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Risk Preferences, Perceptions and systematic Biases

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Outline

Table of Figures

Table of Tables

Introduction and Statement of the Research Problem

Many decisions we face are characterized by risk or uncertainty — we must make choices prior to knowing the outcome. However, we often know the potential outcomes and even have some idea regarding the likelihood of each.

While there are similarities in how people respond to risky decisions, there are also differences related to factors like gender (e.g. Levin et al., 1998) and culture (e.g., Kleinhesselink and Rossa, 1991; Weber et al., 1998). Understanding these similarities and differences can help our understanding of a range of economic phenomena. For example, why does entrepreneurship flourish in some countries while it stagnates in others?

Risk perceptions and risk preferences are widely recognized by economist as the major factors influencing risky behavior. Risk perceptions characterize the likelihood of chance outcomes and are usually framed in economics in terms of subjective probabilities. Risk preferences rank outcomes based on individual wants.

An understanding of how to use public policy to positively influence risky behavior requires understanding to what extent differences in risky behavior are attributable to differences in risk perceptions versus differences in risk preferences. For example, if risk perceptions are the driving factor educational efforts, advertising, and, in general, increased communication about the actual risk may have the desired impact. In the case of entrepreneurship, communication efforts could include information about successful start up companies or seminars on how to successfully establish a new business. If risk preferences are the driving factor, better information alone may be ineffective. Policy makers could instead influence behavior by providing programs to alleviate risk or help individuals manage risk. An insurance program or start up grants in these instances may be a viable policy for improving entrepreneurship.

The purpose of this research is to develop a novel experimental protocol for measuring individual differences in risk perceptions and risk preferences. This experimental protocol will then be used to explore how individual differences in subjective probabilities and risk preferences relate to objective probabilities, demographic characteristics, and information.

The experimental protocol consists of three tasks. After randomly dividing participants into 2 groups, one group is given a short children's story to read. Second, all subjects will be asked to complete a survey. The survey will ask general demographic questions (e.g. age, gender, and family background). It will also ask 20 questions designed to elicit cultural information based on Geert Hofstede (2001). Lastly, subjects will be asked how much they are willing to pay to play a more favorable lottery. This question will be repeated with 20 different lottery combinations, which will vary by the scale of rewards. Furthermore, how a favorable outcome is determined will vary between the two groups. The group that received the short story will have probabilities phrased as randomly choosing of specific word or letter or a combination from story. For the other group, poker chips will be randomly drawn out of a can. A random drawing scheme will be implemented for one randomly selected lottery combination in order to provide incentives for thoughtful responses. Payoffs will be paid out in cash based on the outcome of the chosen lottery and the individual's choice. The experiment will be conducted with a total of 60 undergraduate students from two to three U.S. universities in late spring 2006.

Responses to the lottery questions will be used to fit a state contingent utility function (Arrow, 1953; and Debreu, 1959). A variety of flexible forms will be considered. The parameter estimates for the state contingent utility function will be used to test whether the subjective probability of the favorable outcome equals the objective probability and whether subjective probabilities differ based on how the favorable outcome is determined and the scale of the rewards. Individual differences in subjective probabilities as defined by Chambers and Quiggin (2000) and risk preferences as defined by Yaari (1969) will also be tested. The relationship between demographic (and cultural) characteristics and differences in subjective probabilities and risk preferences will also be explored.

The two treatment variables in this experiment include how a favorable outcome is determined and the scale of the rewards. Varying how a favorable outcome is determined varies the information available to subjects for assessing the likelihood of a favorable reward. A question of interest is whether restricting information influences risk preferences as well as subjective probabilities. With poker chips, subjects have complete information on which to base risk perceptions and we therefore expect to find little difference between subjective and objective probabilities. For randomly selecting a word/letter from a recently read short story, subjects have a restricted set of information upon which to base risk perceptions, which could result in subjective probability judgments substantially differing from the objective probability. The literature suggests a person's subjective probabilities tend to overestimate low and underestimate high objective probabilities. Varying the scale of the reward is expected to influence risk preferences (Hartog et al., 2002; Holt and Laury, 2002). But a question that has not been explored is whether varying the scale of the rewards has an even more profound effect on risk perceptions as defined by Chambers and Quiggin (2000).

Of the demographic information we will collect, gender has been most commonly related to differences in risky behavior. Women often appear more risk averse than men (e.g. Levin et al., 1998), but Hurley and Shogren (2005) suggest gender differences in risky behavior may be better explained by differences in risk perceptions. Our experimental design will allow us to explore this issue more rigorously.

The results of this project will contribute methodologically to the economics literature by providing a refined experimental protocol for measuring differences in individual risk perceptions and risk preferences. This tool will facilitate research on how public policy can be used to positively influence risky behavior. It also will provide more concrete evidence on gender differences in risky behavior, while providing a benchmark for future studies of cross-cultural differences in risky behavior.

A variety of extensions for this research are possible that would be useful for an extended policy debate. Firstly, one could conduct the study with different ethnic groups or in a foreign country to capture the influence of cross-cultural differences. To obtain data on risk preferences and risk perceptions on a different group of people, one could also conduct the study with small farmers in various countries to be able to derive policy implications for technology adoption.

This study has important implications for the advancement of experimental economics as well as risk perception studies. The majority of risk research is concerned with risk preferences. Risk preferences reflect an individuals' intrinsic attitude towards risky behavior or decisions and have been researched extensively. They are important for the evaluation of consequences and thus for decision-making. On the other hand, it has become evident that the perceived rather than the actual risk determines an individual's actions and choices.

Cunnigham (1967) defined risk perceptions as a "consumer's subjective feeling that there is some probability that a choice may lead to an undesirable outcome". One could think of decision-making under risk as a two step process: Firstly, the risk is evaluated using one's own risk perception. Secondly, once the risk is determined, risk preferences come into play to determine what action or alternative is chosen. In this context, it is clear that risk preferences and perceptions have to be analyzed jointly. Few studies have addressed this issue but as shown in Weber et al. (1998) and Pennings et al. (2002) it leads to interesting insights that allow a more robust conceptualization of risky behavior and more refined policy recommendations. Because risk preferences have been studied more extensively in the literature, the emphasis of this research is on risk perceptions while also incorporating risk preferences.

This research relies on the Ramsey-Savage utility decision-making approach (Savage, 1954; Ramsey, 1931). Among others, Davidson, Suppes and Siegel (1957) pointed out that the classical Expected Utility Theory does not adequately represent individual decision-making because individuals cannot be assumed to be perfectly rational and the necessary existence and knowledge of an objective probability for the event in question is unrealistic. Kahnemann and Tversky (1979) have become famous for their prospect theory and consecutively cumulative prospect theory that offers a behavioral economics alternative. Personal, psychological or subjective probabilities have surfaced as alternatives to objective probabilities but have not been recognized by a wide audience even though they have been acknowledged more than 80 years ago by Bruno de Finetti (1937). The concept of subjective probability is defined by Savage (1972, p.3) and similarly de Finetti as a measure of confidence that an individual has in the truth of a particular proposition such as whether it will rain tomorrow. The response is individual specific and thus makes it possible to deal with single events and the induction problem. Given that notion, we will maintain that even subjective probability must adhere to rules of coherence, and certain axioms[1].

Methods of analysis

Theoretical and conceptual framework

The conceptual and theoretical framework used for this research is an expansion of the state-dependent theory developed by Arrow (1953) and Debreu (1959). This approach also connects to Expected Utility Theory and subjective probabilities (Savage, 1954). The concept of subjective probability is based on the behavioristic idea that they are a measure of an individual's belief about the occurrence of an uncertain event (Savage, 1972 and de Finetti, 1937). The measure is individual specific and depends on personal experience as much as on circumstance. we will still maintain that subjective probability must adhere to rules of coherence, and certain axioms.

The basic proposition of the state-dependent model is that goods can be differentiated by states in addition to their physical properties and location in space. The notion of states is applicable to a variety of practical situations and is a wide ranging as different times of the day, different environmental conditions like different cultures or

[1] An example is that the probabilities of all possible events must add up to unity.

alternative investment projects. The state-dependence approach permits the application of standard choice theory to the analysis of decision-making under risk. The theory requires that states are mutually exclusive an that they are exogenous to the decision-maker. They are chosen by nature. An individual's decision could have different outcomes depending on which state occurs. For example, the decision to not carry an umbrella could prove to be a good one in the case that it doesn't rain (state 1). However, if it rains (state 2) the individual gets wet.

More formally, the individual chooses actions a, which yield state-specific outcomes y_S. In our case, the individual has choice between lotteries and is required to state one of the states payoffs that would make him indifferent between 2 different lotteries. Following the notation by Chambers and Quiggin (2000), we can define

$\Omega = \{1,...,S\}$, the set of states

$Y \subseteq \Re^M$, the space of consequences, outcomes or payoffs where $y \in Y$

$A : \Omega \rightarrow \Re^M$, an action generates a range of outcomes according to the realized state of nature ($a \in A$)

$y(A) \in \Re^{M*S}$, each act defines a state dependent outcome

$W : Y^S \rightarrow \Re$, a preference function over states $W(\mathbf{y})$

$u : \Re \rightarrow \Re$, a utility function

p_s, subjective probabilities where $\sum_{s \in \Omega} p_s = 1$ and

p_s, objective probabilities, where $\sum_{s \in \Omega} p_s = 1$

We will maintain that although probability judgments are subjective, they are non-random and influenced by individual characteristics (i.e. experience, knowledge, information) as well as the underlying objective probability. Subjective probabilities are closely related to beliefs, preferences and objective probability. In the example of the decision to carry an umbrella, an individual with the knowledge that clouds and rain are related will place a higher probability on the chance that it will rain if it is cloudy than for the case that there are blue skies and sunshine. This individual will therefore be more likely to carry an umbrella (observed behavior) if it is cloudy out. The objective probability might be unknown but that does not imply it does not exist.

Probability judgments will be inferred from observed behavior. To simplify the analysis, we am restricting the analysis to monetary terms. This relationship is uniquely defined for the case of 2 states and smooth, differentiable, monotone utility functions. We will use the definition for risk aversion by Yaari (1969) and Chambers and Quiggin (2000): A decision-maker is risk-averse with respect to the probability vector if he at least weakly prefers the average income for certain to any other potential distribution of income or more formally:

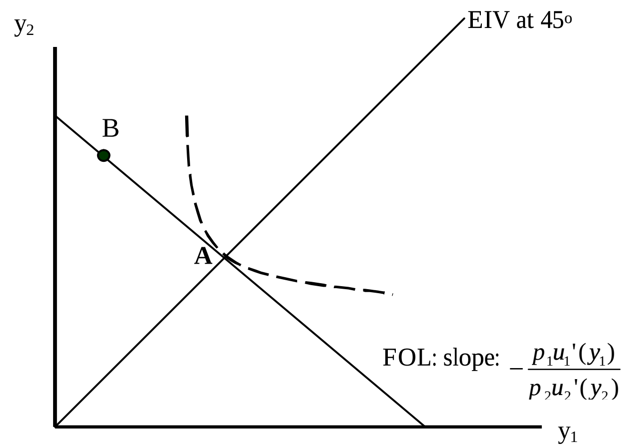
Def.: A decision-maker is risk-averse with respect to the probability vector $p \in \Pi$ if $W(\bar{y}\mathbf{1}^s) \geq W(\mathbf{y}) \quad \forall \mathbf{y}$ where $\bar{y}\mathbf{1}^s$ is a state-contingent outcome vector with $\bar{y} = \sum_{s \in \Omega} p_s y_s$ occurring in each state. (Refers to uncertainty versus certainty)

If preferences are smoothly differentiable, this definition of risk aversion implies an equal slope along the equal incomes vector. The Equal Incomes Vector (EIV) is defined as the vector starting at the origin where payoffs are equal in all states. After estimating the utility function, we can thus derive local measures of risk aversion along the equal incomes vector. Under the additional assumption that preferences remain stable over changes in payoffs, with smooth and differentiable preferences, the vector of probabilities is equal to the marginal rate of substitution (MRS) between state-contingent outcomes. However, if preferences are indeed stable will be tested during this study. In case they are not, the MRS is equal to the ratio of subjective probabilities multiplied by the ratio of marginal utilities:

(1) $$MRS = -\frac{p_1 u_1'(y_1)}{p_2 u_2'(y_2)}$$

A comparison of inferred subjective probabilities with the induced objective probabilities will provide insights into evaluation biases. Assuming 2 states $\Omega = \{1,2\}$, risk-verse smooth preferences and no free disposal, we can depict the basic model graphically as follows:

Figure 1: Graphical illustration of state-dependent model for 2 states



The Fair Odds Line (FOL) is defined as the line that connects all points with the same expected value at given probabilities (Chambers and Quiggin, 2000). For this risk-averse individual, point A must be at least weakly preferred to all other points such as B on the fair-odds line (FOL) because for all other points income is more dispersed. Consequently, they are riskier than A. For a risk-averse individual, in point A, the marginal rate of substitution between y_1 and y_2 will have to equal the ratio of subjective probabilities. Following the notation in Chambers and Quiggin (2000), we can compute probabilities based on a state utility function W from

(2) $$p_s = \frac{\partial W(\mathbf{1}^s)/\partial y_s}{\sum_s \partial W(\mathbf{1}^s)/\partial y_s}.$$

Specifically using subjective expected utility, we can infer subjective probabilities once we have estimated the utility function from the data as

(3) $$p_s = \frac{p_s u'\left(\sum_{s\in\Omega} p_s y_s\right)}{\sum_s p_s u'\left(\sum_{s\in\Omega} p_s y_s\right)}$$

s.t.

(4) $$\sum_{s\in\Omega} p_s = 1.$$

The probabilities have to sum to unity and with non-decreasing preferences they always have to be non-negative.

Topics for Analysis

There are a variety of issues that will be analyzed as part of this research: scale invariance, preference reversal and loss aversion, the difference between objective and subjective probabilities, the impact of information on subjective probabilities and risk preferences, and the importance of individual (and cultural) characteristics and the relevance of an endowment effect.

Certainty Effect

One aspect of people making decisions different than assumed by expected utility theory is the preference for certainty that can be observed with relatively simple experiments. The certainty effect states that individuals prefer outcomes that are certain over outcomes that are probable even though the expected positive gain is higher (within limit). Most events or decisions under risk in real life deal with risky alternatives, which is why this study does not focus on comparing a certain and a risky lottery. However, we included three lotteries containing such a pairing to test whether there is a certainty effect.

Constant Absolute Risk Aversion

In order to identify each individual's subjective probability within the state-dependent framework, we need to ensure constant absolute risk aversion or scale invariance. We can compute the Arrow-Pratt measure of absolute risk aversion, $r(y)$ once we estimated each individual's utility function as

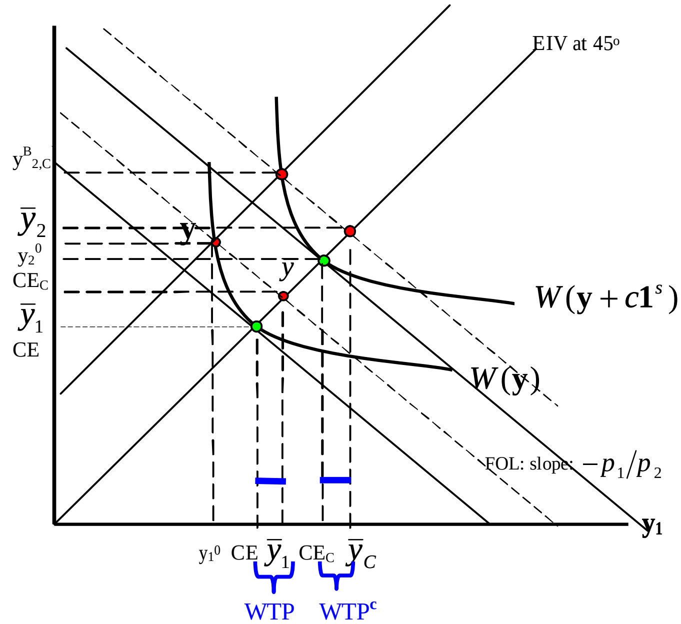
(5) $$r(\mathbf{y}) = -\frac{u''(\mathbf{y})}{u'(\mathbf{y})}$$

Depending on how $r(y)$ changes with changes in income y, the individual can display increasing, constant and absolute risk aversion. Constant absolute risk aversion (CARA) ensures that rescaling of rewards with the same magnitude will result in the same absolute risk premium. Because the scaling factors as well as payoffs in this study are relatively small, we expect CARA to hold.

Def. 1: *The subjective utility function $W(\mathbf{y})$ exhibits constant absolute risk aversion (CARA) if, for any y and $t \in \Re$ $r(\mathbf{y} + t\mathbf{1}^s) = r(\mathbf{y})$.*

Figure 2 shows an illustration of scale invariance and its implications for willingness to pay to trade a risky (**y**) for a certain lottery $\bar{y}$ and the rescaled equivalents.

Figure 2: Scale Invariance



Scale invariance requires that we can confirm $WTP = WTP^C$ or $(\mathbf{CE}_C - \mathbf{CE}) = (\mathbf{y}_C^B - \mathbf{y}^B)$ where B is the risky lottery, no subscript refers to the original lottery, the parameter 'c' indicates the rescaled lottery combination, and CE is the certainty equivalent for the risky lottery in the original as well as the rescaled lottery. The certainty equivalent is the amount of payoff that an agent would have to receive to be indifferent between that payoff and a given gamble. An agent's willingness to pay For a risk-averse agent the certainty equivalent is less than the expected value of the gamble because the agent prefers to reduce uncertainty. Chambers and Quiggin (2001) establish the result that "$W(\mathbf{y})$ displays CARA if and only if $W(\mathbf{y})$ is translation homothetic, that is, a continuous non-decreasing transformation of a function satisfying the translation property".

Failure to confirm scale invariance would prohibit the joint elicitation of risk perceptions and risk preferences because neither could be estimated uniquely any longer.

Changes in willingness to pay for rescaled payoff structures could then be caused by changes in risk preferences and/or changes in risk perceptions.

Constant Relative Risk Aversion

The disadvantage of using absolute risk aversion as a measure of an agent's risk preference lays in its inability to capture changes of risk preferences that are due to changes in wealth. For example, an agent could be risk-loving for small payoffs, risk-averse for medium payoffs and again risk-loving for high payoffs. An alternative would be to weigh the measure of risk aversion by the level of wealth y. In this case we obtain the Arrow-Pratt Measure of Relative Risk-Aversion:

(6) $$R(\mathbf{y}) = -\frac{\mathbf{y}u''(\mathbf{y})}{u'(\mathbf{y})}$$

Def. 2: The subjective utility function $W(\mathbf{y})$ *exhibits constant relative risk aversion (CRRA) if, for any y and* $t \in \Re$ $v(t\mathbf{y}) = v(\mathbf{y})$ *where* $v(\mathbf{y})$ *is the relative risk premium* $v(\mathbf{y}) = \sup\left\{ l > 0 : W\left(\frac{\bar{y}\mathbf{1}^s}{l}\right) \geq W(\mathbf{y})\right\}$.

Constant relative risk aversion means that radial expansions or contractions of the state-contingent return vector should not alter the individual's attitude toward risk. "$W(\mathbf{y})$ displays CRRA if and only if $W(\mathbf{y})$ is homethetic[2], that is, a monotonic transformation of a linearly homogeneous function." (Chambers and Quigging, 2001) In the expected utility framework used for this research, this implies that individuals must have homogeneous preferences. Graphically, any ray from the origin will then cut all indifference curves at points of equal slope (Chambers and Quiggin, 2001).

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[2] A function of two or more arguments is homothetic if all ratios of its first partial derivatives depend only on the ratios of the arguments, not their levels. For competitive consumers or producers optimizing subject to homothetic utility or production functions, this means that ratios of goods demanded depend only on relative prices, not on income or scale (Deardorff, 2001).

Difference between Subjective and Objective Probability

There are a variety of reasons why subjective probabilities might be biased. Table 1 summarizes these biases in assessing probabilities that have been identified in the literature, which could drive differences to objective probabilities and which are relevant for this study.

Table 1: Types of Biases in Assessing Probabilities[3]

Bias	Description
Insensitivity to prior probability of outcomes	Underweighting of prior information (base rates)
Biases due to Retrievability of Instances	Affected by familiarity, salience: overweighting of familiar events, least and most pleasant memories recalled faster
Biases due to the Effectiveness of a Search Set	Availability or ability to recall events
Biases due to Imaginability	Assessment of probability generated by some rule (heuristics)[4]
Overemphasis on strength[3]	Judgments of confidence overemphasize strength of evidence
Underemphasis on weight	Underestimation of impact of evidence/likelihood information à "conservatism"[1]

Figure 3 depicts an example where objective and subjective probabilities differ but the utility function is the same. Assuming a concave, smooth and differentiable utility function and objective probabilities of $p_1 = 0.6$ and $p_2 = 0.4$, we obtain an objective Fair Odds Line with as slope of $-{p_1}/{p_2} = -{3}/{2}$ and a tangency at payoffs of payoffs of $4. As can be seen, the subjective Fair Odds Line is flatter (slope of $-{p_1}/{p_2} = -{0.5}/{0.5} = -1$) although the underlying utility function is the same. Consequently, the high probability was under- and the low probability overestimated.

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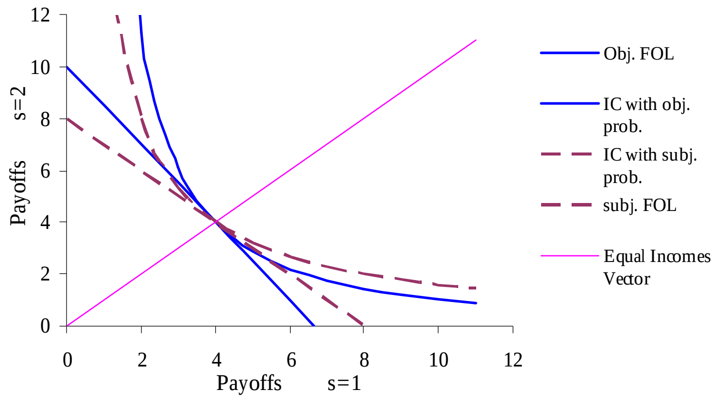
3 Camerer (1995) in Handbook of Experimental Economics: 587-677, Kahneman, Tversky and Slovic (1982), Tversky and Kahneman (1972 and 1971)

4 This bias is not expected to be relevant with the group of participants use for this study because they should have some basic knowledge of probability and the probability is phrased in a straightforward manner.

Figure 3: Example of subjective versus objective probabilities under equal utility functions



Predictors of Risk Perceptions

A number of studies have attempted to explain predictors for individual's risk perception. Socio-demographics appear to play a role along with personal characteristics on a psychological level in determining an individual's risk perception and preference. Cultural factors that affect all individuals of a certain culture similarly are also expected to be relevant.

Perceptions are influenced by amongst others the situation, emotional state of the individual, personal experiences with the same of similar risks, timing, and socio-demographic background like age, gender and location. For example, British people potentially perceive the likelihood of another BSE outbreak as higher than US Americans because they have experienced similar events before while there have only been scattered outbreaks in the US.

Eckel and Grossman (2003) in their effort to test for gender differences could not find significance for other standard demographic variables such as age, race or employment status. Dosman et al. (2001) analyze the significance of socioeconomic determinants of risk perceptions of food safety and health issues using a multivariate approach. They used an ordered probit model with risk rating of a particular hazard as dependent variable and socioeconomic variables as explanatory ones. Out of all socio-economic variables used, only gender differences were significant and robust to all model specifications. We do not expect other socio-economic variables to be significant for this study because We have a self-selected somewhat homogeneous sample of college students at roughly the same age, income and employment level.

Women are more likely to perceive a situation as more risky and also exhibit greater risk aversion than their male counterparts. Specifically, studies have found differences between men and women in the perception of risk towards alcohol and drug use (Spigner, Hawkins and Loren, 1993) catastrophic potential of nuclear war, technology, radioactive waste, industrial hazards and environmental degradation (Flynn, Slovic and Mertz, 1994) and of various recreational activities (Boverie, Scheuffele, and Raymond, 1995). A similar pattern can be observed for risk preference: Women are more risk averse towards gambles than men (Levin et al., 1998).

A number of studies have looked at the different aspects of culture and its influences on individual’s perception of risk. For example, Kleinhesselink and Rossa (1991) showed that students from Japan and the US use similar dimensions to rank hazards but their individual risk perception weighted differently in those dimensions. The biggest question generally lies in the formulation of measures of culture and a variety of theories and measures has been proposed to address this issue.

Weber et al. (1998) used Hofstede’s cultural dimensions and socio-demographic variables to determine influential factors for risk preferences and perceptions. They found significant differences in risk preferences across cultures but these differences were primarily attributed to cultural differences in how the risk is perceived rather than with differences in the attitude towards risk (i.e. risk preferences). Hofstede used a scoring method to form country scores based on a survey of IBM employees around the world and the questions and formulas for index calculation are available in *Cultures Consequences* (Hofstede, 2001). Although the country scores are available deriving country scores and indices will also enable us to test the results and stability of Hofstede's research. The indices for all 5 dimensions are based on the mean score (MS) of the sample in question. Mean scores for questions for the same dimension should correlate but should be uncorrelated to mean scores of questions for different dimensions. Responses to the questions will differ not only by culture but also by demographic variables like education or age. To restrict the survey to college students of roughly the same age with similar backgrounds is therefore beneficial for cross-cultural studies because it controls for the effect of these other variables.

Scores could be formed based on sub-samples for 1. the entire sample, 2. all respondents from the same university and lastly 3. for male and female respondents. The indices typically fall between 0 and 100 but technically scores above 100 or below 0 are possible.

The index for power distance (PDI) measures the extent to which members of the society expect and accept that power is distributed unequally. A low score indicates small power distance (more equal distribution of power) and equivalently a high score indicates large power distance.

(7) $$PDI = -35MS(Q2.3) + 35MS(Q2.6) + 25MS(Q2.14) - 20MS(Q2.17) - 20$$

For the individualism index (IDV) a low score represents strongly collectivist while a high score indicates strongly individualist that is the ties between individuals are loose and a person is expected to look after her/himself.

(8) $$IDV = -50MS(Q2.1) + 30MS(Q2.2) + 20MS(Q2.4) - 25MS(Q2.8) + 130$$

Low values of the masculinity index (MAS) indicate values of strongly feminine and consequently high values represent strongly masculine. This index should not be confused with differences in gender but rather captures societal attitudes. In masculine cultures emotional gender roles are clearly distinct and reflect historical roles such as men being assertive, strong, and focused on material success while women are tender, and more concerned with the quality of life. In cultures with low MAS scores, gender roles overlap.

(9) $$MAS = 60MS(Q2.5) - 20MS(Q2.7) + 20MS(Q2.15) - 70MS(Q2.20) + 100$$

Uncertainty avoidance is expected be the index with the most predictive power for risk attitudes and perceptions. It is designed to capture the extent to which members of a society feel threatened by uncertain, unknown, ambiguous or unstructured events and situations. A low score stands for weak uncertainty avoidance that is members of the society feel weakly threatened.

(10) $$UAI = 25MS(Q2.13) + 20MS(Q2.16) - 50MS(Q2.18) - 15MS(Q2.19) + 120$$

Lastly, long-term orientation (LTO) versus short-term measures how much a society is oriented towards the future rewards. A society oriented to the long-term (high score) will foster virtues like perseverance and thrift while a society with a short-term orientation (low score) will foster virtues related to the past and present like tradition and fulfilling social obligations.

(11) $$LTO = -20MS(Q2.10) + 20MS(Q2.12) + 40$$

The Importance of Information

The impact of information on decision-making under risk has been recognized as a major factor. Behavioral economists such as Tversky, Kahneman and Thaler used experimental economics to show that individuals do not conform to standard Baysian updating and are subject to a variety of biases. We therefore hypothesize that differences between subjective and objective probabilities decreases with the availability of information. The challenge lies in being able to control the objective probability and masquerading information about the underlying probability of a particular event. We assume that risky events have a true probability of occurring. For most events in real life this probability is unknown but can be approximated with more or less accuracy.

Using the example of “will it rain or not”, characteristics such as wind flow, cloud accumulation, air pressure influence whether it will rain and measuring these factors allows meteorologists to estimate the likelihood of rain fall occurring. An individual trying to decide whether or not to carry an umbrella can do a variety of things to influence his subjective judgment about the possibility of rain. For example, he could watch or read the weather forecast, look outside himself and evaluate his past experiences with the weather as well as accuracy of the forecast. Eventually, formulate his subjective judgment about the probability of rain and make a decision about carrying an umbrella based on that. Assuming the collected information is correct and relevant for predicting rain, his subjective probability judgment should converge to the objective probability.

There is a literature that investigates updating with information in particular in the behavioral economics literature. The main issues are: judgments of confidence that overemphasize strength of evidence (Camerer, 1995, p. 587-677) but also underestimation of impact of new information (Kahneman, Tversky and Slovic, 1982), and underweighting of prior information (base rates).

The experimental procedure for this study will test for the influence of information availability on risk perceptions as well as risk preferences. The participants will randomly be divided into 2 groups. One will receive the lotteries with probabilities stated in the form of drawing of poker chips from a can. The information set for this group will be complete providing us with a benchmark. The other group will receive probability statements phrased as picking a word, letter or a combination thereof from a recently read short story. Technically, the information for this group is also complete because they could count the total number of words and the number of occurrences of the particular word and letter and compute the probability. However, participants are not given sufficient time to do so, restricting the information about the probabilities.

Hypotheses

The primary objective of this research is to determine biases for subjective probabilities and how they are affected by knowledge, socio-demographic variables, and objective probabilities. The analysis in this case is restricted to 2 states or events so We can infer subjective probabilities uniquely once a utility function is estimated for each individual. We require that even subjective probabilities must adhere to rules of coherence, and axioms such as that they sum to unity and that they lie in an interval between 0 and 1. Let's denote p as the subjective probability for event 1 and p as the objective probability for the same event and define $p = g(p, Info)$ where $p = g(p, Info) = p$ serves as the benchmark. In line with previous research (e.g., Hurley and Shogren, 2005; Viscusi et al., 1997), we expect low objective probabilities to be over- and high objective probabilities to be underestimated.

H 1: $p > p$ for $p > r$, where r is high.

This approach will yield the derivation of probability ratios. If $p/_{1-p} > p/_{1-p}$ the subjective probability for event 1 is underestimated. The experimental set up for this research does not allow to test for cut off or turning points for this hypothesis because probabilities are held constant throughout the lottery combinations. Probabilities are fixed at 0.25 for state 1 and 0.75 for state 2.

The second goal is to test if indifference curves and evaluation of probabilities are stable over various income levels. We can test this by eliciting multiple indifference curves using various payoffs y and deriving the subjective probabilities along the equal incomes vector.

H 2: $p/_{1-p}$ is the same $\forall y \in Y$,

Previous studies (Hartog et al., 2002; Holt and Laury, 2002) have shown that individuals become more risk-averse with an increase in rewards, which we will also expect to be true here. However, if this is true, eliciting risk preferences and perceptions separately using this approach is compromised. Denoting a_i an individual ***i***'s risk aversion coefficient, we have

H 3: $a_1^i > a_2^i$ if $y_1 > y_2$ $\forall y \in Y$ and $\forall i \in I$

In addition in future studies conducted with multiple cultures or ethnic groups, we can test for cultural differences in risk preferences

H 4: $a^i = a^j \quad \forall\, i \neq j, \forall\, i, j \in I$ where in this case i and j are cultural groups.

And that there are no cultural differences in risk perceptions

H 5: $p_s^i(\cdot) = p_s^j(\cdot) \quad \forall\, i \neq j, \forall\, i, j \in I$ **.**

Although cultural factors have been shown to influence risky behavior (e.g., Kleinhesselink and Rossa, 1991; Weber et al., 1998), this study focuses on undergraduate students in the US who are expected to be fairly homogeneous. Here, individual differences will play a bigger role. Specifically gender differences have been shown to be relevant. Women are more likely to perceive a situation as more risky and also exhibit greater risk aversion than their male counterparts. Specifically, studies have found differences between men and women in the perception of risk towards alcohol and drug use (Spigner, Hawkins and Loren, 1993) catastrophic potential of nuclear war, technology, radioactive waste, industrial hazards and environmental degradation (Flynn, Slovic and Mertz, 1994) and of various recreational activities (Boverie, Scheuffele, and Raymond, 1995). A similar pattern can be observed for risk preference: Women are more risk averse towards gambles than men (Levin et al., 1998).

Lastly, we will test for the influence of information on assessing probabilities. Specifically, we will test if the subjective probability is independent of the information:

H 6: $p_s^i(p, INFO) = p_s^i(p) \quad \forall\, i \in I \; and \; \forall\, s \in S$ **.**

This last section provides the necessary data to test hypotheses H 1 - H 3. Additionally, using the data collected in sections 1 and 2, we can test the influence of individual and cultural characteristics on risk preferences, perceptions and biases thus test H 4 and H 5. By comparing decisions and estimates between the two treatment groups, we can test H 6.

Experimental Design

Survey Set up

The survey consists of 3 sections that can be filled out in about 45 minutes. Section 1 consists of about 10 questions designed to elicit information about general demographic variables like age and gender as well as others like living situation, and source of income that are reflective of our sample of college students. An alternative factor that is expected to be correlated with risk preferences is the level of optimism, which is assessed by asking the participants a question about how they predict their earnings potential in the future.

Section 2 is aimed at forming 5 indices that measure culture in the tradition of Geert Hofstede (2001), whose cultural dimensions have been shown to significantly influence preferences and perceptions alike. The section is aimed at facilitating future research in foreign countries or with participants from different ethnic background with a different pool of participants in the future rather than being emphasized for this analysis. Hofstede used a scoring method to form country scores based on a survey of IBM employees around the world and the questions and formulas for index calculation are available in *Cultures Consequences* (Hofstede, 2001). To enable cross-cultural research, the subgroups are required to be as homogeneous as possible. Therefore, we restrict our analysis to college students of roughly the same age with similar backgrounds in the Midwest.

The third section will consist of the economic experiments out of which one randomly selected will be played out. The lottery choices will elicit indifference payoffs for 20 lottery combinations. The lottery set up will vary by the scale of rewards. In combination with the original set up of the lottery we are then also able to infer risk preferences and subjective probabilities. Students are randomly divided into two treatment groups. The first treatment will serve as the base case when all information about probabilities (and payoffs) is available to the participants. The second treatment group is asked to answer the same lottery combinations. However, to resemble the lack of perfect knowledge about the objective probability in real life settings probabilities will be given in form of likelihood of a word/letter drawn from a given short story. Students will not have sufficient time to determine the actual probability but after reading the story will have an intuition about what it might be.

The lotteries used for the experiments in this study will be phrased in 2 ways after fixing probabilities: 1. we can elicit indifference payoffs for alternatives that are risky versus a certain lottery, i.e. a point on the EIV and 2. we can elicit indifference payoffs based on comparison of 2 risky alternatives. Because the second alternative is more interesting for application, the first one will be used in only 3 out of 20 (or 15%) lottery combinations.

The survey and economic experiments will be conducted with approximately 60 undergraduate students in introductory economics classes in 2 or 3 universities; the University of Minnesota, the University of Wyoming and Iowa State University. The results reported in this paper are based on the first round of experiments conducted at 3 recitation sessions on April 28, 2006 with students from a Principles of Microeconomics class at the University of Minnesota and another session with students from an intermediate microeconomics course also at the University of Minnesota. The questionnaire consist of 2 parts: The first segment asks respondents to answer general questions about their demographics (age, gender, family background). The second section consists of 20 questions designed to elicit cultural dimensions. The questions are directly taken from Geert Hofstede's (2001) research on cultural factors and are widely used to form cultural indicators. Although the participants in this study will be a rather homogeneous group, the study is designed to be extended to include other cultural backgrounds either in the US or other countries in the future. A sample survey can be requested from the authors.

Although payoffs and the objective probability will be the same for both groups, how the outcome of the lottery is determined will vary between both groups. Probabilities for the first group are induced using different colored chips in a bucket and will be explicitly stated in each lottery. The second group will receive a similar experimental set up. However, probabilities are conveyed indirectly but correspond to the same objective probabilities as for the abstract group. Probabilities are induced by presenting students with the short story and will be formed as the likelihood of a certain word or letter occurring in the text. The total number of letters and words in the story is revealed in the instructions. Subjects were provided with the story at the beginning of the experiment but were required to return it before being given the instructions and questionnaire. There was not sufficient time for participants to count all words but they should have an intuition about what the probability will be.

In the interest of obtaining a sufficient number of data points for the empirical analysis without overwhelming participants with a large number of lottery combinations, every subject received only one of the treatments. This set up does not allow direct comparisons of risk preferences and perceptions between complete and incomplete information for each subject. However, assignment occurred based on the recitation session which was outside of the control of the participants and thus eliminates selection bias. In particular, because the recitation groups occur in sequence, assignment of treatments was alternated in case subjects from one group would talk to the next group. In the aggregate, we do not expect this limitation to significantly affect our results.

After reading and explaining the consent form, the treatment group for the complete information case received the questionnaire, record sheet, instructions as well as the 20 lottery combinations. The order of lottery combinations was randomized but because group was small and communication restricted each participant received the same order. This method was chosen to allow subjects to view all payoff combinations, compare and evaluate his or her willingness to pay for each combination given all information. The treatment group for the incomplete information case was handed the short story after reading the consent form. The story "*The Princess and the Pea" by* Hans-Christian Anderson's was chosen because of its length (379 words without the title) and ease of reading and can be found in the appendix. Most students should also be familiar with the story from the childhood although that is not a prerequisite. After the story was read by all participants, the story was collected and subjects received the questionnaire, record sheet, instructions as well as the 20 lottery combinations. Each participant received the same order of lottery combinations, which were also randomized but the order differed compared to the first group. This measure was taken to further limit the usefulness of talking to other subjects in experiment sessions before or after.

The initial round of experiments was conducted without practice rounds but due the at times irrational responses, practice rounds were introduced in the following experiment rounds with students from the intermediate mircoeconomics course to familiarize subjects with the reward mechanism and experimental set up as recommended in the literature (Camerer, 1995). Cooperation with other students (i.e. talking) was not permitted. The economic experiment contained 20 lottery combinations. Respondents were asked to state their willingness to pay to play lottery A instead of lottery B for each of the combinations. Participants were informed that only one randomly selected lottery combination will be executed at the end of the experiment and the rewards are paid in cash and in private at the end of the session. The lottery combination executed will be randomly selected for all participants in each of the two groups after all participants complete the survey and the lottery combinations. The experimental protocol can be summarized as follows:

Experimental protocol

1. Randomly selecting recitation sessions into 2 treatment groups:
   1st group: Complete information group
   2nd group: Incomplete information group: Given a short children's story to read
2. For 2nd round of experiments, a practice round was introduced to familiarize subjects with the incentive mechanism. Students were asked to state their WTP for the first lottery combination, a random price was drawn and feedback about payoffs was provided.
3. All subjects complete the survey sections.
4. Subjects are repeatedly asked how much they are willing to pay to play a more favorable lottery. Lottery combinations vary by the scale of rewards and how a favorable outcome is determined (objective probabilities are equal across lotteries

and both groups)
1st group: Probabilities phrased as randomly drawing a poker chip out of a can
2nd group: Probabilities phrased as randomly choosing of specific word or letter or a combination from the story

4. A lottery combination that is executed is randomly selected.
5. Random price (RP) is drawn between zero and difference of minimum and maximum payoff of randomly selected lottery
   If a subject's stated WTP≥RP **à** play for lottery A payoffs
   If a subject's stated WTP<RP **à** play for lottery B payoffs
6. Execute lottery (draw chip, select phrase) and pay individuals in private

To allow comparison with findings from other researchers, the objective probability for all combinations was fixed at ¼ (e.g., Davidson, Suppes and Siegel) for both treatments. The words and letters picked used for the incomplete information treatment was designed to jointly match the complete information (poker chip) case with the probability of state 1 occurring of 0.25. Specifically, the lottery questions read as follows:

Complete Information Treatment Group (Group 1):

*Suppose one poker chip is drawn from a coffee can containing **40** poker chips, **10** red and **30** white. What is the most you would be willing to pay to play Lottery A instead of Lottery B?*

Color of Poker Chip	***Lottery A Payoff***	***Lottery B Payoff***
Red	$8	$8
White	$18	$11.5

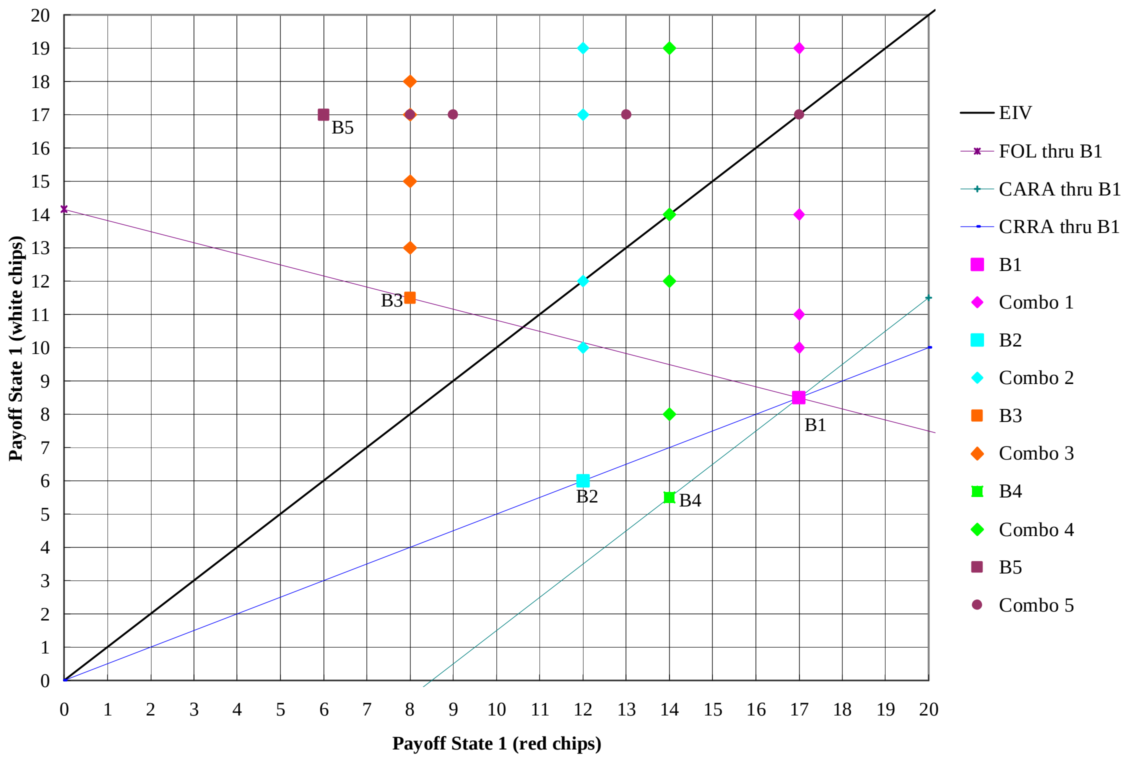
Incomplete Information Treatment Group (Group 2)

Suppose one word or letter is picked randomly from the story you have been read in the beginning. What is the most you would be willing to pay to play Lottery A instead of Lottery B?

Word or letter picked	***Lottery A Payoff***	***Lottery B Payoff***
"she" "it" "e" "k" "a" "o"	$8	$8
All other words or letters	$18	$11.5

This question is repeated with 20 different lottery combinations, which vary in terms of payoffs. The different reward combinations are designed to test the hypotheses. There are 4 base lotteries for lottery B (B1-B4) and there are 5 payoff combinations for lottery A for each of these base lotteries. The payoffs are depicted in Figure 4.

Figure 4: Payoffs for all 20 Lottery Combinations



In designing the payoffs for the experiment, the points are based on B1 and include payoffs along vectors for constant absolute risk aversion and constant relative risk aversion vectors. They correspond to the following equations:

Equal Incomes Vector (EIV)	$y_2 = y_1$
(Objective) Fair Odds Line (FOL)	$y_2 = 14.167 - {}^{p_1}\!/_{p_2}\, y_1 = 14.167 - {}^{1}\!/_{3}\, y_1$
Constant Absolute Risk Aversion (CARA)	$y_2 = -8.5 + y_1$
Constant Relative Risk Aversion (CRRA)	$y_2 = 0.5 y_1$

The payoff combinations are designed around B1 and in the context an objective probability of $p_1 = 0.25$ and $p_2 = 1 - p_1 = 0.75$. The slope of the (objective) Fair Odds Line (FOL) at these probabilities is $-\frac{p_1}{1-p_1} = -\frac{1}{3}$. Lottery A for all lottery combinations is chosen to always be more favorable than the appropriate lottery B, thus payoffs are always greater or equal in both states. Base lottery B2 was chosen to test for constant relative risk aversion, B3 has the same expected value as B1, which is why it is on the FOL and B4 was chosen to test for constant absolute risk aversion.

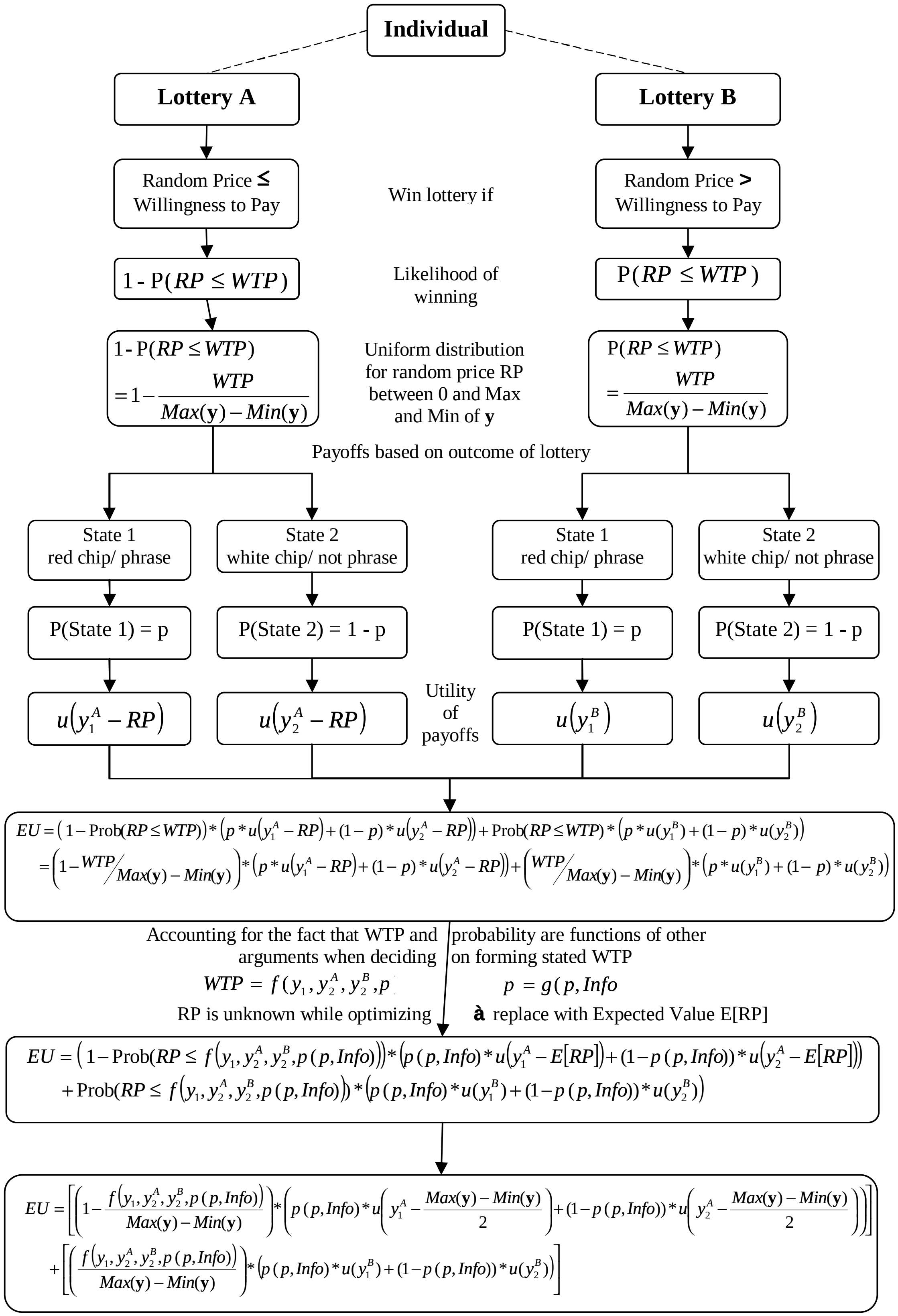
There are 3 payoff combinations for Lottery A representing a certainty point, such that irrespective of the state occurring, the reward remains the same. Lastly 2 combinations for lottery A are designed to test for scale variance implying that they are on a line parallel to the equal incomes vector as well as payoffs between the 2 are proportional.

Incentive Mechanism

A common incentive mechanism to elicit subjective probabilities is the use of scoring rules (Camerer, 1995). However, their use requires the assumption of risk-neutral preferences, which is very limiting for practical applications. The incentive mechanism for this study avoids assumptions on risk preferences and is modeled after a sealed-price auction. Participants are asked to state their willingness to pay to play lottery A instead of lottery B. Because lottery A is more favorable, a rational individual's WTP will always be non-negative. Each subject is asked to write down their WTP on the record sheet for each of the 20 lottery combinations. This mechanism reflects the sealed bid auction scenario. Players are asked to remain quiet throughout the experiment and they are seated away from each other. Strategic interaction is also impossible and because the outcome of the lottery is independent of other players, any incentive for strategic behavior is eliminated. Consequently, the private value and independence of bids assumptions hold.

For each experiment group one of the 20 lottery combinations will be randomly selected and executed. A random price (RP) between zero and the difference of the maximum and minimum payoff of the chosen lottery $RP \in (0, \max(\mathbf{y}) - \min(\mathbf{y}))$ where $\mathbf{y} = (y_1^A, y_2^A, y_1^B, y_2^B)$ will be determined using the aid of a computer. All subjects with a willingness to pay above the random price win the right to play lottery A and all players below the random price will play lottery B. The experiment will then be executed by either drawing a chip out of a coffee can or by randomly picking a word or letter from the story. Following that, earnings will be determined based which lottery was played. For lottery A players, final earnings are determined by subtracting the random price from the winning payoff of the lottery based on the outcome of the random draw of the chip or phrase. All lottery B players will receive the payoffs based on the outcome of the random draw of the chip or phrase. Figure 6 illustrates the incentive mechanism and overall experiment set up using a flowchart.

Figure 5: Flowchart of the experiment set up and incentive mechanism

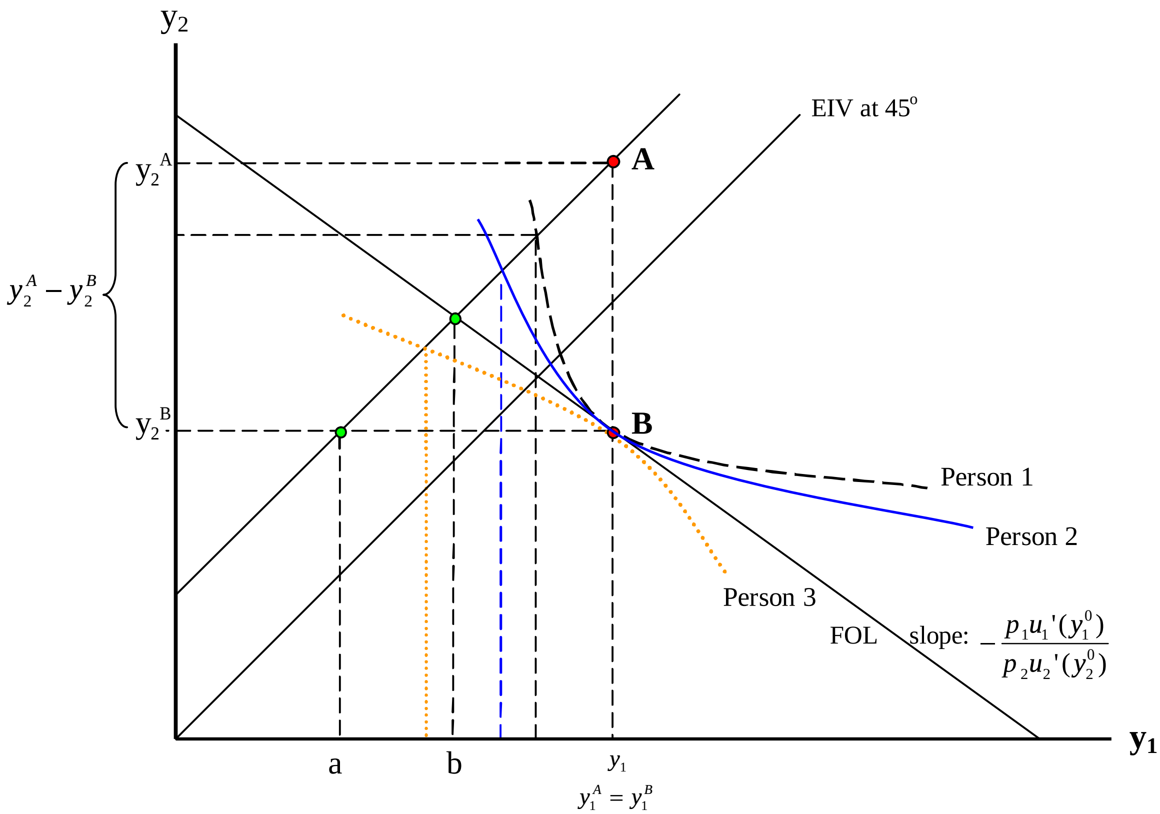


A random price auction rather than an n-price auction was chosen to minimize strategic interactions among participants and to potentially allow more subjects to be able to play the more favorable lottery. Vickrey (1961) showed that there are no efficiency gains from using a sealed price auction with $n > 2$, which would only permit one person to play lottery A, which could potentially discourage risk-seeking or risk-neutral subjects to exert the necessary effort to determine his true valuation. The mechanism can best be illustrated by using a graph. Figure **7** illustrates an example where $\left(y_1 > y_2^B\right)$ such that the random price lies in the interval $(0, y_2^A - y_2^B)$. Lottery B is a lottery with payoffs $\left(y_1^B, y_2^B\right)$ and Lottery A is the more favorable alternative with payoffs $\left(y_1^A, y_2^B\right)$.

Participants are asked to state their willingness to pay to play lottery A instead of Lottery B. The stated willingness to pay for any rational individual will lie in the same interval as the random price. To be more specific, a risk-averse individual will state a willingness to pay between zero and $(y_1 - b)$[5]. A risk-seeking individual should state a willingness to pay between zero and $(b - a)$. Lastly, a risk neutral individual should state a willingness to pay of $\left(y_1^A - b\right)$.

[5] Note that $\left(y_1^A = y_1^B\right)$

Figure 6: Random price sealed bid reward mechanism



The incentive mechanism was designed to elicit truthful statements of individual's valuations. Stating a willingness to pay below the true WTP, increases the probability that the random price is above the stated WTP, leading to loss of the right to play lottery A which yields higher earnings und thus could make the person worse off. Stating a WTP above the true value, increases the probability that the random price is below leading to increased odds of playing the favorable lottery A. However, because earnings for lottery A are determined by subtracting the random price from the payoff of the lottery, the individual could be made worse off. Consequently, all subjects will be best off revealing their true valuation.

Empirical Analysis

The first step of the empirical analysis is to estimate a utility function for each individual. We impose only basic restrictions on this function such that it is smooth, twice differentiable and monotone. We are using expected utility in combination with subjective probabilities to analyze the properties in question and test the hypotheses. We will follow 2 approaches: a) Estimating three commonly used flexible forms - the translog, generalized Leontief and symmetric generalized McFadden (Terrell, 1996) and b) function approximation.

Flexible functional forms

A flexible functional form is a functional form that has enough parameters to approximate an arbitrary twice differentiable function to the second order (Diewert, 1974, p. 133). The translog and generalized Leontief of both second order Taylor expansions, thus are local approximations. The translog is globally well-behaved only for the special case of a Cobb-Douglas function (eliminating the second order terms). As Jorgenson, Lau and Stoker (1982) note, global monotonicity is impossible with the existence of second order terms that are logarithmic. The generalized Leontief is well behaved as long as all parameters are non-negative.

For example, the translog function would look as follows:

(12) $$W(\mathbf{y}) = \ln u(\mathbf{y}) = b_0 + \sum_{s\in\Omega} a_s p_s \ln y_s + \tfrac{1}{2}\sum_{s\in\Omega}\sum_{z\in\Omega} b_{s,z} p_s \ln y_s * p_z \ln y_z + e \ .$$

Based on the experiments, we will be able to estimate the parameters for multiple functions for each individual for a number of payoff levels based on several points obtained thru the economic experiment. The probabilities have to sum to unity, $\sum_{s\in\Omega} p_s = 1$ and with non-decreasing preferences they always have to be non-negative.

Additionally, we will require monotone preferences. Based on equation (1), subjective probabilities p_s will be inferred for $s = 1,2$. Equation (4) transforms into

(13) $$W(\mathbf{y}) = \ln u(\mathbf{y}) = b_0 + a_1 p_1 \ln y_1 + a_2 p_2 \ln y_2 + \tfrac{1}{2} b_{1,1} p_1 \ln y_1 * p_1 \ln y_1 + \tfrac{1}{2} b_{1,2} p_1 \ln y_1 * p_2 \ln y_2 + \tfrac{1}{2} b_{2,2} p_2 \ln y_2 * p_2 \ln y_2 + e$$

Assuming scale invariance (constant absolute risk aversion) for each individual, we know that the Marginal Rate of Substitution between payoffs in each state has to equal the ratio of probabilities at the intersection of Fair Odds Line and Equal Incomes Vector. For the case of 2 states, this relationship is uniquely defined

(14) $$MRS_{y_1, y_2} = \left. \frac{\partial W(\mathbf{y})}{\partial y_1} \middle/ \frac{\partial W(\mathbf{y})}{\partial y_2} \right|_{y_1 = y_2} = \frac{p_1}{1 - p_1}$$

At the intersection of objective FOL and EIV, we can then compute the subjective probability which will define the subjective FOL. A comparison between both Fair Odds Lines will indicate biases.

A flatter subjective FOL than the objective FOL results in $\frac{p_1}{1-p_1} < \frac{p_1}{1-p_1}$, implying $p_1 < p_1$. In this case, $p_1 = 0.25$, which is a relatively low probability that would have been overestimated as hypothesized. Furthermore, we can relate these estimates to individual and information characteristics using a limited dependent multivariate analysis.

To identify risk preferences following Chambers and Quiggin (2000), the relative risk premium can be calculated as

(15) $$RP = \frac{\bar{y}}{u^{-1}\left(\sum_{s\in\Omega} p_s u(y_s)\right)},$$

which will also be used for comparisons between individuals. Additionally, we can determine if an individual displays increasing, constant or decreasing absolute and relative risk aversion, which can also be used for hypothesis testing. For example, if an individual experiences constant absolute risk aversion (CARA), the allocation of wealth between a safe and a risky asset will be independent of proportional increases in payoffs.

The empirical analysis will also use a limited dependent multivariate model to test the remaining hypotheses and identify individual characteristics that influence risky behavior.

The generalized Leontief demand is defined as

(16) $$W(\mathbf{y}) = a_0 + 2a'\mathbf{y} + \mathbf{y}'A\mathbf{y},$$

where a_0 is a scale parameter, a is a vector of parameters, $\mathbf{y}$ is the vector of payoffs and $A = \lfloor a_{ij} \rfloor$ is a symmetric matrix of parameters. For the case of 2 states, the generalized Leontief will transform to

(17) $$W(\mathbf{y}) = a_0 + 2a_1 y_1 + 2a_2 y_2 + a_{11} y_1^2 + a_{12} y_1 y_2 + a_{21} y_1 y_2 + a_{22} y_2^2$$

Estimation Procedure

Utility of indifference points is the same so we can use that to determine a relationship between estimates. A limited dependent multivariate analysis (logit or probit) will use the difference between the objective and subjective probability as the dependent variable for state 1: $p_1 - p_1$. For the limited dependent model, it would have to be the probability that we have overestimation. We could also use the actual difference to also capture magnitude effects. A negative value for this difference implies overestimation of the objective probability.

(18) $\left(p_1 - p_1\right) = a + \boldsymbol{\beta}_d \mathbf{Demo} + \boldsymbol{\beta}_c \mathbf{Culture} + b_R RiskAversion + b_{INFO} Info + e$, where

$\mathbf{Demo} = b_{gen} Gender + b_{age} Age$

$\mathbf{Culture} = b_{PDI} PDI + b_{UAI} UAI + b_{InI} InI + b_{MAS} MAS + b_{LTO} LTO$

Info is a dummy variable with value equal to 1 (one) if subjects have complete information. Secondly, the equation will be estimated separately for both treatment groups to analyze differences in coefficient estimates for the other variables.

According to the basic hypotheses outlined before, this implies:

H 1`: $a < 0$ for $p < r$,where r is small and determined by the data. Roughly speaking if $r < 0.4$ can be considered small.

Function Approximation

Rather than assuming a specific structure of the underlying functional form as with the flexible functional forms described above, interpolation methods are used to approximate an analytically intractable function f with a computationally tractable function $\hat{f}$, given limited information (Miranda and Fackler, 2002). Constricting the analysis to the more practical linear combination of set of n known linearly independent basis (univariate) functions $f_1, f_2, ..., f_n$ with basis coefficients $c_1, c_2, ..., c_n$,

(19) $\hat{f}(x) = \sum_{j=1}^{n} c_j f_j(x)$.

It is also important to keep in mind that there are *n* unknown parameters requiring *n* conditions to be able to fix an approximant. The first condition is that the approximant matches the value of the original function at the interpolation nodes $x_1, x_2, ..., x_n$ (available data points). Consequently, one fixes the coefficients $c_1, c_2, ..., c_n$ of $\hat{f}$ by solving

(20) $$\sum_{j=1}^{n} c_j f_j(x) = f(x_i) \qquad \forall i = 1,...n$$

Equivalent to regression analysis, one can find the approximant by minimizing the sum of squared errors

(21) $$e_i = f(x) - \sum_{j=1}^{n} c_j f_j(x)$$

Leading to the least squared result

(22) $$\mathbf{c} = (\boldsymbol{\varphi}'\boldsymbol{\varphi})^{-1}\boldsymbol{\varphi}'\mathbf{y}$$

with $\boldsymbol{\varphi}\mathbf{c} = \mathbf{y}$ [6], $y_i = f(x_i)$ and $f_{ij} = f_j(x_i)$. The analysis can be extended to interpolate function values as well as derivates at specified points (Miranda and Fackler, 2002). There are two practical approaches to function approximation: Chebyshev polynomial and polynomial spline approximation. The interpolation methods can be extended for the multivariate case as necessary for this study.

Results

The first round of experiments was conducted April 28, 2006 with 10 students from the Principles of Macroeconomics class at the Department of Applied Economics at the University of MN. Average earnings were approximately $8.00, which was below

[6] $\boldsymbol{\varphi}$ is the interpolation matrix, which has to be non-singular.

expectations. The first round of experiments yielded in indifference curves that greatly violated all standard assumptions. We therefore conducted a second round of experiments without the rest of the questionnaire with a practice round to familiarize subjects with the payoff structure and incentive mechanism. The results are promising but still not yet enough to start estimating functional forms for the utility function.

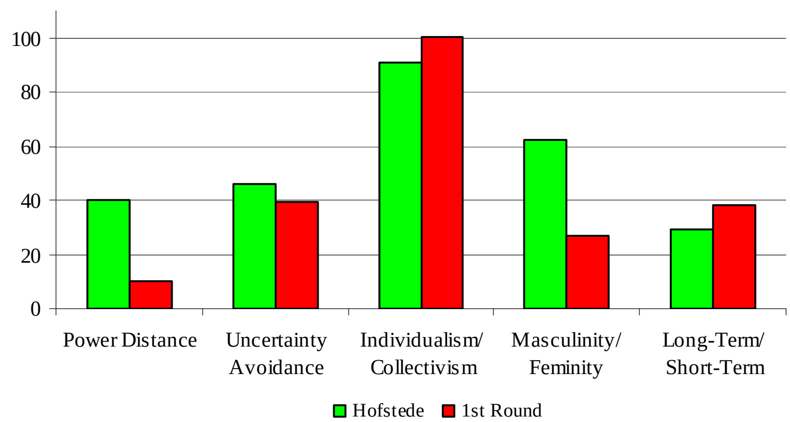
Summary Statistics

The first sample consisted of 40% females and 100% Caucasian, who were between 20 and 22 years old, grew up in Minnesota (70%), North Dakota (10%) and Wisconsin (20%), and who except for one person lived in Minnesota at their current residence for at least 7 years. The remaining person lives in Wisconsin. The majority (80%) rated their political views as center (40%) to conservative (40%) and also rated their family's income as well as future income prospects as intermediate (3 on a scale from 1 to 5). Personal savings was used to supplement income from parents, the government or salary income. In our sample, 4 subjects did not work, while 3 were working part-time and full-time during breaks, respectively (1 subject was working part-time and full-time during breaks). 50% of our sample receives support by his or her parents, 50% from the government and 50% from salary income or a combination of all three sources of income.

Cultural Dimensions

Cultural Dimensions are similar to Hofstede's (2001) results for the US for all indices but deviations correspond to expectations one would have considering the sample. We surveyed undergraduate students who are going to be well-educated, more socially aware individuals for whom gender equality and consideration for the future are part of this education. The indices computed for our sample in comparison with the indices computed by Hofstede for the US can be found in Figure 6.

Figure 7: Comparison of 1st round of experiments with Hofstede (2001)



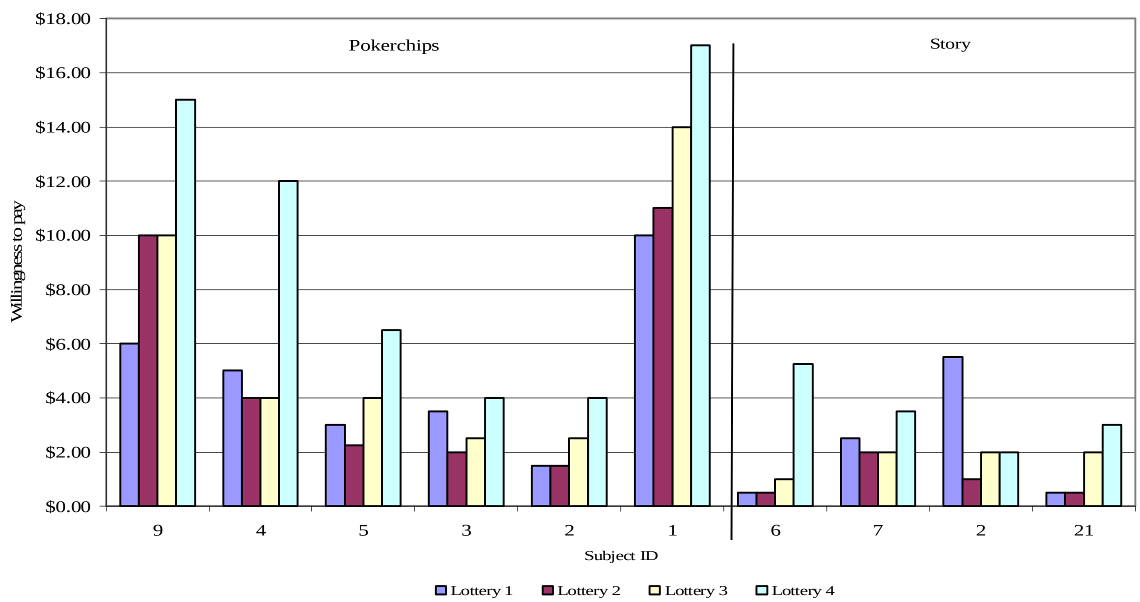
The index for power distance (PDI) measures the extent to which members of the society expect and accept that power is distributed unequally. A low score indicates small power distance (more equal distribution of power) and equivalently a high score indicates large power distance. The US in general exhibits an average PDI but our sample is significantly lower expressing more aptitude for an equal distribution of power. The individualism index (IDV) a low score represents strongly collectivist while a high score indicates strongly individualist that is the ties between individuals are loose and a person is expected to look after her/himself. Low values of the masculinity index (MAS) indicate values of strongly feminine and consequently high values represent strongly masculine. In cultures with low MAS scores, gender roles overlap.

Uncertainty avoidance is expected be the index with the most predictive power for risk attitudes and perceptions. It is designed to capture the extent to which members of a society feel threatened by uncertain, unknown, ambiguous or unstructured events and situations. A low score stands for weak uncertainty avoidance that is members of the society feel weakly threatened. Lastly, long-term orientation (LTO) versus short-term measures how much a society is oriented towards the future rewards. A society oriented to the long-term (high score) will foster virtues like perseverance and thrift while a society with a short-term orientation (low score) will foster virtues related to the past and present like tradition and fulfilling social obligations.

Risk Preferences and Perceptions

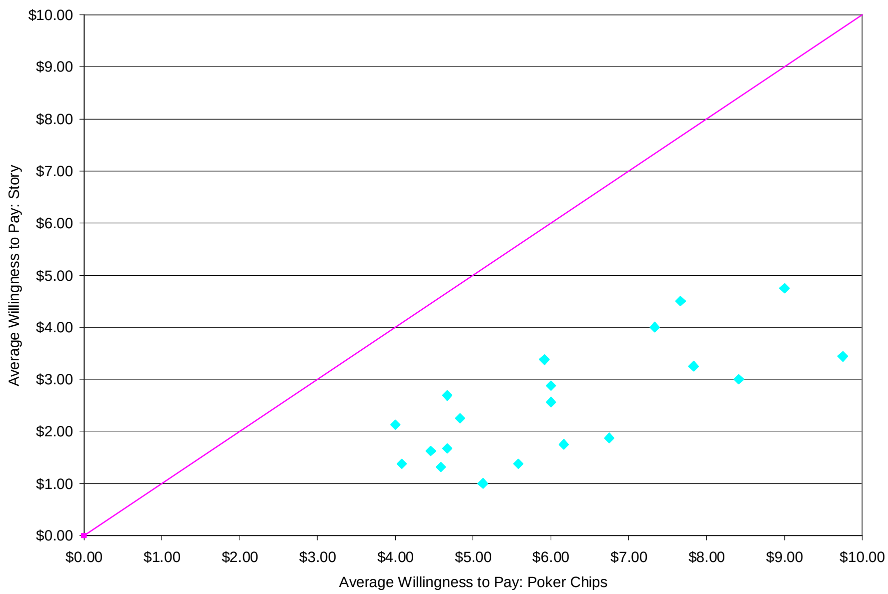
A first glance at the original sample and responses reveals a lack of understanding of the incentive mechanism as well as some inconsistencies. However, the initial glance also reveals an overall tendency for willingness to pay to be lower when information is restricted. Table 3 provides an overview of differences in willingness to for the first set of 4 lotteries, which use the same base lottery B1.

Figure 8: Willingness to Pay for all Subjects for Lotteries with Base Lottery B1



Combining both samples, we can depict average willingness to pay for lottery A for the poker chips versus the story group. Results are shown in Figure 9.

Figure 9: Average Willingness to Pay for lottery A – Story (incomplete information) versus Poker chip (complete information) group



It can bee seen that the willingness to pay is on average smaller for the incomplete (story) information treatment group for all lottery combinations. This effect could be due to either a misunderstanding of the payoff mechanism or actual differences in risk perceptions. In a second step, we looked at the derived indifference curves for each individual. Simply for illustrative purposes, two examples are depicted in Figure 9.

Figure 10: Sample Indifference Curves for Players 2 (Poker Chips) and 21 (Story)

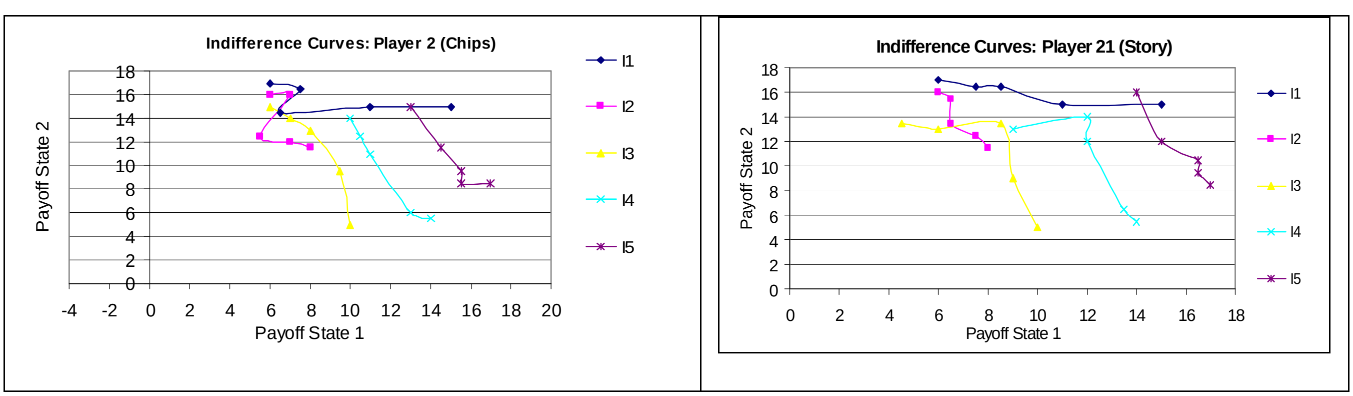


Figure 11 and 11 look at the base lottery B1 and computed indifference points for all individuals depending on the treatment. The shaded areas represent the irrationality space that is subject to doubt whether participants understood the payoff mechanism. The irrationality space is defined as the space where the payoffs for both evens are smaller than the base lottery B1 thru B4. Without any formal analysis, it appears as a) individuals are risk-averse, b) individual's risk preferences differs and c) the slope of the indifference curves (for the rational answers in both groups) is steeper on the equal incomes vector for the incomplete information group. The later observation indicates that risk perceptions might be influenced by information and the lack of complete information seems to make individuals overestimate the low probability more than if all information is available.

Figure 11: Lottery B1 and Indifference Points for Complete Information Treatment

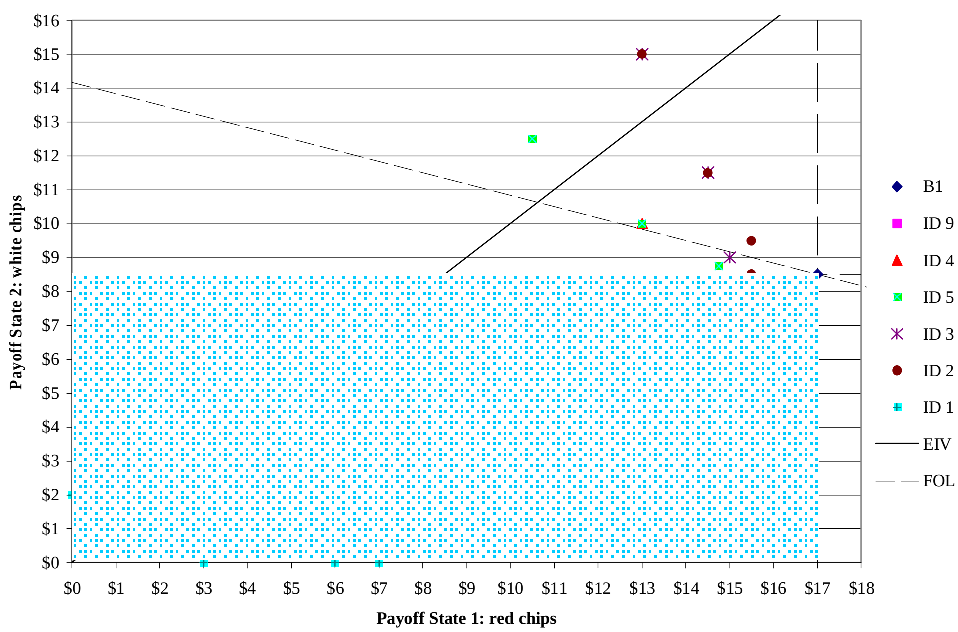
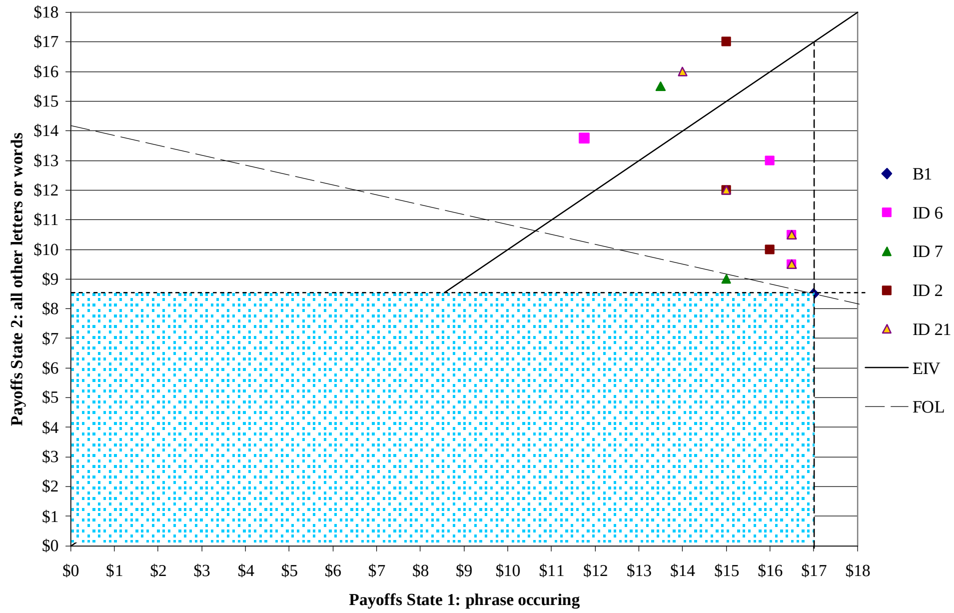
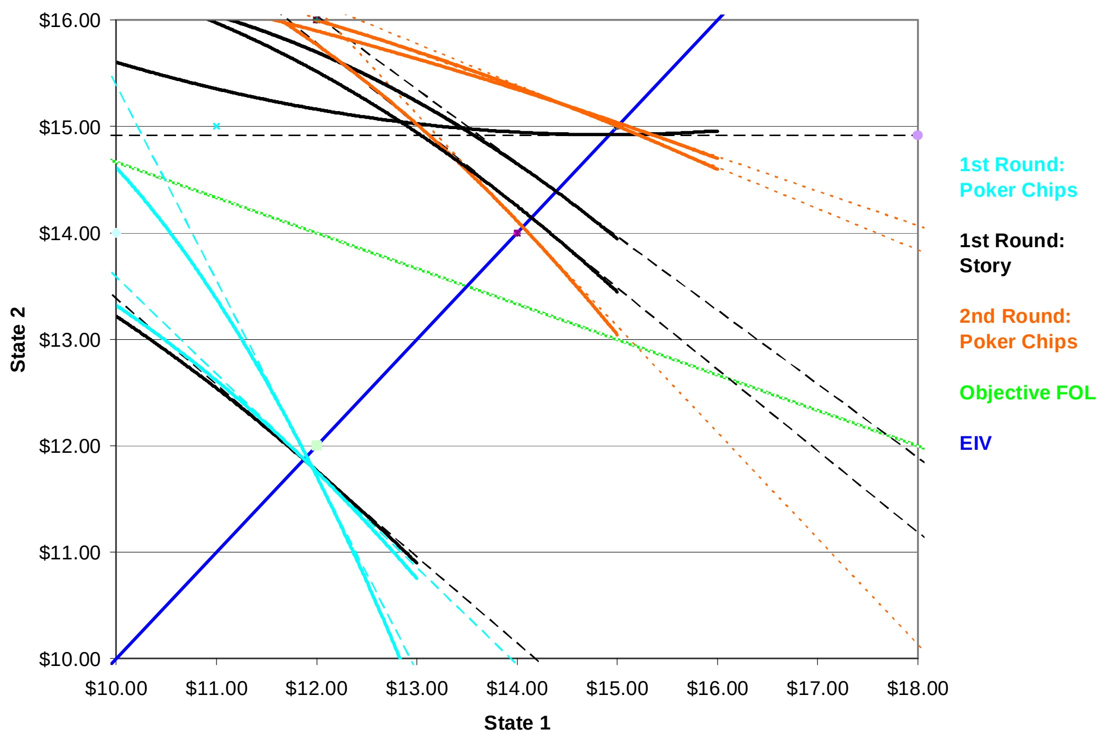


Figure 12: Lottery B1 and Indifference Points for Incomplete Information Treatment



These initial results based on the first sample show that improvements in the experimental set up are necessary. The introduction of the practice round proved successful in that the indifference curves are more stable and consistent. To step ahead, we estimated a functional form for the indifference curves for lottery combinations based on B5, computed the tangency line at the intersection with the equal incomes vector and compared the slopes (derived subjective probabilities) to the objective probability fair odds line. The results although preliminary are illustrated in Figure 13. The on average steeper slopes for the tangency line (subjective fair odds line) for most subjects seem to confirm that subjects overestimate low and underestimate high probabilities. Furthermore, we can see that as anticipated, the subjective FOL is close to the objective FOL for some people in the group with practice rounds under complete information and to a lesser extend for the incomplete group. Assuming this result holds up for a representative sample, this could confirm that an increase in information leads to more accurate probability assessment and eliminates some of the bias.

Figure 13: Indifference Curves Combo #5 for Story versus Poker Chips



In summary, although the results have to be estimated more precisely, it appears as if we can confirm the already established result that individuals overestimate low probabilities and underestimate high probabilities. This effect is even more pronounced when information is incomplete. Lastly, not surprisingly risk preferences as well as perceptions differ between individuals. An additional induced value experiment will be used to validate the incentive mechanism. A prediction of probabilities experiment will be used to narrow down on the influence of information on probability assessments/risk perceptions. In combination, we should be able to support many if not all hypotheses of the research objective.

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Appendix

Selected Short Story:

Hans Christian Andersen: The Princess and the Pea

Once upon a time there was a prince who wanted to marry a princess; but she would have to be a real princess. He traveled all over the world to find one, but nowhere could he get what he wanted. There were princesses enough, but it was difficult to find out whether they were real ones. There was always something about them that was not as it should be. So he came home again and was sad, for he would have liked very much to have a real princess.

One evening a terrible storm came on; there was thunder and lightning, and the rain poured down in torrents. Suddenly a knocking was heard at the city gate, and the old king went to open it. It was a princess standing out there in front of the gate. But, good gracious! What a sight the rain and the wind had made her look. The water ran down from her hair and clothes; it ran down into the toes of her shoes and out again at the heels. And yet she said that she was a real princess. Well, we will[7] soon find that out, thought the old queen. But she said nothing, went into the bed-room, took all the bedding off the bedstead, and laid a pea on the bottom; then she took twenty mattresses and laid them on the pea, and then twenty eider-down beds on top of the mattresses. On this the princess had to lie all night. In the morning she was asked how she had slept. “Oh, very badly!” said she. “I have scarcely closed my eyes all night. Heaven only knows what was in the bed, but I was lying on something hard, so that I am black and blue all over my body. It’s horrible!” Now they knew that she was a real princess because she had felt the pea right through the twenty mattresses and the twenty eider-down beds. Nobody but a real princess could be as sensitive as that. So the prince took her for his wife, for now he knew that he had a real princess; and the pea was put in the museum, where it may still be seen, if no one has stolen it.

There, that is a true story.

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[7] The original translation of the story reads “we’ll” instead of “we will”. However, it was changed to facilitate the composition of the objective probability I an effort to find letters and words with a combined probability of occurring as close to .25 as possible.

Computation of objective probability for incomplete information (story) group

The story has 380 words and 1,476 letter excluding title and author. We have numbered these words from 1-380 and letters from 381 to 1856. We randomly drew a number from 1 to 1855 such that each number is equally likely. The word or letter associated with that number determined the outcome of both lotteries for the selected decision problem. For example, if the randomly selected number drawn was 274 the associated 274th word in the story is "knows". The probability is determined such that

$P(phrase\, occuring) = \frac{\sum_{p \in \Gamma} x_p}{1856}$, where x_p are the # of times the *p* elements of the phrase, i.e. "she" "it" "e" "k" "a" "o", and Γ is the word and letter space, which occur in the story. In particular, the objective probability underlying this experiment was 0.25 for both the poker chip and the story group. The phrase for the lotteries in the story group was designed to match that. Table 2 provides the probabilities of the individual components that determined the probability of one of the element of the phrase occurring.

Table 2: Probabilities for each component of the phrase for the lotteries using the story to determine the outcome

Phrase	x_p - **# of times, phrase occurs in the story**	**Probability**
she	10	0.54%
it	8	0.43%
e	200	10.78%
k	13	0.70%
a[8]	129	6.95%
o	104	5.60%
Total		**25.00%**

[8] Counts double as a letter and as a word