
α	Positive income RRA normalization	-0.9882	0.0204	<0.0001	-1.0283	-0.9481
μ_0	RLP Fechner error	0.0963	0.0119	<0.0001	0.0729	0.1197
ρ_n	Prior weight: confidentiality	0.1860	0.1413	0.1880	-0.0909	0.4628
$\rho_{b\|n}$	Prior weight: consequence | non-confidential	0.7560	0.2070	<0.0001	0.3503	1.1617
$\rho_{b\|c}$	Prior weight: consequence | confidential	0.2852	0.2155	0.1860	-0.1371	0.7075
ϕ	CRUA coefficient	-0.1746	0.2678	0.5140	-0.6994	0.3503
μ_1	Fechner error	0.1559	0.0790	0.0490	0.0001	0.3107
Pseudo log-likelihood = -2926.4906 Observations = 4217						

Table 34. Model 3: Uncertainty Neutral in Confidentiality Domain with Treatment Effects

Variable	Description	Coefficient	Standard Error	p-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.8246	0.0147	<0.0001	0.7958	0.8534
α	Positive income RRA normalization	-0.9859	0.0870	<0.0001	-1.1564	-0.8153
μ_0	RLP Fechner error	0.0962	0.0122	<0.0001	0.0724	0.1201
ρ_n	Prior weight: confidentiality	0.1886	0.1567	0.2290	-0.1184	0.4957
$\rho_{b\|n}$	Prior weight: consequence | non-confidential					
Constant		0.7837	0.2487	0.0020	0.2964	1.2711
Anchor	LSR anchoring treatment	-0.0371	0.3612	0.9180	-0.7451	0.6709
$\rho_{b\|c}$	Prior weight: consequence | confidential	0.2849	0.2279	0.2110	-0.1618	0.7317
ϕ	CRUA coefficient	-0.1719	0.2883	0.5510	-0.7370	0.3931
μ_1	Fechner error	0.1539	0.0977	0.1150	-0.0375	0.3454
Pseudo log-likelihood = -2926.4837 Observations = 4217						

Figure **15** graphically compares the distribution of likelihood ratios from Models 2 and 3 to the normal distribution. The Shapiro-Wilk statistic, W = 0.922 n = 53, rejects normality of the distribution and Clarke's (2003, 2006) sign test is appropriate to discriminate between models. Model 3 yields higher likelihood values for 31 out of 52 non-zero differences. With a *p*-value = 0.1058, Model 3 is "better than" Model 2.

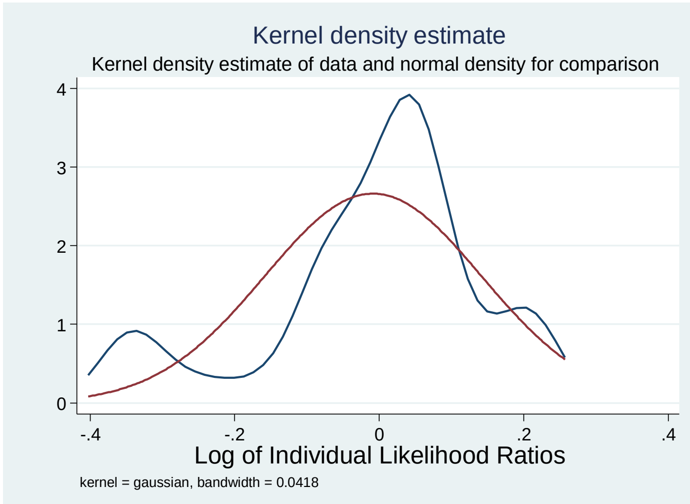


Figure 15. Distribution Likelihood Ratios: Model 2 vs. Model 3

Constraining sellers to be uncertainty neutral in both confidentiality and consequences domains, point estimates in Table **35** describe a belief structure comparable to Models 3. Table **36** rejects anchoring bias at conventional levels, $\hat{\rho}_{b|nAnchor} = -0.0397$ with *p*-value = 0.941.

Table 35. "SEU" Model: Uncertainty Neutral in Confidentiality and Consequences Domains

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.8256	0.0167	<0.0001	0.7930	0.8583
α	Positive income RRA normalization	-0.9868	0.0617	<0.0001	-1.1078	-0.8659
μ_0	RLP Fechner error	0.0969	0.0121	<0.0001	0.0731	0.1207
ρ_n	Prior weight: confidentiality	0.1657	0.1419	0.2430	-0.1125	0.4438
$\rho_{b\|n}$	Prior weight: consequence | non-confidential	0.8720	0.1994	<0.0001	0.4812	1.2629
$\rho_{b\|c}$	Prior weight: consequence | confidential	0.1739	0.1257	0.1670	-0.0726	0.4204
μ_1	Fechner error	0.2034	0.0621	0.0010	0.0816	0.3252
Pseudo log-likelihood = -2926.685 Observations = 4217						

Table 36. "SEU" Model: Uncertainty Neutral in Confidentiality and Consequences Domains with Treatment Effects

Variable	Description	Coefficient	Standard Error	*p*-value	Lower 95% CI	Upper 95% CI
r	RRA at zero income	0.8258	0.0176	<0.0001	0.7914	0.8602
α	Positive income RRA normalization	-0.9899	0.0550	<0.0001	-1.0976	-0.8821
μ_0	RLP Fechner error	0.0969	0.0123	<0.0001	0.0728	0.1209
ρ_{n}	Prior weight: confidentiality	0.1689	0.1511	0.2640	-0.1272	0.4651
$\rho_{\mathrm{b\vert n}}$	Prior weight: consequence | non-confidential					
Constant		0.8992	0.2945	0.0020	0.3220	1.4765
Anchor	LSR anchoring treatment	-0.0396	0.5411	0.9420	-1.1002	1.0209
$\rho_{\mathrm{b\vert c}}$	Prior weight: consequence | confidential	0.1754	0.1260	0.1640	-0.0716	0.4224
μ_1	Fechner error	0.2002	0.0789	0.0110	0.0455	0.3549
Pseudo log-likelihood = -2926.6808 Observations = 4217						

The "SEU" model (Table **35**) is nested in Models 3 (Table **33**) by the constraint $\phi = 0$. The likelihood ratio test applied to observations from the LSR and ELP decisions failed to reject the equivalence of Model 3 and the "SEU" model ($\chi_1^2 = 0.5224$).

5.4 Experiment Summary

Chapter 5 set out to test two hypotheses.

HYPOTHESIS 5: Subjects' willingness-to-accept confidentiality loss is lower when making indirect sales of information to a party that does not have a direct mechanism to harm the subject.

HYPOTHESIS 6: Subjects cognitively differentiate between uncertain confidentiality breach and consequences.

Estimates from the hurdle model (Table **28**) in Section 5.3.1 demonstrated that the "privacy paradox" survives strict experimental controls for hypothetical bias, deceitful practices, and other regarding preferences at levels greater than 10%. The average WTA privacy loss was estimated to be $1.99 higher when trading directly with someone who may do harm. The analysis failed to reject hypothesis 5 at the 0.117 level. Willingness-to-accept confidentiality loss was lower when making indirect sales of information to a party that did not have a direct mechanism to do harm.

To test hypothesis 6, two different specifications of the uncertain priors models were estimated. The first, Model 2 (equation (4)), assumed attitudes towards uncertainty were neutral towards consequences and potentially non-neutral to confidentiality. Model 3 (equation (5)), assumed subjects were uncertainty neutral in the confidentiality domain and potentially non-neutral in the consequences domain. Conclusions from the Clarke (2003, 2006) test are evidence in favor of Model 3 and hypothesis 6. However, the likelihood ratio test failed to reject equivalence of Model 3 (Table **33**) and “SEU” preferences (Table **35**). It should also be recognized that estimated beliefs assuming Model 3 and the “SEU” model were behaviorally consistent, where as Model 2 assigned significant positive weight on non-confidentiality.

6. CONCLUSIONS

There is no "privacy paradox." The dichotomy in the canonical "loyalty card" framework (Acquisti and Grossklags 2005a) is attributable to asymmetric subjective beliefs (Syverson 2003; and Rifon, LaRose, and Lewis 2007) and subjects' do not exhibit significant amounts of uncertainty aversion (Acquisti and Grossklags 2004 and 2005a) over either confidentiality or consequences. These conclusions are based on the results of three separate studies.

Chapter 3 presented an experiment in individual decision making under uncertainty, experimentally testing Ellsberg's canonical two-color choice problem. The data did not support Ellsberg's hypothesis of uncertainty aversion. Subjects believed bets on the color ball drawn from Ellsberg's ambiguous urn were equally likely to pay and estimated attitudes towards uncertainty were insignificant. Savage's subjective expected utility model explains subjects' choices. The results contrast with previous findings (Camerer and Webber 1992; Halevy 2007; and others). These differences deserve further investigation. It was also demonstrated that use of an objective compound lottery to induce uncertainty did not affect subjects' choices. Smith's hypothesis is supported, however, in an entirely different way than expected.

Chapter 4 extended the concept of uncertainty to commodities where quality and accuracy of a quality report are potentially ambiguous. The uncertain priors model was naturally extended to allow for potentially different attitudes towards these two sources of uncertainty, quality and accuracy. As they relate to privacy, quality and accuracy of a quality report are metaphors for online security and consumer trust in e-commerce. The results of parametric structural tests demonstrated that it is possible to discriminate between econometric models allowing subjects to have different preferences towards different uncertain processes. Allowing subjects to be uncertainty averse in the quality domain and not the report domain outperformed the alternative which only allows for uncertainty aversion in the accuracy domain only. Estimated beliefs placed significantly more weight on report accuracy, supporting trust as an experimental confound in Spiekerman, Grossklags, and Berendt (2002), Berendt, Günther, and Spiekerman (2005). Subjects weighted

Finally, chapter 5 identifies subjects' privacy beliefs which support the hypothesis of Syverson (2003) and Rifon, LaRose, and Lewis (2007), only. The difference between WTA privacy loss in direct-sale and indirect-sale groups was positive and significant at levels greater than 10%. The roles of asymmetric beliefs and attitudes towards uncertainty were identified using parametric structural likelihood methods. Subjects were uncertainty neutral and believed "bad" events were more likely to occur when their private information was not confidential. The uncertainty aversion hypothesis of Acquisti and Grossklags (2004) and (2005a) was not supported. Asymmetric beliefs explained subject's privacy behavior (Syverson 2003).

APPENDIX A: IRB HUMAN RESEARCH APPROVAL

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Elisabet E. Rutstrom** and Co-PIs: **David R. Rivenbark, Glenn W. Harrison**

Date: **January 20, 2010**

Dear Researcher:

On 1/20/2010, the IRB approved the following human participant research until 1/19/2011 inclusive:

Type of Review:	Submission Response for UCF Initial Review Submission Form
Project Title:	Uncertainty, Identification, and Privacy
Investigator:	Elisabet E. Rutstrom
IRB Number:	SBE-10-06661
Funding Agency:	Research and Commercialization, University of Central Florida, University of Central Florida
Grant Title:	N/A
Research ID:	n/a

The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 1/19/2011, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Joseph Bielitzki, DVM, UCF IRB Chair, this letter is signed by:

Signature applied by Joanne Muratori on 01/20/2010 10:27:21 AM EST

Joanne Muratori

IRB Coordinator

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APPENDIX B: THREE-COLOR ELLSBERG PROBLEM

Consider Ellsberg's (1961, p. 653) three-color problem. There is one urn containing 90 balls. Thirty balls are known to be red. The remaining 60 are black and yellow, in unknown proportion. One ball will be drawn from the urn at random and decision-makers are to consider the four bets shown in Table 37.

Table 37. Ellsberg's Three One Urn, Three-Color Problem

	Red	Black	Yellow
I	\$100	\$0	\$0
II	\$0	\$100	\$0
III	\$100	\$0	\$100
IV	\$0	\$100	\$100

Choosing I is a bet on red, II is a bet on black, III is a bet on red or yellow, and IV is a bet on black or yellow. Ellsberg hypothesizes that a frequent response pattern is $\text{I} \succ \text{II}$ and $\text{IV} \succ \text{III}$. These preferences violate the Sure-thing Principle. The two sets of bets I vs. II and III vs. IV differ only by the payoff if yellow occurs, which is constant in each pair of bets.

The preference of I to II implies decision-makers believe there are less than 30 black balls in the urn, which in turn implies the event "red or yellow" has more than two-thirds chance of occurring. Thus the contradiction occurs when decision-makers prefer the two-thirds chance of winning \$100 (bet IV) to a greater than two-thirds chance (bet III). The uncertainty aversion hypothesis explains these preferences by claiming that decision-makers "don't like" the possibility that there are really more than 30 black balls in the urn. These preferences can be explained using the uncertain priors model

$$W(\mathbf{z}) = \sum_{i=1}^{I} \rho_i u\left(\sum_{j=1}^{J} \sum_{k=1}^{K} \sigma_{ijk} v\left(z_{jk}\right) \right), \tag{2}$$

with K = 1 and j = {red, black, yellow}.

Assume the decision-maker has two priors that he weights equally, $\boldsymbol{\rho} = (0.5, 0.5)$. Under prior 1, he believes there are 40 black balls in the urn and his subjective probabilities are $\boldsymbol{\sigma}_1 = \left(\frac{1}{3}, \frac{4}{9}, \frac{2}{9}\right)$. Under prior 2, he believes there are 20 black balls in the urn and $\boldsymbol{\sigma}_2 = \left(\frac{1}{3}, \frac{2}{9}, \frac{4}{9}\right)$. If his first-order preferences are defined by $v(x) \equiv \sqrt{x}$, for some argument *x*, the evaluation of $\sum_{j=1}^{J} \sigma_{ij} v(z_{jk})$ for bet I is

$$\text{I:} \qquad \tfrac{1}{3}10 + \tfrac{4}{9}0 + \tfrac{2}{9}0 = 3.3333,$$

under prior 1 and

$$\text{I:} \qquad \tfrac{1}{3}10 + \tfrac{2}{9}0 + \tfrac{4}{9}0 = 3.3333,$$

under prior 2. With second-order utility defined by $u(x) \equiv x^{0.9}$, the decision-maker's UP preferences for bet I are

$$W(\text{I}) = 0.5\left[3.3333^{0.9}\right] + 0.5\left[3.3333^{0.9}\right] = 2.955.$$

Similar calculations for bets II, III, and IV yield

$$W(\text{II}) = 0.5\left[4.4444^{0.9}\right] + 0.5\left[2.2222^{0.9}\right] = 2.9401,$$

$$W(\text{III}) = 0.5\left[5.5555^{0.9}\right] + 0.5\left[7.7777^{0.9}\right] = 5.5077,$$

$$W(\text{IV}) = 0.5\left[6.6666^{0.9}\right] + 0.5\left[6.6666^{0.9}\right] = 5.5146.$$

Comparing these preference values, *W*(I) > *W*(II) and *W*(IV) > *W*(III) which explains Ellsberg's hypothesized pattern of preferences. If there was no aversion to uncertainty such that $u(x) \equiv x$ apart from arbitrary normalizations, then *W*(I) = *W*(II) and *W*(III) = *W*(IV). This result is not what Ellsberg predicted and suggests the preferences

$I \succ II$ and $IV \succ III$ may result from a systematic resolution of indifference where decision-makers focus on bets I and IV.

APPENDIX C: SOURCE-DEPENDENT RISK ATTITUDES

Nau (2006, Model II, Theorem 2, p. 143) presents an axiomatic proof of the source-dependant risk aversion (SDRA) model capable of explaining the behavior in Ellsberg's example. The SDRA model may formally be represented as a special case of the UP model, and is interpreted as assuming that the decision-maker only considers uncertain processes where the ambiguous urns contains either all red or all black balls (Nau 2007).

From equation (1), if the decision-maker forms priors equal in number to the set of possible uncertain events, let $I = J$ and rewrite π_{ij}^{U} as π_{i}^{U}. Then, by making the further assumption that each prior i is degenerate, so that $\pi_{i}^{U} = \{1, 0\}$, the UP model becomes

$$W(\mathbf{z}) = \sum_{i=1}^{I} \rho_i u\left(\sum_{k=1}^{K} \pi_k^C v(z_{ik}) \right), \tag{A1}$$

which is the SDRA model, where by definition $i = \{\mathrm{r}, \mathrm{b}\}$ and $k = \{\mathrm{R}, \mathrm{B}\}$.

In equation (2), the decision-maker can be viewed as if he evaluates $v(\cdot)$ first, then he evaluates $u(\cdot)$ at the expectation of $v(\cdot)$, taken over $k = \{\mathrm{R}, \mathrm{B}\}$. Finally, preferences for the lotteries in Table **1** are determined by the evaluation of the expectation of $u(\cdot)$, taken over $i = \{\mathrm{r}, \mathrm{b}\}$. In this case, the decision-maker simply behaves *as if* the uncertain urn contains either all red balls or all black balls.

For both lotteries L_2 and L_3 his expectation of utility over certain event k is $5 = \frac{1}{2} \cdot 10 + \frac{1}{2} \cdot 0$. Table 38 shows the decision-maker's expectation of $v(\cdot)$ for each lottery, under these assumptions.

Table 38: Expected EU Assuming SDRA Model

U events	L_1	L_2	L_3	L_4
U_r	$5 = \frac{1}{2} \cdot 10 + \frac{1}{2} \cdot 0$	$0 = \frac{1}{2} \cdot 0 + \frac{1}{2} \cdot 0$	$10 = \frac{1}{2} \cdot 10 + \frac{1}{2} \cdot 10$	$5 = \frac{1}{2} \cdot 10 + \frac{1}{2} \cdot 0$
U_b	$5 = \frac{1}{2} \cdot 10 + \frac{1}{2} \cdot 0$	$10 = \frac{1}{2} \cdot 10 + \frac{1}{2} \cdot 10$	$0 = \frac{1}{2} \cdot 0 + \frac{1}{2} \cdot 0$	$5 = \frac{1}{2} \cdot 10 + \frac{1}{2} \cdot 0$

From these calculations, it is easy to see how the SDRA model can also explain the pattern of preferences assumed in Ellsberg's example. The decision-maker will have final utility for L_2 equal to that of L_3, and utility from L_1 will equal L_4. However, if the decision-maker believes that "r" is less likely than "b" and $u(\cdot)$ is sufficiently concave, then it is easy to see how he could have the preference relations described above. Lotteries L_1 and L_4 hedge the uncertainty surrounding which color ball will be drawn from urn 2.

APPENDIX D: EXPERIMENTAL INSTRUCTIONS FOR CHAPTER 3

D.1 Experimenter Instructions

Experimenter Instructions

Welcome. This is an experiment in individual decision making. You can earn cash based on the choices you make today. Money you earn today will be paid to you in cash at the end of the experiment. You will be paid $5 for participating in the experiment. The experiment will last no more than **2** hours. Please make sure that you can stay until the end. In addition to the participation fee, your earnings will depend partly on chance and partly on the choices you make today. The instructions are simple and you will benefit from following them carefully.

There are three stages today:

1. We will ask you a series of questions about yourself, such as some basic information about your age. The computer will prompt you for these questions, and you should just work through them at your own pace when we log you in.
2. We will then pause and provide instructions on some choices you are to make over different amounts of money that have different chances of occurring. These choices will directly affect your earnings.
3. We will then pause again, and provide some instructions on the final task, which involves you making some more choices over different amounts of money that have different chances of occurring. These choices will also directly affect your earnings.

The instructions for the second and third stage will provide more information on the type of choices you are being asked to make.

The experimenters will then collate all of your earnings and pay you for the money you have earned.

Your choices are private, and will only be associated with an ID that we will enter when we log you in to the computer. So your name, address and SSN will not be linked to any choices you make. We will pay you privately, one at a time, to keep your earnings private.

Are there any questions? If not, go ahead and answer the questions until the computer pauses and asks for a password. When everyone is finished this stage we will announce the password and we can go on to the second stage. There is no hurry, so take your time.

[Wait for everyone to finish demographics]

There is an instruction book in front of each of you. Please open it and follow along as I read the instructions out loud.

[Do Ellsberg task, read instructions out load]

Before I spin Cage #1 and Cage #2, each of you have the chance to make another choice, with much higher potential payoffs. Our research assistants are passing around the decision sheets for this task. If you choose to participate in this task, we will not pay you for the decision that you just made. You have the choice which decision we will pay you for: the one you just completed, or the new one we are offering you now.

As you can see from the decision book just handed out, earnings from this next choice may be very large, but they may also be small. If you decide not to participate in this task, please use the pen on your desk to cross out the title of your new book: *DECISION TASK*. This is your decision to make. If you decide to participate, please circle the title of the decision book and cross out the title of your old book: *INDIVIDUAL DECISION MAKING*. We will pay you today for all money earned in this task if you choose to participate. Are there any questions?

[Do belief elicitation task, read instructions out load]

Now that each of you has made your decisions for each of these tasks and we know which decision you will be paid for, I will uncover Cage #2. As you can see, Cage #2 is filled with orange and white balls. I would like to ask for one final volunteer to come up and verify that there are exactly 50 balls in Cage #2.

I will now spin each cage. You will be paid according to the choices you have made and the color ball chosen from each cage.

Now that everyone has completed the second stage of today's experiment, research assistants are passing around instruction books for the third and final stage.

[Do random lottery pairs task, read instructions out load.]

D.2 Stage 1: Demographics Questionnaire

Vecon Lab Questionnaire Program: Review Questions

Please review the questions you have entered.
The next page will provide a link for revisions and changes.

Questionnaire Title: Demographic Questions

Welcome Statement:

In this survey your responses are completely confidential. The questions are purely descriptive and you will not be graded or paid. Please think carefully about each question and give your best answers.

What is your age? (required)

What is your sex? (required)
- Male
- Female

Which of the following categories best described you? Check one only. (required)

What is your major? Check one only. (required)

What is your class standing? Check one only. (required)

What is the highest level of education you expect to complete? (required)
- Bachelors degree
- Masters degree
- Doctoral degree
- First professional degree

What was the highest level of education that your father (or male guardian) completed? (required)
- Less than high school
- GED or High School Equivalency
- High School

- Vocational or trade school
- College or university

What was the highest level of education that your mother (or female guardian) completed? (required)
- Less than high school
- GED or High School Equivalency
- High School
- Vocational or trade school
- College or university

What is your citizenship status in the United States? (required)
- U.S. Citizen
- Resident Alien
- Non-Resident Alien
- Other Status

Are you a foreign student on a Student Visa? (required)
- Yes
- No

Are you currently..... (required)
- Single and never married?
- Married?
- Separated, divorced or widowed?

On a 4-point scale, what is your current GPA if you are doing a Bachelors degree, or what was it when you did a Bachelor's degree? This GPA should refer to all of your coursework, not just the current year. Please pick one: (required)

How many people live in your household? Include yourself, your spouse and any dependents. Do not include your parents orroomates unless you claim them as dependents. (required)

Please select the category below that describes the total amount of income earned in 2009 by the people in your household (as household is defined above). Please consider all forms of income, including salaries, tips, interest and dividend payments, scholarship support, student loans, parental support, social security, alimony, child support, and others. (required)

Please select the category below that describes the total amount of income earned in 2009 by your parents. Please consider all forms of income, including salaries, tips, interest and dividend payments, scholarship support, student loans, parental support, social security, alimony, child support, and others. (required)

Do you work part-time, full-time, or neither? (required)

- Part-time
- Full-time
- Neither

Do you smoke? (required)

- No, never
- Not now
- Yes -- less than a pack a day
- Yes -- between 1 and 2 packs a day
- Yes -- more than 2 packs a day

How would you classify your religious beliefs? Please check the one that best represents them. (required)

A bat and a ball cost $1.10 in total. The bat costs $1.00 more than the ball. How much does the ball cost? (_____ cents) (required)

If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets? (_____ minutes) (required)

In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? (_____ days) (required)

What was your SAT score for admission to UCF? (required)

Closing Statement: Thanks for your responses!

Continue to Revise or Submit Questions

Vecon Lab - January 21, 2010

D.3. Stage 2: Ellsberg / Smith Instructions

D.3.1 Ellsberg Task

We are interested in your choices, which might be different from the choices someone else would make. The only right answer is what you really would choose. That is why the choices are for real money.

In the front of the room there are two bingo cages, labeled Cage #1 and Cage #2. There are 25 orange balls and 25 white balls in front of Cage #1. Cage #2 is covered and contains 50 balls. Each ball is either orange or white. You will not be told how many balls are orange or white. Before we start, I would like to ask one person to come up and inspect Cage #1. The volunteer will verify that there are 25 orange balls and 25 white balls and then place each ball in Cage #1. If you would like to volunteer please raise your hand.

On the last page of this booklet there is a record sheet with four paired choices for you to make between "Option A" and "Option B." These four decisions are reprinted here.

Row	Option A	Option B	Decision		
1	Win $10 if orange ball is drawn from Cage #1 Win $0 if white ball is drawn from Cage #1	Win $0 if orange ball is drawn from Cage #1 Win $10 if white ball is drawn from Cage #1	**A**	**B**	**Don't Care**
2	Win $10 if orange ball is drawn from Cage #2 Win $0 if white ball is drawn from Cage #2	Win $0 if orange ball is drawn from Cage #2 Win $10 if white ball is drawn from Cage #2	**A**	**B**	**Don't Care**
3	Win $10 if orange ball is drawn from Cage #1 Win $0 if white ball is drawn from Cage #1	Win $10 if orange ball is drawn from Cage #2 Win $0 if white ball is drawn from Cage #2	**A**	**B**	**Don't Care**
4	Win $0 if orange ball is drawn from Cage #1 Win $10 if white ball is drawn from Cage #1	Win $0 if orange ball is drawn from Cage #2 Win $10 if white ball is drawn from Cage #2	**A**	**B**	**Don't Care**

In each row you will be asked to circle one of the three decisions. Only one of the four decisions you make will end up affecting your earnings, but you will not know in advance which decision will be used. Your earnings from this decision will depend on your choice and the outcome of a spin of each of the bingo cages in the front the room.

Please look at row 1, at the top of the table. Option A will pay $10 if the ball drawn from Cage #1 is orange, and Option B will pay $10 if the ball drawn from Cage #1 is white. The other decisions are similar. For the last row, Option A will pay $10 if the ball drawn from Cage #1 is white, and Option B will pay $10 if the ball drawn from Cage #2 is white.

In the column labeled “Decision” there are three choices for each row. For each row, circle the letter of the option that you prefer. If you do not care whether you receive Option A or Option B, circle “Don’t Care.”

After making each of your four decisions, please raise your hand and wait for assistance. A research assistant will bring you a 6-sided die that you will roll to determine which row from the record sheet you will be paid from. If you roll a 1, 2, 3, or 4 then you will be paid according to that row. If a 5 or 6 are rolled, you will roll the die again until you roll a 1, 2, 3, or 4. If you choose Don’t Care in the decision that we play out, we will pick one for you using a 10-sided die, where the numbers 1-5 correspond to Option A and the numbers 6-10 correspond to Option B.

After we know which decision is binding, we will uncover Cage #2 then spin both bingo cages to see if you receive the higher amount or the lower amount for the choice that you made. If you choose Option A you would be paid the appropriate amount in Option A. If you choose Option B you would be paid the appropriate amount in Option B.

Before you circle your decisions, lets uncover the cages under this blue sheet and use them to do an example together. For each of the four decisions, we will flip a coin to determine if we choose option A or option B. We will use the white board to keep track of our four decisions.

For row 1, option A will pay $10 if the ball drawn from Cage #1 is orange. Option B will pay $10 if the ball drawn from Cage #1 is white.

For row 2, option A will pay $10 if the ball drawn from Cage #2 is orange. Option B will pay $10 if the ball drawn from Cage #2 is white.

For row 3, option A will pay $10 if the ball drawn from Cage #1 is orange. Option B will pay $10 if the ball drawn from Cage #2 is orange.

For row 4, option A will pay $10 if the ball drawn from Cage #1 is white. Option B will pay $10 if the ball drawn from Cage #2 is white.

Now that we have made each of our four choices, we will roll a 6-sided die to determine which row is played for this example.

Now that we know which row will be used to determine how we are paid, we will pick one ball from Cage #1 and Cage #2 to determine what our earnings would be.

Are there any questions?

You may now mark **your decisions** for each row of the decision sheet. When you are satisfied with the decisions that you have made, please raise your hand and wait for a research assistant to bring the dice to determine which row you will be paid from.

D.3.1.1 Smith Treatment

We are interested in your choices, which might be different from the choices someone else would make. The only right answer is what you really would choose. That is why the choices are for real money.

In the front of the room there are three bingo cages, labeled Cage #1, Cage #2, and Cage #3. There are 25 orange balls and 25 white balls in front of Cage #1. Cage #2 is empty, and will be filled with 50 balls. Each ball will be either orange or white. You will not be told how many balls are going to be orange and how many are going to be white. The composition of balls filling Cage #2 will be determined by drawing 1 out of 51 numbered balls from Cage #3. Each ball will have a number between 0 and 50 written on it. Before we start I would like to ask one person to come up and inspect Cage #1. The volunteer will verify that there are 25 orange and 25 white balls. If you would like to volunteer please raise your hand.

On the last page of this booklet there is a record sheet with four paired choices for you to make between "Option A" and "Option B." These four decisions are reprinted here.

Row	Option A	Option B	Decision		
1	Win $10 if orange ball is drawn from Cage #1 Win $0 if white ball is drawn from Cage #1	Win $0 if orange ball is drawn from Cage #1 Win $10 if white ball is drawn from Cage #1	**A**	**B**	**Don't Care**
2	Win $10 if orange ball is drawn from Cage #2 Win $0 if white ball is drawn from Cage #2	Win $0 if orange ball is drawn from Cage #2 Win $10 if white ball is drawn from Cage #2	**A**	**B**	**Don't Care**
3	Win $10 if orange ball is drawn from Cage #1 Win $0 if white ball is drawn from Cage #1	Win $10 if orange ball is drawn from Cage #2 Win $0 if white ball is drawn from Cage #2	**A**	**B**	**Don't Care**
4	Win $0 if orange ball is drawn from Cage #1 Win $10 if white ball is drawn from Cage #1	Win $0 if orange ball is drawn from Cage #2 Win $10 if white ball is drawn from Cage #2	**A**	**B**	**Don't Care**

In each row you will be asked to circle one of the three decisions. Only one of the four decisions you make will end up affecting your earnings, but you will not know in advance which decision will be used. Your earnings from this decision will depend on your choice and the outcome of a spin of each of the bingo cages in the front the room.

Please look at row 1, at the top of the table. Option A will pay $10 if the ball drawn from Cage #1 is orange, and Option B will pay $10 if the ball drawn from Cage #1 is white. The other decisions are similar. For the last row, Option A will pay $10 if the ball drawn from Cage #1 is white, and Option B will pay $10 if the ball drawn from Cage #2 is white.

In the column labeled "Decision" there are three choices for each row. For each row, circle the letter of the option that you prefer. If you do not care whether you receive Option A or Option B, circle "Don't Care."

After making each of your four decisions, please raise your hand and wait for assistance. A research assistant will bring you a 6-sided die that you will roll to determine which row from the record sheet you will be paid from. If a 1, 2, 3, or 4 is rolled, you will be paid according to that row. If a 5 or 6 are rolled, you will roll the die again until you roll a 1, 2, 3, or 4. If you choose Don't Care in the decision that we play out, we will pick one for you using a 10-sided die, where the numbers 1-5 correspond to Option A and the numbers 6-10 correspond to Option B.

After we know which decision is binding, I will ask one person to come and verify that there are 51 balls numbered between 0 and 50 in front of Cage #3. The same person will then place each of these balls in Cage #3, and spin and draw one ball. The number on that ball will determine the number of orange balls that we will place in Cage

#2. The remaining balls, up to 50, will be white. We will then spin Cage #1 and Cage #2 and draw out one ball from each, to see if you receive the higher amount or the lower amount for the choice that you made. If you choose Option A you would be paid the appropriate amount in Option A. If you choose Option B you would be paid the appropriate amount in Option B.

Before you circle your decisions, lets uncover the cages under this blue sheet and use them to do an example together. For each of the four decisions, we will flip a coin to determine if we choose option A or option B. We will use the white board to keep track of our four decisions.

For row 1, option A will pay $10 if the ball drawn from Cage #1 is orange. Option B will pay $10 if the ball drawn from Cage #1 is white.

For row 2, option A will pay $10 if the ball drawn from Cage #2 is orange. Option B will pay $10 if the ball drawn from Cage #2 is white.

For row 3, option A will pay $10 if the ball drawn from Cage #1 is orange. Option B will pay $10 if the ball drawn from Cage #2 is orange.

For row 4, option A will pay $10 if the ball drawn from Cage #1 is white. Option B will pay $10 if the ball drawn from Cage #2 is white.

Now that we have made each of our four choices, we will roll a 6-sided die to determine which row is played for this example.

Now that we know which row will be used to determine how we are paid, we will pick one ball from Cage #3 to determine how many orange balls and how many white balls there will be in Cage #2.

We will now fill Cage #2 with the appropriate number of orange and white balls.

Now we will pick one ball from Cage #1 and Cage #2 to determine what our earnings would be.

Are there any questions?

You may now mark **your decisions** for each row of the decision sheet. When you are satisfied with the decisions that you have made, please raise your hand and wait for a research assistant to bring the dice to determine which row you will be paid from.

D.3.5 Ellsberg / Smith Task Decision Sheet

Record Sheet

Row	Option A	Option B	Decision		
1	Win $10 if orange ball is drawn from Cage #1 Win $0 if white ball is drawn from Cage #1	Win $0 if orange ball is drawn from Cage #1 Win $10 if white ball is drawn from Cage #1	**A**	**B**	**Don't Care**
2	Win $10 if orange ball is drawn from Cage #2 Win $0 if white ball is drawn from Cage #2	Win $0 if orange ball is drawn from Cage #2 Win $10 if white ball is drawn from Cage #2	**A**	**B**	**Don't Care**
3	Win $10 if orange ball is drawn from Cage #1 Win $0 if white ball is drawn from Cage #1	Win $10 if orange ball is drawn from Cage #2 Win $0 if white ball is drawn from Cage #2	**A**	**B**	**Don't Care**
4	Win $0 if orange ball is drawn from Cage #1 Win $10 if white ball is drawn from Cage #1	Win $0 if orange ball is drawn from Cage #2 Win $10 if white ball is drawn from Cage #2	**A**	**B**	**Don't Care**

To be completed by Staff:

Row Number Selected: ___________ Option Selected: ___________

Ball Chosen from Cage #1: ___________ Ball Chosen from Cage #2: ___________

Earnings: ___________

D.3.3 Belief Elicitation Instructions

Before I spin each cage you will make one decision which will be used to determine how much money you make. Your decision sheet for this task is on the following page. Before you make your choice, lets discuss the decision sheet.

You will be paid based on the choice you circle and the color ball drawn from Cage #2.

Choice 1, at the top of the decision sheet, pays $0 if the ball chosen from Cage #2 is orange and $50 if the ball chosen from Cage #2 is white. If you are certain that Cage #2 is filled entirely with white balls then you should select Choice 1.

Choice 51, at the bottom of the decision sheet, pays $50 if the ball chosen from Cage #2 is orange and $0 if ball chosen from Cage #2 is white. If you are certain that Cage #2 is filled entirely with orange balls then you should select Choice 51.

Choices with low numbers pay more if a white ball is drawn from Cage #2, and less if an orange ball is drawn from Cage #2. Choices with high numbers pay more if an orange ball is drawn from Cage #2, and less if a white ball is drawn from Cage #2.

Are there any questions?

Please circle your choice on the decision sheet.

Choice	Payment if Ball Drawn from Cage #2 is Orange	Payment if Ball Drawn from Cage #2 is White
1	$0.00	$50.00
2	$0.50	$49.50
3	$1.50	$48.50
4	$2.00	$48.00
5	$2.50	$47.50
6	$3.50	$46.50
7	$4.00	$46.00
8	$4.50	$45.50
9	$5.50	$44.50
10	$6.00	$44.00
11	$6.50	$43.50
12	$7.00	$43.00
13	$8.00	$42.00
14	$8.50	$41.50
15	$9.00	$41.00
16	$10.00	$40.00
17	$10.50	$39.50
18	$11.00	$39.00
19	$12.00	$38.00
20	$12.50	$37.50
21	$13.00	$37.00
22	$14.00	$36.00
23	$14.50	$35.50
24	$15.00	$35.00
25	$16.00	$34.00
26	$16.50	$33.50
27	$17.00	$33.00
28	$18.00	$32.00
29	$18.50	$31.50
30	$19.00	$31.00
31	$19.50	$30.50
32	$20.50	$29.50
33	$21.00	$29.00
34	$21.50	$28.50
35	$22.50	$27.50
36	$23.00	$27.00
37	$23.50	$26.50
38	$24.50	$25.50
39	$25.00	$25.00
40	$27.00	$23.00
41	$29.00	$21.00
42	$31.50	$18.50
43	$33.50	$16.50
44	$35.50	$14.50
45	$37.50	$12.50
46	$39.50	$10.50
47	$41.50	$8.50
48	$44.00	$6.00
49	$46.00	$4.00
50	$48.00	$2.00
51	$50.00	$0.00

Row Choice: ___________

To be completed by Staff:

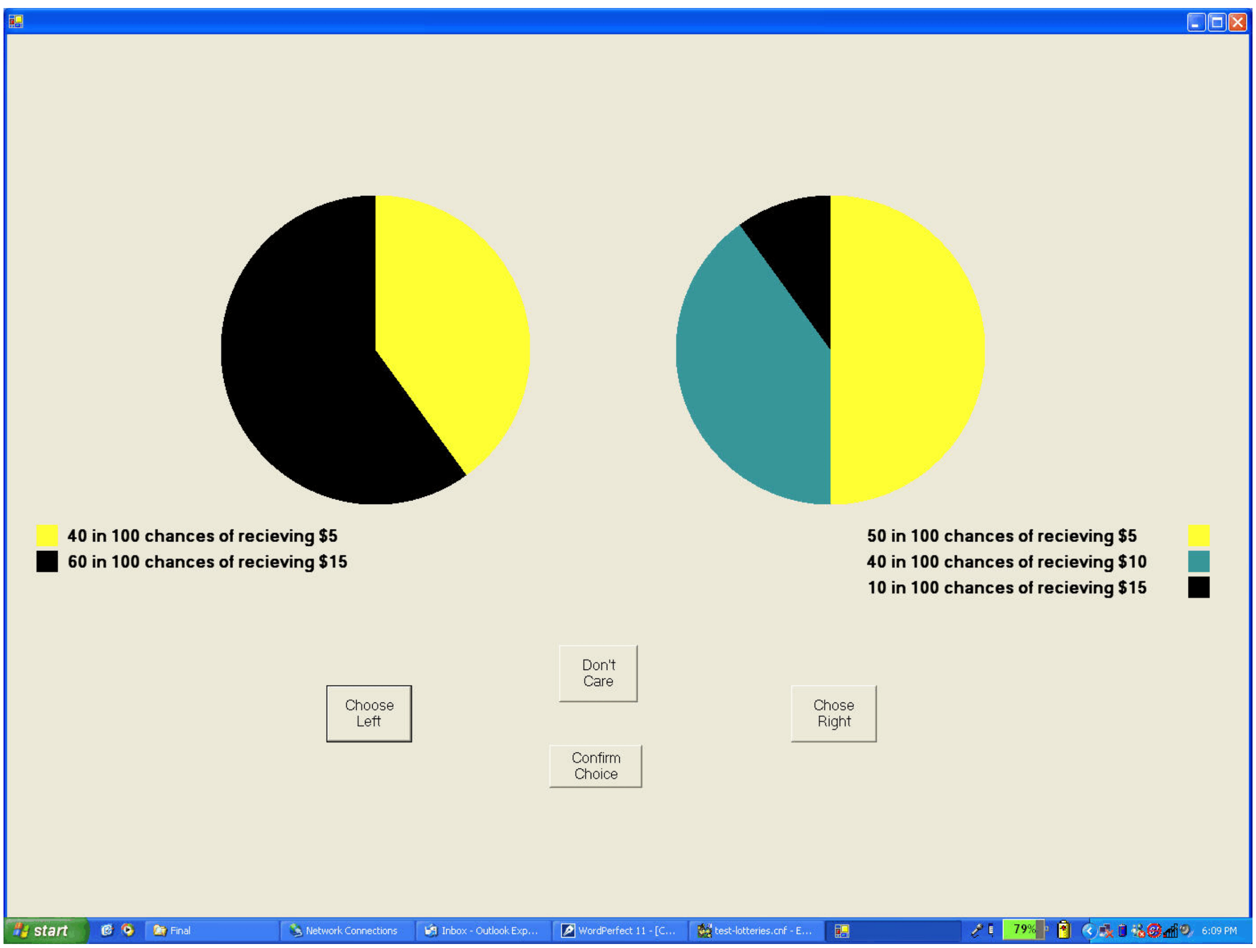
Ball Drawn from Cage #2: _________ Earnings: __________

D.4 Stage 4: Lottery Task Instructions

Your Instructions

Here, you will be asked to choose between lotteries with varying prizes and chances of winning. You will be presented with a series of lotteries where you will make choices between pairs of them. There are 45 pairs in the series. For each pair of lotteries, you should indicate which of the two lotteries you prefer to play. You will actually get the chance to play one of the lotteries you choose, and will be paid according to the outcome of that lottery, so you should think carefully about which lotteries you prefer.

Here is an example of what the computer display of such a pair of lotteries will look like. The display on your screen will be bigger and easier to read.



The outcome of the lotteries will be determined by the draw of a random number between 1 and 100. Each number between (and including) 1 and 100 is equally likely to occur. In fact, you will be able to draw the number yourself using two 10-sided dice.

In the above example the left lottery pays five dollars ($5) if the number on the dice that is rolled is between 1 and 40, and pays fifteen dollars ($15) if the number is between 41 and 100. The yellow color in the pie chart corresponds to 40% of the area and illustrates the chances that the number on the dice rolled will be between 1 and 40 and your prize will be $5. The black area in the pie chart corresponds to 60% of the area and illustrates the chances that the number on the dice rolled will be between 41 and 100 and your prize will be $15.

We have selected colors for the pie charts such that a darker color indicates a higher prize. White will be used when the prize is zero dollars ($0).

Now look at the pie in the chart on the right. It pays five dollars ($5) if the number on the dice rolled is between 1 and 50, ten dollars ($10) if the number is between 51 and 90, and fifteen dollars ($15) if the number is between 91 and 100. As with the lottery on the left, the pie slices represent the fraction of the possible numbers which yield each payoff. For example, the size of the $15 pie slice is 10% of the total pie.

Each pair of lotteries is shown on a separate screen on the computer. On each screen, you should indicate which of the lotteries you prefer to play by clicking on one of the three boxes beneath the lotteries. You should click the LEFT box if you prefer the lottery on the left, the RIGHT box if you prefer the lottery on the right, and the DON’T CARE box if you do not prefer one or the other.

You should approach each pair of lotteries as if it is the one out of the 45 that you will play out. If you chose DON'T CARE in the lottery pair that we play out, you will pick one using a 10-sided die, where the numbers 1-5 correspond to the left lottery and the numbers 6-10 to the right lottery.

After you have worked through all of the pairs of lotteries, raise your hand and an experimenter will come over. You will then roll two 10-sided die to determine which pair of lotteries that will be played out. You roll the die until a number between 1 and 45 comes up, and that is the lottery pair to be played. If you picked DON'T CARE for that pair, you will use the 10-sided die to decide which one you will play. Finally, you will roll the two 10-sided dice to determine the outcome of the lottery you chose.

For instance, suppose you picked the lottery on the left in the above example. If the random number you rolled was 37, you would win $5; if it was 93, you would get $15. If you picked the lottery on the right and drew the number 37, you would get $5; if it was 93, you would get $15.

Therefore, your payoff is determined by three things:

• by which lottery pair is chosen to be played out in the series of 45 such pairs using the two 10-sided die;

• by which lottery you selected, the left or the right, for that pair; and

• by the outcome of that lottery when you roll the two 10-sided die.

This is not a test of whether you can pick the best lottery in each pair, because none of the lotteries are necessarily better than the others. Which lotteries you prefer is a matter of personal taste. The people next to you will have different lotteries in front of them when you make your choices, and may have different tastes, so their responses should not matter to you. Please work silently, and make your choices by thinking carefully about each lottery.

All payoffs are in cash, and are in addition to the $5 show-up fee that you receive just for being here and any earnings from the previous stage.

We will now come around to your computer and get you started. When you are finished, please signal someone to come around to play out your lottery and record your earnings.

APPENDIX E: EXPERIMENTAL INSTRUCTIONS FOR CHAPTER 4

E.1 Experimenter Instructions

Experimenter Instructions

Welcome. This is an experiment in individual decision making. You can earn cash based on the choices you make today. Money you earn today will be paid to you in cash at the end of the experiment. You will be paid $5 for participating in the experiment. The experiment will last no more than **2** hours. Please make sure that you can stay until the end. In addition to the participation fee, your earnings will depend partly on chance and partly on the choices you make today. The instructions are simple and you will benefit from following them carefully.

There are three stages today:

4. We will ask you a series of questions about yourself, such as some basic information about your age. The computer will prompt you for these questions, and you should just work through them at your own pace when we log you in.
5. We will then pause and provide instructions on some choices you are to make over different amounts of money that have different chances of occurring. These choices will directly affect your earnings.
6. We will then pause again, and provide some instructions on the final task, which involves you making some more choices over different amounts of money that have different chances of occurring. These choices will also directly affect your earnings.

The instructions for the second and third stage will provide more information on the type of choices you are being asked to make.

The experimenters will then collate all of your earnings and pay you for the money you have earned.

Your choices are private, and will only be associated with an ID that we will enter when we log you in to the computer. So your name, address and SSN will not be linked to any choices you make. We will pay you privately, one at a time, to keep your earnings private.

Are there any questions? If not, go ahead and answer the questions until the computer pauses and asks for a password. When everyone is finished this stage we will announce the password and we can go on to the second stage. There is no hurry, so take your time.

[Wait for everyone to finish demographics]

There is an instruction book in front of each of you. Please open it and follow along as I read the instructions out loud.

[Do individual choice task, read instructions out loud]

Now that everyone has completed the second stage of today's experiment, research assistants are passing around instruction books for the third and final stage.

[Do random lottery pair task, read instructions out loud]

E.2 Stage 1: Demographics Questions

Demographics questions were identical to those in Appendix D.2.

E.3 Stage 2: Commodity Betting Instructions

E.3.1 Commodity Choice Task

On the last page of this booklet there is a decision sheet with twenty paired choices between "Option I" and "Option II." In each row you will be asked to circle one of the three decisions shown in the right-hand column. Before you start making your twenty choices, let me explain how these choices affect you potential earnings.

Although you will make twenty decisions, only one choice will affect your earnings. You will not know in advance which decision you make will end up affecting your earnings. After completing the twenty choices you will roll a 20-sided die the result corresponds to the row from the decision sheet you will play. Obviously, each decision has an equal chance of being used in the end.

Once the row has been selected we will use a two 10-sided dice to play the option I or II corresponding to your decision on the selected row. The final result will be written on the decision sheet.

Please look at row 1, at the top of the table. Option I pays C if the die shows a number between 1 and 5, and it pays B if the die shows a number between 6 and 100. Option II pays A if the die shows a number between 1 and 5, and it pays D if the die shows a number between 6 and 100. The other choices are similar.

Each of these letters A, B, C, and D labels one of the sodas on the table in the front of the room. If the soda you win is a Coke, we will pay you $10. If the soda you win is Pepsi we will pay you $0.

In the column labeled “Decision,” there are three choices for each row. For each row, circle the Roman numeral of the option that you prefer. If you do not care whether you receive Option I or Option II, circle “Don’t Care.”

After making each of your twenty decisions, please raise your hand and wait for assistance. A research assistant will bring you a 20-sided die that you will roll to determine which row from the record sheet you will be paid from. For example, if you roll a 1 then your decision for row 1 will be binding. If you choose Don't Care in the decision that we play out, we will pick one for you using a 10-sided die, where the numbers 1-5 correspond to Option I and the numbers 6-10 correspond to Option II.

After we know which decision is binding, you will roll the two 10-sided die to determine which soda you will be paid for. Remember, we will pay you $10 if you win a Coke. If you win Pepsi, we will pay you $0.

At the conclusion of this session you can have either a Coke or a Pepsi, which ever you prefer. You should not let the fact that you like to drink one soda brand over the other influence the 20 choices you make. You can have whichever soda you prefer at the end of the session.

Consider the following examples.

If you chose Option I for row 1 and you then roll a 3 using the two 10-sided dice, you will be paid based on the brand of soda C. In fact, if your roll any number less than or equal to 5, you will be paid based on the brand of soda C. On the other hand, if you roll a 6 or higher you will be paid based on the brand of soda B.

Alternatively, if you chose Option II for row 1 and you then roll a 3 using the two 10-sided dice, you will be paid based on the brand of soda A. In fact, if your roll any number less than or equal to 5, you will be paid based on the brand of soda A. On the other hand, if you roll a 6 or higher you will be paid based on the brand of soda D.

If row 20 is the row that we play out, and if you choose Option I, you will be paid based on the brand of soda C. On the other hand, if you choose Option II then you will be paid based on the brand of soda A.

Remember, at the conclusion of this session you can have either a Coke or a Pepsi, which ever you prefer. You should not let the fact that you like to drink one soda brand over the other influence the 20 choices you make. You can have whichever soda you prefer at the end of the session.

Before you make your choices, you may come to the front of the room to taste each soda.

Are there any questions?

You may now mark **your decisions** for each row of the decision sheet. When you are satisfied with the decisions that you have made, please raise your hand and wait for a research assistant to bring the dice to determine which row you will be paid from.

E.3.1.1 Ungraded Treatment

In the ungraded treatment each soda A, B, C, and D was covered with 2 to 3 layers of blue painters tape. Soda labels were not visible. The instructions were identical to those used in the branded treatment, above.

E.3.1.2 Graded Treatment

In the graded treatment the following text is inserted before subjects are asked to make their choices.

Before you make your choices, I would like to ask for a volunteer to come taste each soda and then make a guess whether each is Coke or Pepsi. This volunteer will write his guesses on the index cards in front of each can. If this volunteer correctly guesses the brand of each soda he will be paid $10 in addition to his/her earning from his/her decisions.

If you would like to volunteer please raise your hand. If there is more than one volunteer we will pick one randomly.

Before you make your choices, you may come to the front of the room to taste each soda.

E.3.2 Commodity Choice Task Decision Sheet

Row	Option I	Option II	Decision		
1	5/100 of C and 95/100 of B	95/100 of D and 5/100 of A	**I**	**II**	**Don't Care**
2	8/100 of C and 92/100 of B	92/100 of D and 8/100 of A	**I**	**II**	**Don't Care**
3	11/100 of C and 89/100 of B	89/100 of D and 11/100 of A	**I**	**II**	**Don't Care**
4	15/100 of C and 85/100 of B	85/100 of D and 15/100 of A	**I**	**II**	**Don't Care**
5	18/100 of C and 82/100 of B	82/100 of D and 18/100 of A	**I**	**II**	**Don't Care**
6	21/100 of C and 79/100 of B	79/100 of D and 21/100 of A	**I**	**II**	**Don't Care**
7	24/100 of C and 76/100 of B	76/100 of D and 24/100 of A	**I**	**II**	**Don't Care**
8	28/100 of C and 72/100 of B	72/100 of D and 28/100 of A	**I**	**II**	**Don't Care**
9	31/100 of C and 69/100 of B	69/100 of D and 31/100 of A	**I**	**II**	**Don't Care**
10	34/100 of C and 66/100 of B	66/100 of D and 34/100 of A	**I**	**II**	**Don't Care**
11	37/100 of C and 63/100 of B	63/100 of D and 37/100 of A	**I**	**II**	**Don't Care**
12	40/100 of C and 60/100 of B	60/100 of D and 40/100 of A	**I**	**II**	**Don't Care**
13	44/100 of C and 56/100 of B	56/100 of D and 44/100 of A	**I**	**II**	**Don't Care**
14	47/100 of C and 53/100 of B	53/100 of D and 47/100 of A	**I**	**II**	**Don't Care**
15	50/100 of C and 50/100 of B	50/100 of D and 50/100 of A	**I**	**II**	**Don't Care**
16	60/100 of C and 40/100 of B	40/100 of D and 60/100 of A	**I**	**II**	**Don't Care**
17	70/100 of C and 30/100 of B	30/100 of D and 70/100 of A	**I**	**II**	**Don't Care**
18	80/100 of C and 20/100 of B	20/100 of D and 80/100 of A	**I**	**II**	**Don't Care**
19	90/100 of C and 10/100 of B	10/100 of D and 90/100 of A	**I**	**II**	**Don't Care**
20	100/100 of C and 0/100 of B	0/100 of D and 100/100 of A	**I**	**II**	**Don't Care**

To be completed by Staff:

Row Number Selected: ___________ Option Selected: ___________

Roll of 100-Sided Die: ___________ Prize Won: ___________ Dollar Value of prize: __________

E.3.3 Belief Elicitation Instructions

E.3.3.1 Brand Elicitation

Please read these instructions quietly to yourself. If you have any questions please raise your hand and a research assistant will come by and answer your questions privately.

In this task you will place a bet that the soda you won is either Coke or Pepsi. At the conclusion of this session, we will uncover each can to reveal the brands.

Your decision sheet for this task is on the following page. Before you make your choice, lets discuss the decision sheet.

You will be paid based on the choice you circle and the brand of the soda you won in the previous task. The true brand will be determined when we uncover each can at the conclusion of this stage of today's session. Before you make your report, lets discuss the decision sheet.

If you believe with 100% certainty that the **correct brand** for the soda you won is Coke then you should select row 100%. Row 100% pays $50 if the **correct brand** for the soda you won is Coke and $0 if the **correct brand** for the soda you won is Pepsi.

Similarly, if you are sure that the **correct brand** for the soda you won is Pepsi then you should select row 0%. Selecting row 0% means that you believe there is a 0% chance certainty that the **correct brand** for the soda you won is Coke. Row 0% pays $0 if that the **correct brand** for the soda you won is Coke and $50 if that the **correct brand** for the soda you won is Pepsi.

Are there any questions?

Please circle your **belief** on the decision sheet.

DECISION SHEET

Row	Payment if the correct brand for the soda you won is Coke	Payment if the correct brand for the soda you won is Pepsi
0%	$0.00	$50.00
1%	$0.50	$49.50
3%	$1.50	$48.50
4%	$2.00	$48.00
5%	$2.50	$47.50
7%	$3.50	$46.50
8%	$4.00	$46.00
9%	$4.50	$45.50
11%	$5.50	$44.50
12%	$6.00	$44.00
14%	$7.00	$43.00
15%	$7.50	$42.50
16%	$8.00	$42.00
18%	$9.00	$41.00
19%	$9.50	$40.50
20%	$10.00	$40.00
22%	$11.00	$39.00
23%	$11.50	$38.50
24%	$12.00	$38.00
26%	$13.00	$37.00
27%	$13.50	$36.50
28%	$14.00	$36.00
30%	$15.00	$35.00
31%	$15.50	$34.50
32%	$16.00	$34.00
34%	$17.00	$33.00
35%	$17.50	$32.50
36%	$18.00	$32.00
38%	$19.00	$31.00
39%	$19.50	$30.50
41%	$20.50	$29.50
42%	$21.00	$29.00
43%	$21.50	$28.50
45%	$22.50	$27.50
46%	$23.00	$27.00
47%	$23.50	$26.50
49%	$24.50	$25.50
50%	$25.00	$25.00
54%	$27.00	$23.00
58%	$29.00	$21.00
62%	$31.00	$19.00
65%	$32.50	$17.50
69%	$34.50	$15.50
73%	$36.50	$13.50
77%	$38.50	$11.50
81%	$40.50	$9.50
85%	$42.50	$7.50
88%	$44.00	$6.00
92%	$46.00	$4.00
96%	$48.00	$2.00
100%	$50.00	$0.00

Row Choice: __________

To be completed by Staff:

Correct Brand Coke (yes/no)?: ________ Earnings: _________

E.3.3.2 Prediction Accuracy Elicitation

Please read these instructions quietly to yourself. If you have any questions please raise your hand and a research assistant will come by and answer your questions privately.

In this task you will place a bet that the brands of both sodas in your chosen option were predicted correctly by our volunteer. At the conclusion of this session, we will uncover each can to reveal the brands.

Your decision sheet for this task is on the following page. Before you make your choice, lets discuss the decision sheet.

You will be paid based on the choice you circle and the accuracy of the brand prediction marked on each index card for the sodas in you chosen option from the previous task. The true brand will be determined when we uncover each can at the conclusion of this stage of today's session. Before you make your report, lets discuss the decision sheet.

If you believe with 100% certainty that the brands for **both** sodas in your chosen option were predicted correctly then you should select row 100%. Row 100% pays $50 if **both** sodas in your chosen option were predicted correctly and $0 if the brand for **at least one** of the sodas in your chosen option was predicted incorrectly.

Similarly, if you are sure that the brand for **at least one** of the sodas in your chosen option is not correct then you should select row 0%. Selecting row 0% means that you believe there is a 0% chance certainty that the brands for **both** sodas in your chosen option were predicted correctly. Row 0% pays $0 if the brands for **both** sodas in your chosen option were predicted correctly and $50 if the brand for **at least one** of the sodas in your chosen option is not correct.

Are there any questions?

Please circle your **belief** on the decision sheet.

DECISION SHEET

Row	Payment if both soda brands in your chosen option are predicted correctly	Payment if at least one soda brands in your chosen option are predicted incorrectly
0%	$0.00	$50.00
1%	$0.50	$49.50
3%	$1.50	$48.50
4%	$2.00	$48.00
5%	$2.50	$47.50
7%	$3.50	$46.50
8%	$4.00	$46.00
9%	$4.50	$45.50
11%	$5.50	$44.50
12%	$6.00	$44.00
14%	$7.00	$43.00
15%	$7.50	$42.50
16%	$8.00	$42.00
18%	$9.00	$41.00
19%	$9.50	$40.50
20%	$10.00	$40.00
22%	$11.00	$39.00
23%	$11.50	$38.50
24%	$12.00	$38.00
26%	$13.00	$37.00
27%	$13.50	$36.50
28%	$14.00	$36.00
30%	$15.00	$35.00
31%	$15.50	$34.50
32%	$16.00	$34.00
34%	$17.00	$33.00
35%	$17.50	$32.50
36%	$18.00	$32.00
38%	$19.00	$31.00
39%	$19.50	$30.50
41%	$20.50	$29.50
42%	$21.00	$29.00
43%	$21.50	$28.50
45%	$22.50	$27.50
46%	$23.00	$27.00
47%	$23.50	$26.50
49%	$24.50	$25.50
50%	$25.00	$25.00
54%	$27.00	$23.00
58%	$29.00	$21.00
62%	$31.00	$19.00
65%	$32.50	$17.50
69%	$34.50	$15.50
73%	$36.50	$13.50
77%	$38.50	$11.50
81%	$40.50	$9.50
85%	$42.50	$7.50
88%	$44.00	$6.00
92%	$46.00	$4.00
96%	$48.00	$2.00
100%	$50.00	$0.00

Row Choice: __________

To be completed by Staff:

Correct Brand Predicted (yes/no)?: ________ Earnings: _________

E.4 Stage 3: Lottery Task Instructions

Lottery task instructions were identical to those used in Appendix D.4.

APPENDIX F: EXPERIMENTAL INSTRUCTIONS FOR CHAPTER 5

F.1 Experimenter instructions

Experimenter Instructions

Welcome. This is an experiment in individual decision making. You can earn cash based on the choices you make today. Money you earn today will be paid to you in cash at the end of the experiment. You will be paid $5 for participating in the experiment. The experiment will last no more than **2 and ½** hours. Please make sure that you can stay until the end. In addition to the participation fee, your earnings will depend partly on chance and partly on the choices you make today. The instructions are simple and you will benefit from following them carefully.

There are three stages today:

7. We will ask you a series of questions about yourself, such as some basic information about your age. The computer will prompt you for these questions, and you should just work through them at your own pace when we log you in.
8. We will then pause and provide instructions on some choices you are to make over different amounts of money that have different chances of occurring. These choices will directly affect your earnings.
9. We will then pause again, and provide some instructions on the final task, which involves you making some more choices over different amounts of money that have different chances of occurring. These choices will also directly affect your earnings.

The instructions for the second and third stage will provide more information on the type of choices you are being asked to make.

The experimenters will then collate all of your earnings and pay you for the money you have earned.

Your choices are private, and will only be associated with an ID that we will enter when we log you in to the computer. So your name, address and SSN will not be linked to any choices you make. We will pay you privately, one at a time, to keep your earnings private.

Are there any questions? If not, go ahead and answer the questions until the computer pauses and asks for a password. When everyone is finished this stage we will announce the password and we can go on to the second stage. There is no hurry, so take your time.

[WAIT FOR EVERYONE TO FINISH DEMOGRAPHICS]

There is an instruction book in front of each of you. Please open it and follow along as I read the instructions out loud.

[Do public goods game, read instructions out loud]

Now that everyone has finished this game, I would like to introduce the next decision task. Our research assistants are handing out the decision books for this task.

[Do WTA task, read instructions out loud.]

Thank you. Now that everyone has finished this task, research assistants will come by to play everyone's decisions.

Before we record your earnings from the sale of your record sheet and play out the punishment phase of this session, each of you has the chance to make another choice, with much higher potential payoffs. Research assistants are passing around the decisions book for the choice that Sellers will now be allowed to make if they want to. If you choose to participate in this task, we will not pay you for the decisions that you have made so far.

Earnings from this next choice may be very large, they may also be small. If you decide not to participate in this task, please use the red pen on your desk to cross out the title of your new book: *DECISION TASK*. This is your decision to make. If you decide to participate, please circle the title of the new decision book and cross out the title of your old book: *INDIVIDUAL DECISION MAKING*. Remember, while some of the payoffs are large, there is no catch. We will pay you today for all money earned in this task. You have the choice which decision we will pay you for.

Before we proceed, if anyone has any questions please raise your hand and we will answer your questions privately.

[Do belief elicitation task, read instructions out loud]

By now everyone should be finished making your selections. If you have not finished please raise your hand.

Before you play your bet, each of you has a decision to make. You can replace the bet you just made with the spin of a bingo cage. Let me explain how this works.

If you decide to replace the bet you just made with the spin of a bingo cage, write REPLACE at the bottom of your decision sheet for the task we just completed. If you don't care, write DON'T CARE. If you write DON'T CARE, you will pick one using a 10-sided die, where the numbers 1-5 correspond to the keeping your bet and the numbers 6-10 to replacing your bet. If your bet is replaced, a research assistant will bring you a small bingo cage filled with balls numbered between 0 and 100. Before you make this decision, lets do an example to show you how this works.

For row **19%**: If this bet is replaced and you draw a bingo ball numbered between 0 and 19 we will pay $9.50. On the other hand, if you draw a bingo ball number between 20 and 100 we pay $40.50.

Lets do one more example.

For row **77%**: If this bet is replaced and you draw a bingo ball numbered between 0 and 77 we will pay $38.50. On the other hand, if you draw a bingo ball numbered between 78 and 100 we pay $11.50.

Are there any questions?

[ANSWER QUESTIONS]

Remember, if you decide to replace the bet you just made with the spin of a bingo cage, write REPLACE at the bottom of your decision sheet for the task we just completed. If you don't care, write DON'T CARE. If you write DON'T CARE, you will pick one using a 10-sided die, where the numbers 1-5 correspond to the keeping your bet and the numbers 6-10 to replacing your bet. This decision is final. Make you decision now.

[WAIT FOR DECISIONS TO BE MADE]

Has everyone made their decision?

Please put your pens down and wait for a research assistant to come verify that your decision has been made. If you chose REPLACE or DON'T CARE, you will play that decision now.

[SPIN CAGE FOR THOSE SUBJECTS WHO REPLACE]

[FOLD WTA DECISION BOOKS SO SENDER & PUNISHER DECISIONS SHEETS ARE SHOWING.]

[FOLD WTA BOOKS OF SELLERS TO KEEP THEIR IDENTITIES SECRET]

[Task 4 – Punishment]

If you are a Sender and the seller you are paired with sold their record sheet we will now pass it to you.

[PASS RECORD SHEETS AND BLANKS]

If your role is Sender, we would like you to make your decision to either keep the sellers information confidential or pass it to the punisher now. Please circle either A or B on the decision sheet in front of you. If you are not a Sender or you did not receive a seller's record sheet you have no decision to make.

[WAIT FOR DECISIONS TO BE MADE]

We will now collect all record sheets and give them to the punishers according to the decisions made by the sellers and senders they are paired with.

[COLLECT DECISION SHEETS FROM SENDERS]

[WRITE SENDER DECISION ON THE BOTTOM OF THE SELLER'S RECORD SHEET]

[COLLECT BLANKS FROM ALL SELLERS AND PUNISHERS]

[PASS RECORD SHEETS AND BLANKS TO PUNISHERS]

[PASS BLANKS TO SELLERS AND SENDERS]

If you have been assigned the role of Punisher, we would like you to make your decision now.

[WAIT FOR DECISIONS TO BE MADE]

[COLLECT RECORD SHEETS AND BLANKS]

[IF SELLER IS PUNISHED, WRITE PUNISHED ON THEIR RECORD SHEET]

Research assistant will now come by and calculate your final earnings for this stage.

[COLLECT RECORD SHEETS FROM PUNISHERS. IF THEY PUNISH WRITE PUNISHED ON THEM.]

[COLLECT BLANKS FOR SELLERS, SENDERS, AND SOME PUNISHERS]

[GIVE SELLERS THEIR ORIGINAL RECORD SHEET FROM FIRST GAME]

[GIVE BLANKS TO SENDERS AND PUNISHERS]

This stage is now over.

F.2 Stage 1: Demographics Questions

Demographics questions were identical to those in Appendix D.2.

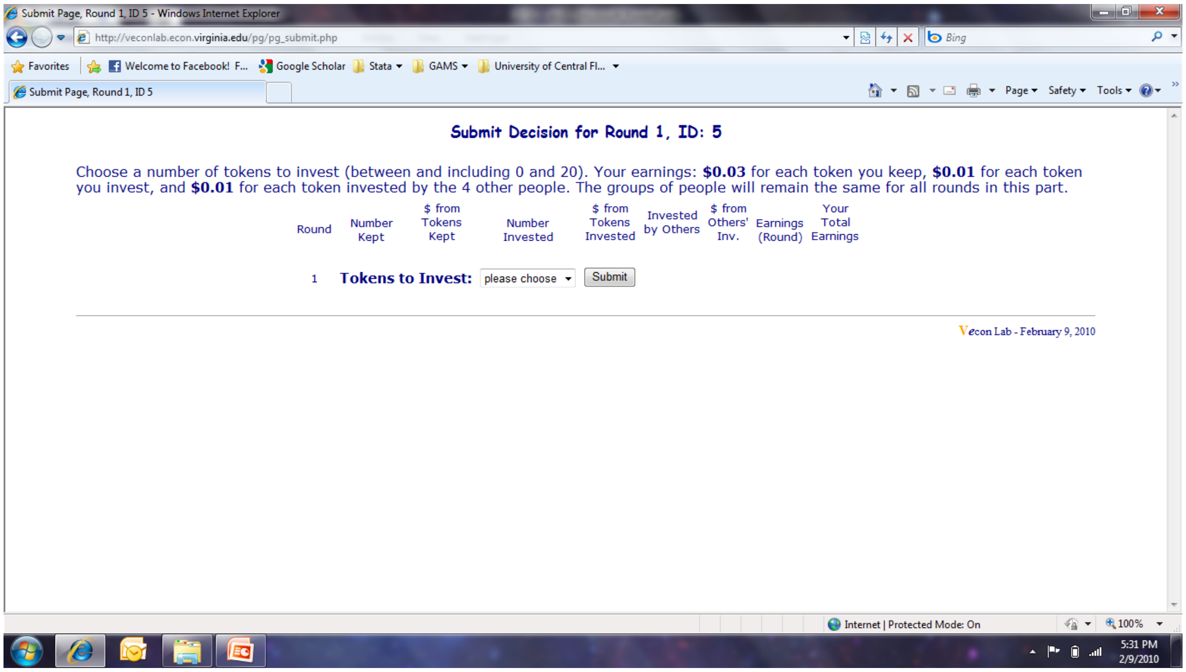
F.3 Stage 2: Privacy task Instructions

F.3.1 Public Goods Instructions

The task that will be described to you next will be repeated 10 times. Each repetition will be referred to as a round. In each round you will be matched with four other people in this room.

You begin each round with 20 “tokens.” Your task is to decide how to use your tokens. You have to decide how many of the 20 tokens you want to invest and how many of the 20 tokens to keep for yourself. The people you are matched with will decide how many of their tokens to keep, and how many to invest. The consequences of your decision are explained in detail below.

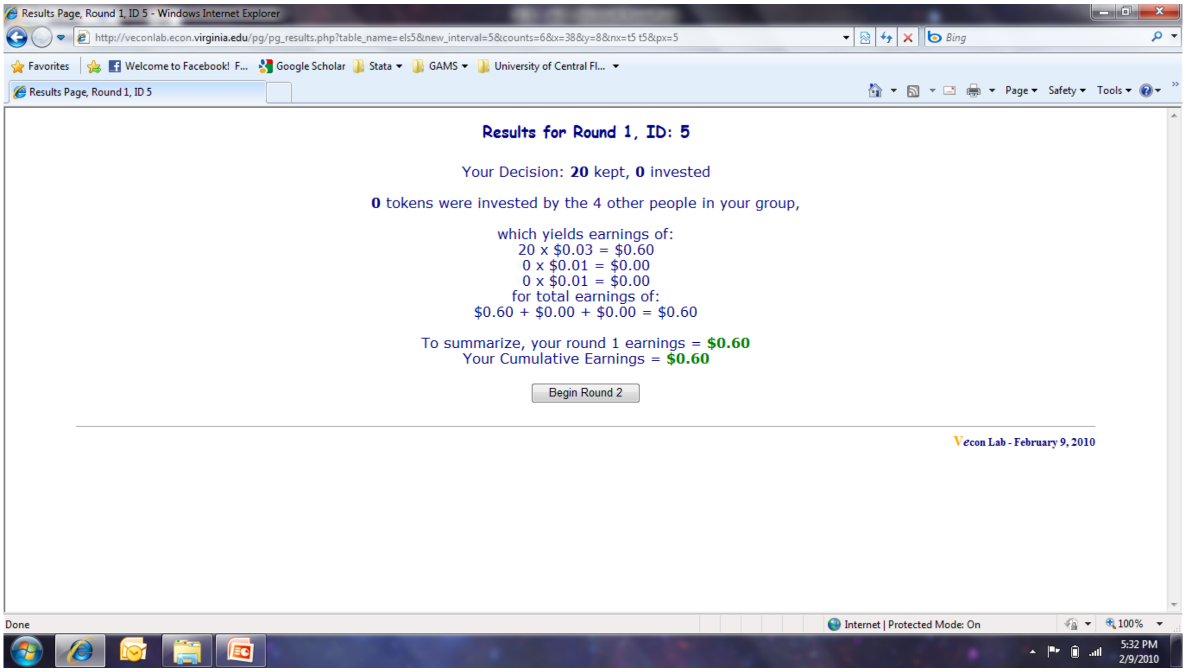
At the beginning of each round a screen similar to this will appear:



The round number and your ID number appear at the top middle of the screen. The round number is also indicated in the left hand column titled "Round." Your decision must be made before the next round can begin.

You have to decide how many tokens you want to invest by choosing a number between 0 and 20 in the drop-down box labeled "Number Invested," located in the middle of your screen. This field can be found by clicking "please choose" next to "Tokens to Invest." As soon as you have decided how many tokens to invest, you have also decided how many tokens you keep for yourself, since this is **20 tokens minus your investment**. After entering your investment, you must press "Submit." Once you have done this, you will be asked to confirm your decision for that round. Once you confirm your investment, your decision can no longer be revised.

After you and everyone else have made your decisions the following earnings screen will show you the total amount of tokens invested. This screen also shows you how much money you have earned during the round.



Your earnings consist of two parts:

1) The tokens which you have kept for yourself

2) The earnings from investment. This is calculated as follows:

Your earnings from investment = 1 cents x the sum of the investments from everyone this round.

Your earnings for each round are therefore:
3 cents x (20 - your investment) + 1 cents x (sum of all investments)

The earnings **from investment** that go to each of you are calculated in the same way, which means that each person receives the same earnings from investment. Suppose the sum of the contributions is 20 tokens. In this case each of you receives earnings from investment of 1 cent x 20 = 20 cents. On the other hand, if the total investment is 3 tokens, then each member of the group receives earnings of 1 cent x 3 = 3 cents **from investment**.

Each token that you keep for yourself **adds 3 cents to your earnings**. If you invested 1 additional token, then your earnings from investment would rise by **1 cents x 1=1 cents**. The earnings of the other people would also rise by 1 cents, so that the combined earnings for all of you from investment would rise by 5 cents. Your investment therefore also increases the earnings of the other people. On the other hand you also get earnings for each token invested by the others. For each token invested by the others you also earn 3 cents x 1=3 cents.

Of course, every additional token you contribute to the project is 1 less token that goes towards "Earnings from private tokens kept."

To summarize: For each token you invest, your earnings are reduced 3 cents by the token you invest and increased by the investment earnings of 1 cents. In addition, your earnings are increased by 1 cents for each token contributed by the others. After you review the earnings screen, please press the button at the bottom to begin the next round.

Before we start the actual experiment you will have a chance to practice this task for two rounds.

F.3.1.1 Public Goods Treatments

The public goods game task used a 2×2 design, setting endowments to {20 tokens, 30 tokens} and public return from investment {2 tokens, 1 token}.

F.3.2 BDM / WTA Privacy Loss Instructions

In this task each of you has been assigned one of three roles: **Seller**, **Sender**, or **Punisher**. Your role is indicated at the top of the next page of this booklet. Please do not read ahead.

Let me explain these roles here.

Sellers have the chance to sell **us** a copy of their **record sheet** from the game that was just played. If the Seller sells **us** their record sheet **we will then give the record sheet to** either a **Sender** or a **Punisher**. Sellers will know in advance the role of the person who we would give the record sheet to. However, Sellers will not know their true identity. And they will not know the Sellers true identity.

If a Seller's record sheet is sold and then given to a **Sender**, that Sender will decide whether to keep the records confidential or to share the records with a **Punisher**. This decision is entirely up to the Sender. Remember that the Sender will not know the true identity of the Seller or the Punisher. And the Punisher and Seller will not know the true identity of the Sender.

At the end of this stage, each person assigned to the role of **Punisher** will have a choice to make. Punishers will choose to:

(a) deduct 50% of the Seller's earning from the first game

(b) deduct no earnings.

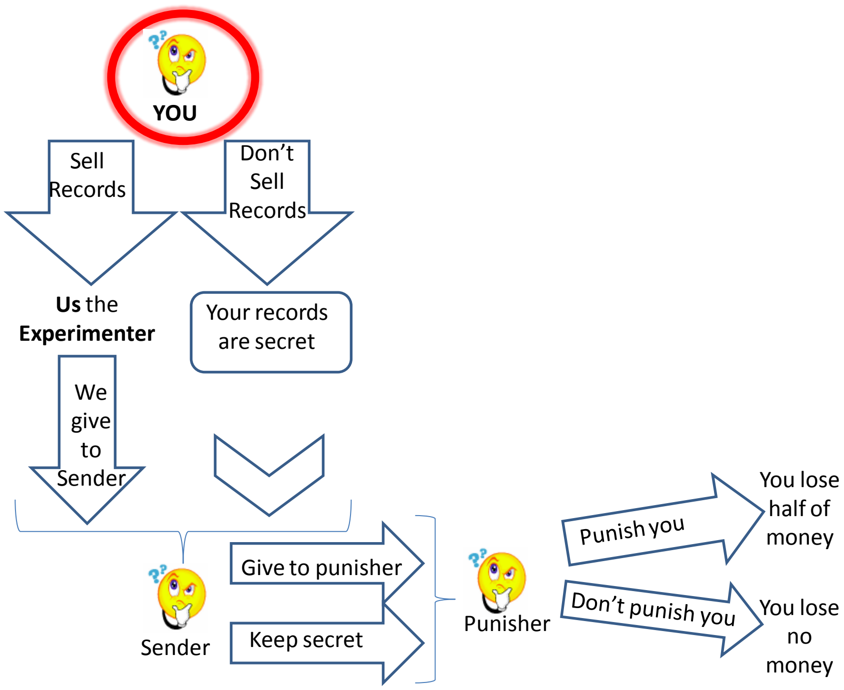
Punishers may deduct earnings from a **Seller even if the seller did not sell their record sheet**. This decision is entirely up to the Punisher.

Remember, each **Sender will decide to keep a record sheet confidential or to share the record sheet with a Punisher**. Each **Punisher will decide whether or not to deduct earnings from the Seller**.

The next page of this booklet indicates your role: **Seller**, **Sender**, or **Punisher**.

Please read the instructions, on the following page quietly to yourself. If you have any questions please raise your hand and a research assistant will come by and answer your questions privately.

In this experiment, you are a **Seller**. The cartoon below shows your role, circled in red, along with the roles of the people you are paired with.



If you sell your record sheet to us, we will give it to the Sender you are paired with. The Sender will decide whether to keep your records confidential or to share the records with a **Punisher**. The punisher will choose to:

(a) deduct 50% of the Seller's earning from the first game

(b) deduct no earnings.

Before we proceed, if you have any questions please raise your hand and we will answer your questions privately.

Now that everyone has had a chance to understand their role and ask questions, we will explain how **Sellers** can sell a copy of their record sheet from the first task.

Before we explain how Sellers sell us their record sheet, **Senders** and **Punishers** can also sell us their record sheet. But, we will keep **Senders'** and **Punishers'** record sheets confidential.

To summarize, we would like to buy **everyone's** record sheet. If your role is **Seller**, we will give your record sheet to either a Sender or Punisher, as indicated on the previous page of your instructions. If your role is **Sender** or **Punisher** we will keep your record sheet confidential.

If you have any questions please raise your hand and a research assistant will come by and answer your questions privately.

We will now explain how you can sell your record sheet.

On the last page of this decision book you have an decision sheet. It reads as follows:

"I will sell record sheet for $______."

In order to provide you with an incentive to think about the value of your record sheet, and tell us that value, we will do the following. We will randomly choose a price between $0.00 and $20.99 to pay for a record sheet. We will not pay more than $20.99. Before you write your offer in the blank space provided, let me explain how the sale will work.

After you write your price in the blank provided on the last page of this booklet, a research assistant will bring you one 20-sided die and two 10-sided dice. You will roll each of these dice to determine how much money **we** are willing to pay for the record sheet. Numbers on the 20-sided die will represent dollars. The numbers rolled with the two 10-sided dice will represent cents. Consider the following examples.

Example 1: "John Doe" is willing to sell his record sheet for $7.78, so he would write 7.78 on the last page of his booklet. If he then rolls a 5 on the 20-sided die and a 65 with the two 10-sided dice, then we are only willing to pay $5.65 for "John Doe's" record sheet. Because we are not willing to pay the price that "John Doe" has asked, no sale takes place and "John Doe" keeps his record sheet private.

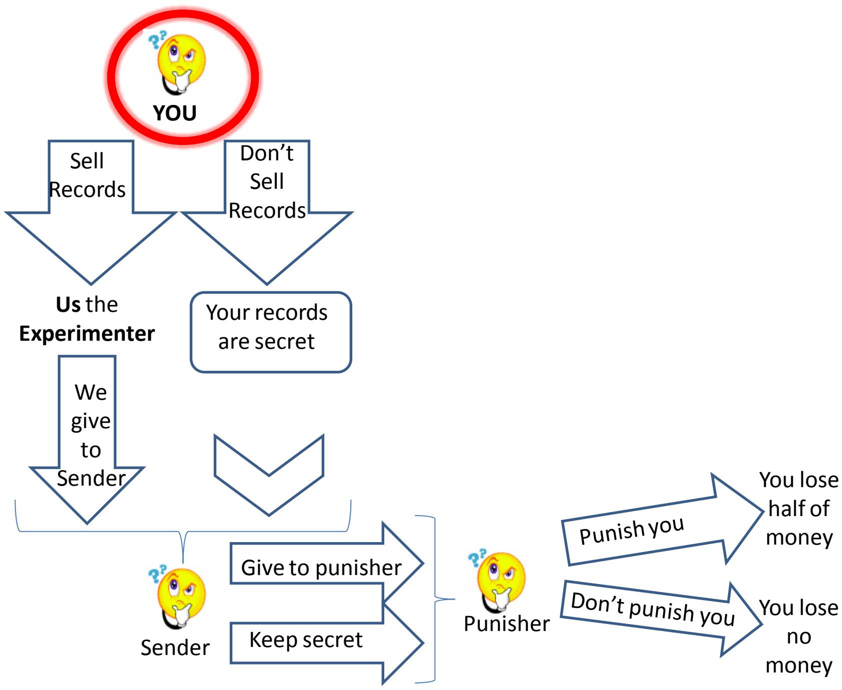
Example 2: "Jane Doe" is willing to sell her record sheet for $4.33, so she would write 4.33 on the last page of her booklet. If she then rolls a 4 on the 20-sided die and a 73 with the two 10-sided dice, then we are willing to pay $4.73 for "Jane Doe's" record sheet. Because we are willing to pay more than the price that "Jane Doe" has asked, a sale takes place and in exchange for a copy of her record sheet "Jane Doe" will receive $4.73.

Your best interest is served by simply telling us the value of the record sheet to you. If the price you write down is too high or too low, then you are passing up opportunities that you would prefer.

- For example, suppose Jane would be willing to sell her record sheet for $12 but instead she marked $15. If the amount of money drawn at random is anything between the $12 and $15 (for example $13.50), she would keep her record sheet and lose the $13.50 that she would have been willing to make the trade for.
- Suppose John would be willing to sell his record sheet for $15 but he marked $12. If the amount of money drawn at random is between the $15 and $12 (for example $13.50) then he would be forced to sell the record sheet even though at that price he prefers to keep the record sheet secret.

You may now mark your decision on the decision sheet.

DECISION SHEET



Remember, the cartoon above shows your role, circled in red, along with the roles of the people you are paired with. Please write the amount of money you are willing to sell your record sheet for in the blank space provided on the next line.

I will sell record sheet for $__________

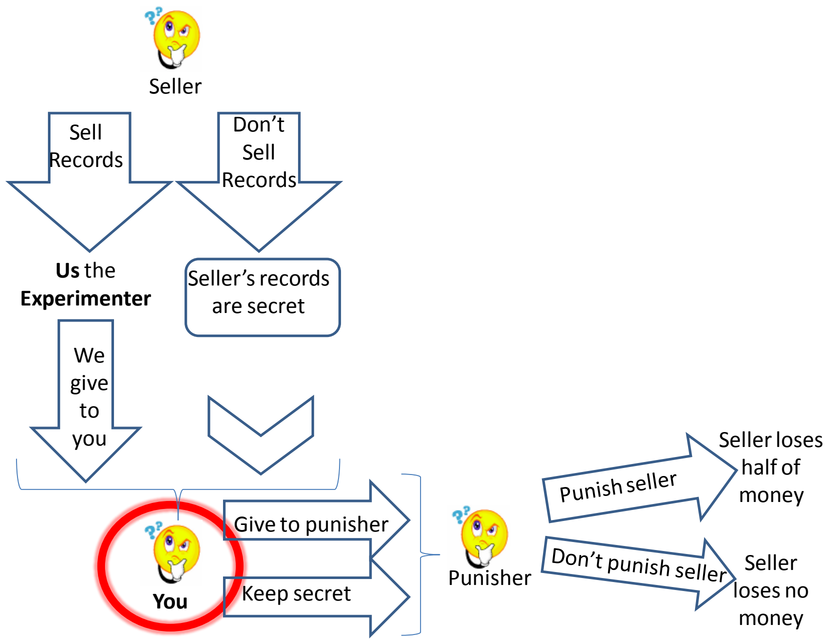
20-sided Roll	1st 10-sided Die Roll	2nd 10-sided Die Roll

Did sale take place? Yes No

If yes, amount paid $___________

F.3.2.1 Private Instructions and Decision Sheet for Sender in Indirect-Sale

In this experiment, you are a **Sender**. The cartoon below shows your role, circled in red, along with the roles of the people you are paired with.

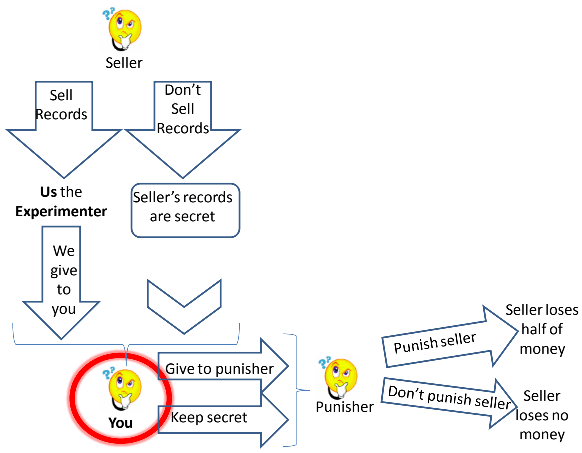


At the end of this session you may or may not receive the record sheet of a Seller. If you receive a seller's record sheet, it will include the Seller's earnings in the game that was just played.

You have a decision to make at the end of the session. You will need to decide to either keep information confidential or pass the information to a punisher, who may or may not reduce the Seller's earning from the game that was just played by 50%. This decision is entirely up to you.

Before we proceed, if you have any questions please raise your hand and we will answer your questions privately.

DECISION SHEET



Remember, the cartoon above shows your role, circled in red, along with the roles of the people you are paired with.

Please write the amount of money you are willing to sell your record sheet for in the blank space provided on the next line.

I will sell record sheet for $__________

At the end of this stage you will have a decision to make. For this decision, you will need to circle either A or B for your choice. Do not make this choice yet. We will tell you when to make your decision.

Keep the Seller's record sheet confidential: **A**

Pass the Seller's record sheet to the Punisher: **B**

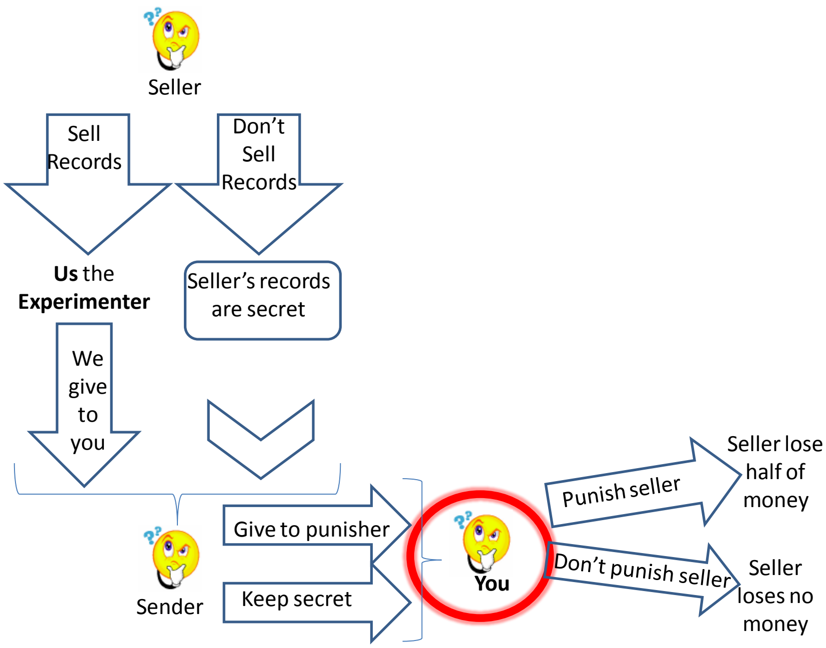
20-sided Roll	1st 10-sided Die Roll	2nd 10-sided Die Roll

Did sale take place? Yes No

If yes, amount paid $___________

F.3.2.2 Private Instructions and Decision Sheet for Punisher in Indirect-Sale

In this experiment, you are a **Punisher**. The cartoon below shows your role, circled in red, along with the roles of the people you are paired with.



You may or may not receive the record sheet of a Seller. If you receive a seller's record sheet, it will include the Seller's earnings in the game that was just played.

You have a decision to make **at the end of the stage**. You will need to decide to either

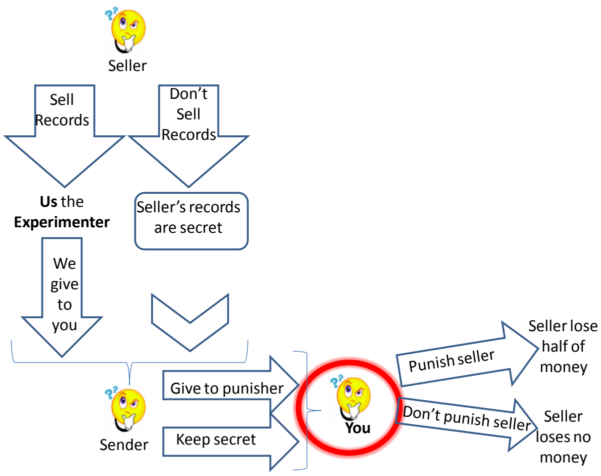
(a) deduct 50% of the Seller's earning from the first game

(b) deduct no earnings.

This decision is entirely up to you.

Before we proceed, if you have any questions please raise your hand and we will answer your questions privately.

DECISION SHEET



Remember, the cartoon above shows your role, circled in red, along with the roles of the people you are paired with.

Please write the amount of money you are willing to sell your record sheet for in the blank space provided on the next line.

I will sell record sheet for $__________

At the end of this stage you will have a decision to make. For this decision, you will need to circle either A or B for your choice. Do not make this choice yet. We will tell you when to make your decision.

Deduct none of the Seller's earnings from the first game: **A**

Deduct 50% of the Seller's earning from the first game: **B**

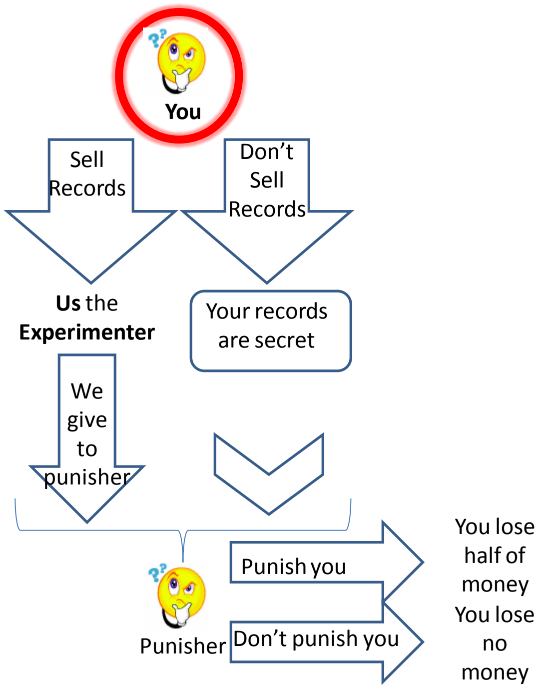
20-sided Roll	1st 10-sided Die Roll	2nd 10-sided Die Roll

Did sale take place? Yes No

If yes, amount paid $___________

F.3.2.3 Private Instructions and Decision Sheet for Seller in Direct-Sale

In this experiment, you are a **Seller**. The cartoon below shows your role, circled in red, along with the role of the person you are paired with.



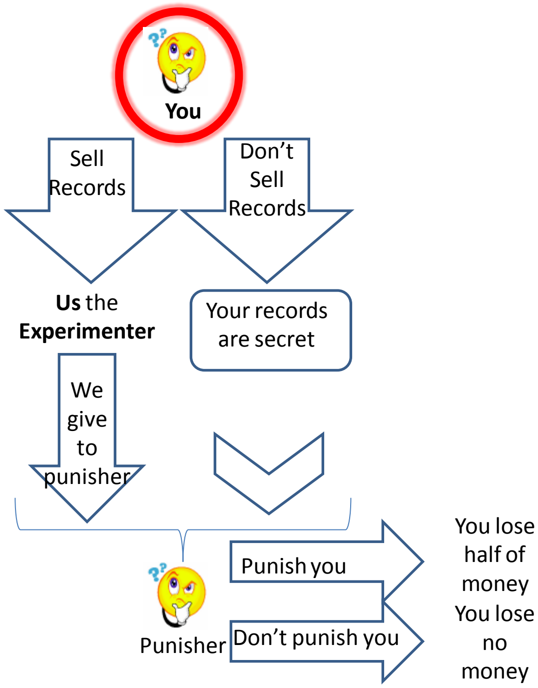
If you sell your record sheet to us, we will give it to the Punisher you are paired with. The punisher will choose to:

(c) deduct 50% of the Seller's earning from the first game

(d) deduct no earnings.

Before we proceed, if you have any questions please raise your hand and we will answer your questions privately.

DECISION SHEET



Remember, the cartoon above shows your role, circled in red, along with the role of the person you are paired with. Please write the amount of money you are willing to sell your record sheet for in the blank space provided on the next line.

I will sell record sheet for $__________

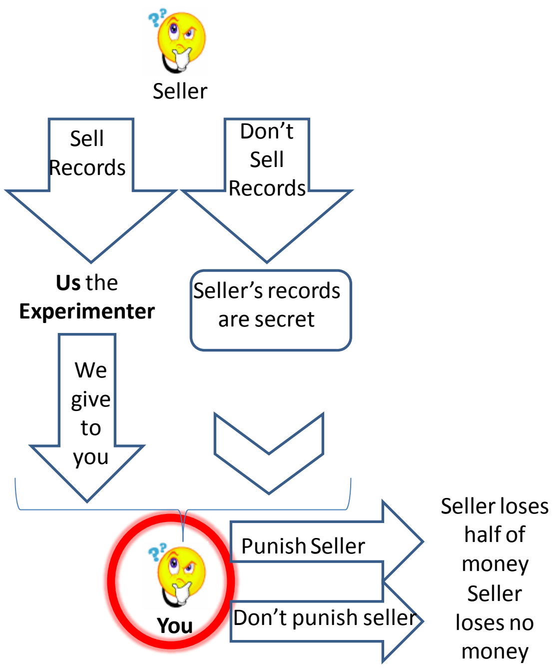
20-sided Roll	1st 10-sided Die Roll	2nd 10-sided Die Roll

Did sale take place? Yes No

If yes, amount paid $___________

F.3.2.4 Private Instructions and Decision Sheet for Punisher in Direct-Sale

In this experiment, you are a **Punisher**. The cartoon below shows your role, circled in red, along with the role of the person you are paired with.



You may or may not receive the record sheet of a Seller. If you receive a seller's record sheet, it will include the Seller's earnings in the game that was just played.

You have a decision to make **at the end of the stage**. You will need to decide to either

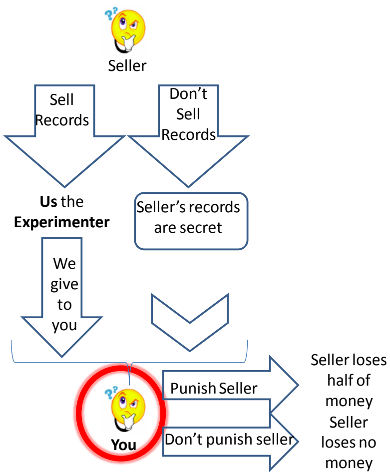
(c) deduct 50% of the Seller's earning from the first game

(d) deduct no earnings.

This decision is entirely up to you.

Before we proceed, if you have any questions please raise your hand and we will answer your questions privately.

DECISION SHEET



Remember, the cartoon above shows your role, circled in red, along with the role of the person you are paired with.

Please write the amount of money you are willing to sell your record sheet for in the blank space provided on the next line.

I will sell record sheet for $__________

At the end of this stage you will have a decision to make. For this decision, you will need to circle either A or B for your choice. Do not make this choice yet. We will tell you when to make your decision.

Deduct none of the Seller's earnings from the first game: **A**

Deduct 50% of the Seller's earning from the first game: **B**

20-sided Roll	1st 10-sided Die Roll	2nd 10-sided Die Roll

Did sale take place? Yes No

If yes, amount paid $___________

F.3.3 Belief Elicitation Instructions

F.3.3.1 Elicitation of Punishment Beliefs

Please read these instructions quietly to yourself. If you have any questions please raise your hand and a research assistant will come by and answer your questions privately.

In this task you will place a bet that the Punisher reduces your earnings from the first game by 50%.

Your decision sheet for this task is on the following page. Before you make your choice, lets discuss the decision sheet.

You will be paid based on the choice you circle and if the Punisher reduces your earnings from the first game by 50%.

If you believe with 100% certainty the Punisher will reduce you earnings from the first game then you should select row 100%. Row 100% pays $50 if the Punisher reduces you earnings from the first game and $0 if the Punisher does not reduce you earnings from the first game

Similarly, if you are sure the Punisher will not reduce you earnings from the first game then you should select row 0%. Selecting row 0% means that you believe there is a 0% chance that the Punisher will reduce you earnings from the first game. Row 0% pays $0 if the Punisher reduces you earnings from the first game and $50 if the Punisher does not reduce you earnings from the first game

If you have any questions please raise your hand and a research assistant will come by to assist you.

Please circle your **belief** on the decision sheet.

DECISION SHEET

Row	Payment if the Punisher reduces your earning from the first game by 50%		Payment if the Punisher *does not* reduces your earning from the first game by 50%	
0%	$0.00		$50.00	
1%	$0.50		$49.50	
3%	$1.50		$48.50	
4%	$2.00		$48.00	
5%	$2.50		$47.50	
7%	$3.50		$46.50	
8%	$4.00		$46.00	
9%	$4.50		$45.50	
11%	$5.50		$44.50	
12%	$6.00		$44.00	
14%	$7.00		$43.00	
15%	$7.50		$42.50	
16%	$8.00		$42.00	
18%	$9.00		$41.00	
19%	$9.50		$40.50	
20%	$10.00		$40.00	
22%	$11.00		$39.00	
23%	$11.50		$38.50	
24%	$12.00		$38.00	
26%	$13.00		$37.00	
27%	$13.50		$36.50	
28%	$14.00		$36.00	
30%	$15.00		$35.00	
31%	$15.50		$34.50	
32%	$16.00		$34.00	
34%	$17.00		$33.00	
35%	$17.50		$32.50	
36%	$18.00		$32.00	
38%	$19.00		$31.00	
39%	$19.50		$30.50	
41%	$20.50		$29.50	
42%	$21.00		$29.00	
43%	$21.50		$28.50	
45%	$22.50		$27.50	
46%	$23.00		$27.00	
47%	$23.50		$26.50	
49%	$24.50		$25.50	
50%	$25.00		$25.00	
54%	$27.00		$23.00	
58%	$29.00		$21.00	
62%	$31.00		$19.00	
65%	$32.50		$17.50	
69%	$34.50		$15.50	
73%	$36.50		$13.50	
77%	$38.50		$11.50	
81%	$40.50		$9.50	
85%	$42.50		$7.50	
88%	$44.00		$6.00	
92%	$46.00		$4.00	
96%	$48.00		$2.00	
100%	$50.00		$0.00	

Report: __________

To be completed by Staff:

Did punisher reduce by 50% (yes/no)?: ________ Earnings: _________

F.3.3.2 Elicitation of Confidentiality Beliefs

Please read these instructions quietly to yourself. If you have any questions please raise your hand and a research assistant will come by and answer your questions privately.

In this task you will place a bet that the Sender will pass your record sheet to the Punisher.

Your decision sheet for this task is on the following page. Before you make your choice, lets discuss the decision sheet.

You will be paid based on the choice you circle and if Sender passes your information to the Punisher.

If you believe with 100% certainty that your information will be passed to the Punisher then you should select row 100%. Row 100% pays $50 if your information is passed to the Punisher and $0 if your information is not passed to the Punisher.

Similarly, if you are sure that your information is not going to be passed to the Punisher then you should select row 0%. Selecting row 0% means that you believe there is a 0% chance that your information will be passed to the Punisher. Row 0% pays $0 if your information is passed to the Punisher and $50 if your information is not passed to the Punisher.

If you have any questions please raise your hand and a research assistant will come by to assist you.

Please circle your **belief** on the decision sheet.

DECISION SHEET

Row	Payment if your record sheet <u>is passed</u> to the Punisher	Payment if your record sheet *is not passed* to the Punisher
0%	$0.00	$50.00
1%	$0.50	$49.50
3%	$1.50	$48.50
4%	$2.00	$48.00
5%	$2.50	$47.50
7%	$3.50	$46.50
8%	$4.00	$46.00
9%	$4.50	$45.50
11%	$5.50	$44.50
12%	$6.00	$44.00
14%	$7.00	$43.00
15%	$7.50	$42.50
16%	$8.00	$42.00
18%	$9.00	$41.00
19%	$9.50	$40.50
20%	$10.00	$40.00
22%	$11.00	$39.00
23%	$11.50	$38.50
24%	$12.00	$38.00
26%	$13.00	$37.00
27%	$13.50	$36.50
28%	$14.00	$36.00
30%	$15.00	$35.00
31%	$15.50	$34.50
32%	$16.00	$34.00
34%	$17.00	$33.00
35%	$17.50	$32.50
36%	$18.00	$32.00
38%	$19.00	$31.00
39%	$19.50	$30.50
41%	$20.50	$29.50
42%	$21.00	$29.00
43%	$21.50	$28.50
45%	$22.50	$27.50
46%	$23.00	$27.00
47%	$23.50	$26.50
49%	$24.50	$25.50
50%	$25.00	$25.00
54%	$27.00	$23.00
58%	$29.00	$21.00
62%	$31.00	$19.00
65%	$32.50	$17.50
69%	$34.50	$15.50
73%	$36.50	$13.50
77%	$38.50	$11.50
81%	$40.50	$9.50
85%	$42.50	$7.50
88%	$44.00	$6.00
92%	$46.00	$4.00
96%	$48.00	$2.00
100%	$50.00	$0.00

Report: ___________

To be completed by Staff:

Was the record sheet passed (yes/no)?: ________ Earnings: __________

F3.3.3 Elicitation of Beliefs from Senders and Punishers

Please read these instructions quietly to yourself. If you have any questions please raise your hand and a research assistant will come by and answer your questions privately.

In this task you will place a bet you receive the seller's record sheet from the first game we played.

Your decision sheet for this task is on the following page. Before you make your choice, lets discuss the decision sheet.

You will be paid based on the choice you circle and if you receive the seller's record sheet.

If you believe with 100% certainty that you will receive the seller's record sheet then you should select row 100%. Row 100% pays $50 if you receive the seller's record sheet and $0 if you do not.

Similarly, if you are sure that you will not receive the seller's record sheet then you should select row 0%. Selecting row 0% means that you believe there is a 0% chance that you will receive the seller's record sheet. Row 0% pays $0 if you receive the seller's record sheet and $50 if you do not receive the seller's record sheet.

If you have any questions please raise your hand and a research assistant will come by to assist you.

Please circle your **belief** on the decision sheet.

DECISION SHEET

Row	Payment if you receive the seller's record sheet	Payment if you *do not* receive the seller's record sheet
0%	$0.00	$50.00
1%	$0.50	$49.50
3%	$1.50	$48.50
4%	$2.00	$48.00
5%	$2.50	$47.50
7%	$3.50	$46.50
8%	$4.00	$46.00
9%	$4.50	$45.50
11%	$5.50	$44.50
12%	$6.00	$44.00
14%	$7.00	$43.00
15%	$7.50	$42.50
16%	$8.00	$42.00
18%	$9.00	$41.00
19%	$9.50	$40.50
20%	$10.00	$40.00
22%	$11.00	$39.00
23%	$11.50	$38.50
24%	$12.00	$38.00
26%	$13.00	$37.00
27%	$13.50	$36.50
28%	$14.00	$36.00
30%	$15.00	$35.00
31%	$15.50	$34.50
32%	$16.00	$34.00
34%	$17.00	$33.00
35%	$17.50	$32.50
36%	$18.00	$32.00
38%	$19.00	$31.00
39%	$19.50	$30.50
41%	$20.50	$29.50
42%	$21.00	$29.00
43%	$21.50	$28.50
45%	$22.50	$27.50
46%	$23.00	$27.00
47%	$23.50	$26.50
49%	$24.50	$25.50
50%	$25.00	$25.00
54%	$27.00	$23.00
58%	$29.00	$21.00
62%	$31.00	$19.00
65%	$32.50	$17.50
69%	$34.50	$15.50
73%	$36.50	$13.50
77%	$38.50	$11.50
81%	$40.50	$9.50
85%	$42.50	$7.50
88%	$44.00	$6.00
92%	$46.00	$4.00
96%	$48.00	$2.00
100%	$50.00	$0.00

Report: __________

To be completed by Staff:

Was the record sheet received (yes/no)?: ________ Earnings: _________

F.4 Stage 3: Lottery Task Instructions

Lottery task instructions were identical to those used in Appendix D.4.

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