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Measuring Risk Attitudes Controlling for Personality Traits*

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Abstract: *This study measures risk attitudes using two paid experiments: the Holt and Laury (2002) procedure and a variation of the game show Deal or No Deal. The participants also completed a series of personality questionnaires developed in the psychology literature including the risk domains of Weber, Blais, and Betz (2002). As in previous studies risk attitudes vary within subjects across elicitation methods. However, this variation can be partially explained by individual personality traits. Specifically, subjects behave as though the Holt and Laury task is an investment decision while the Deal or No Deal task is a gambling decision.*

JEL Codes: C9, D8
Keywords: Risk Attitudes, Risk Taking Behavior, Personality Traits, Laboratory Experiments

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> "Perhaps the relatively modest predictive validity of risk aversion for actual risk-taking behaviour (for example, Barsky et al.1997) might be improved considerably with a multidimensional and domain-specific approach to its measurement." – Borghans, Duckworth, Heckman, and ter Weel (2008, p. 39)

1. Introduction

People routinely have to make decisions under uncertainty due to incomplete information. The perceived degree of uncertainty by individuals affects their decisions regarding consumption, saving and investing decisions, and selection of warranties and insurance policies. It also impacts the decision to engage in certain activities such as crime, extreme sports, and unprotected sex, as well as more pedestrian matters such as crossing the street. In a first price sealed bid procurement auction, how much a potential supplier should bid is a function of the bidder's risk parameter and beliefs regarding the risk parameters of the other bidders (see Cox, Smith, and Walker 1988, Harrison 1990 and Van Boening, Rassenti, and Smith 1998). The decision to even hold such an auction is based upon the buyer's risk preferences and belief about the risk preferences of the potential bidders.

The standard technique used in economics and finance is to model risk with a particular functional form. The two most common are constant relative risk aversion (CRRA) which is modeled as $u(x) = \frac{x^{1-\gamma}}{1-\gamma}$, where *r* denotes the coefficient of risk aversion, and constant absolute risk aversion (CARA) which is modeled as $u(x) = \frac{\exp(-\sigma x)}{-\sigma}$, where σ denotes the coefficient of risk aversion.[1] Disappointingly, these models have not proven satisfying. Consider the equity

[1] The current paper focuses on CRRA as it remains predominant in the economics literature. However, a variety of other forms have been promoted, most notably the model of prospect theory in which the agent is risk averse over gains and risk loving over losses. Andersen et al. (2006a) provide an application of the expo-power utility function introduced by Saha (1993) which generalizes the CARA and CRRA functions and Andersen et al. (2007) consider hyperbolic absolute risk aversion.

premium puzzle which emerges from the problem faced by an individual when deciding between riskless and risky assets for their investment portfolio. The term "equity premium puzzle" emerged from a study by Mehra and Prescott (1985) where the authors showed that the observed difference between the stock market return and the return offered by government bonds in the US implied an implausibly high degree of individuals' risk aversion. For example, according to Benartzi and Thaler (1995), the degree of risk aversion that is consistent with the observed difference would make an individual indifferent between a bet that pays US$ 50,000 or US$ 100,000 and a certain payoff of US$ 51,209, in other words extremely risk averse. A similar argument is made by Rabin (2000). Fudenberg and Levine (2006) proposed an alternative model of behavior in which individuals make a distinction between small stakes and large stakes.[2]

Given the ubiquitous nature of decision making under uncertainty in society, it is no wonder that numerous researchers have studied risk attitudes in a variety of settings. One that has received considerable attention recently is the game show Deal or No Deal (see Deck, Lee, and Reyes 2008, Bombardini and Trebbi 2005, Mulino, Scheelings, Brooks, and Faff 2006, De Roos and Sarafidis 2006, Baltussen, Post, Thaler, and van den Assem 2008, Andersen et al. 2006a,b, and Blavatsky and Pogrebna 2006, and Botti et al. 2007).[3] There is typically a wide variation of measured risk attitudes in a study and across studies. As suggested by Mulino, Scheelings, Brooks, and Faff (2006) and Botti et al. (2007) risk aversion is affected by individual-specific characteristics, such as age and gender. Additionally, as hinted by Baltussen, Post, Thaler, and van den Assem (2008), the effects of prior outcomes and the role of cultural,

[2] See Cox, Sadiraj, Vogt, and Dasgupta (2007) for a test of various models of risk aversion including the dual self model of Fudenberg and Levine (2006).

[3] Deal or no Deal is not a unique program in its ability to provide insight on behavior. Other shows that also provide natural experiments on risk attitudes include *Card Sharks* (Gertner, 1993), *Final Jeopardy!* (Metrick, 1995), for *Illinois Instant Riches* (Hersch and McDougall, 1997), *Lingo* (Beetsma and Schotman, 2001), *Hoosier Millionaire* (Fullenkamp, Terino, and Battalio, 2003), and *Who Wants To Be A Millionaire* (Hartley, Lanet, and Walker, 2005).

social and/or economic background could play a substantial role in explaining the high variation observed in the estimates for individuals' risk aversion parameters.

Controlled laboratory experiments can also be used to study risk attitudes. Numerous researchers have attempted to elicit certainty equivalents for lotteries through theoretically truthfully revealing mechanisms such as the BDM procedure developed by Becker, Degroot and Marshak (1963). An alternative approach to measuring risk attitudes is through observing bids in first price private value auctions as mentioned above. Holt and Laury (2002) developed a series of binary comparisons in which the prizes are the same for each comparison but the probability of receiving the higher payoff varies across comparisons. Eckel and Grossman (2002) constructed a similar method but hold the probabilities fixed and vary the payoffs. A troubling result from the experimental literature is that the degree of risk aversion of an individual varies across elicitation techniques over similar sized stakes. Isaac and James (2000) find that risk attitudes differ between first price auctions and the BDM procedure (see also Berg, Dickhaut, McCabe 2005 and Schoemaker, 1990). Dave, Eckel, Johnson, and Rojas (2007) report that the Eckel and Grossman mechanism and the Holt and Laury mechanism give significantly different estimates of risk aversion. It is not simply the case that a particular mechanism makes everyone look more risk averse. Rather, as stated by Isaac and James (2000) there is a "significant reordering of individuals in terms of the ranking of implied risk parameters" (p.187).[4]

An alternative approach to measuring risk has evolved in the psychology literature. Psychologists have attempted to identify individual differences in personality and attitudes that

[4] Interestingly, Harrison, Johnson, McInnes and Rutström (2005) find that the implied risk attitudes of the Holt and Laury procedure are stable over time as shown by retesting subjects after a period of several months.

account for variance in performance on decision-making tasks that involve risk. For example, researchers have shown that broad personality traits, such as those included in Costa and McRae's (1992) Five-Factor Model of personality (neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness), predict risk taking propensity across a variety of situations and tasks (see Gullone and Moore, 2000; Markey, Markey, Ericksen, and Tinsley, 2006). In addition, researchers have demonstrated that self-reported measures of risk attitudes, such as Weber, Blais, and Betz's (2002) domain-specific Risk-Attitude Scale predict risky decision-making behavior across different domains (see Horvath and Zuckerman, 1993; Sitkin and Weingart, 1995). Thus, there is evidence that a dispositional approach may be useful to understanding risk propensity and psychological measures that capture risk may be useful for the *a priori* prediction of risk propensity. Consequently, individual differences may help explain the apparent within-subject inconsistency between different behavioral measures of risks, consistent with the argument put forward by Borghans, Duckworth, Heckman, and ter Weel (2008). To explore this hypothesis, a series of laboratory experiments were conducted to measure risk under three elicitation methods (a modified Holt and Laury procedure with real stakes, a variation of the game show Deal or No Deal with real stakes, and a hypothetical questionnaire) and measure the subject's personality traits using the Five Factor Model and the Risk-Attitude Scale.

As a prelude to the results, the familiar result that subjects are not consistent across the elicitation techniques is observed. However, certain personality characteristics are found to significantly impact observed risk behavior in some elicitation techniques and not in others. For example, a subject's risk attitude towards investment decisions as measured by Weber et al. (2002) influences behavior in the Holt and Laury task but not in Deal or No Deal. In contrast, attitudes towards gambling impact behavior in Deal or No Deal, but not the Holt and Laury task.

The remainder of the paper is organized as follows. The next section describes the experimental design including the elicitation techniques and the survey instruments. The results are presented and discussed in a separate section and the final section contains concluding comments.

2. Experimental Design

The experiments consisted of three computerized parts; the Holt and Laury task, the Deal or No Deal task, and a survey. Subjects were paid their earnings for both the Holt and Laury and Deal or No Deal tasks at the end of the experiment. Each subject was assigned to one of 6 treatments, which differed in the order that the parts were presented to the subjects. This design controls for sequencing effects, and creates the possibility of wealth effects as some subjects will have earned different amounts of money prior to completing one of the paid tasks. This design is intentional as one can directly measure wealth effects *ex post*.

A total of 75 subjects participated in the experiment. The subjects were drawn from the undergraduate student, graduate student, faculty, and staff population of the business school at a state university and thus represented a wide variety of ages, incomes, and education levels. Each participant was paid $2.50 plus earnings for participating in the approximately 30 minute experiment.[5] The average salient payment was $14.45. Given the individual nature of these experiments, subjects were allowed to begin the experiment at any point during a block of time lasting several hours. Thus, most but not all observations were concurrent with observations in other treatments. When a subject arrived at the lab she would draw a slip of paper containing a subject number from a bag. This subject number determined the treatment (ordering). As

[5] Subjects were told that the experiment could last up to 45 minutes, but was expected to last about 30 minutes.

subjects used this number instead of their names, their response to the sometimes sensitive survey items could not be connected to the individual.

2.1 Holt and Laury task

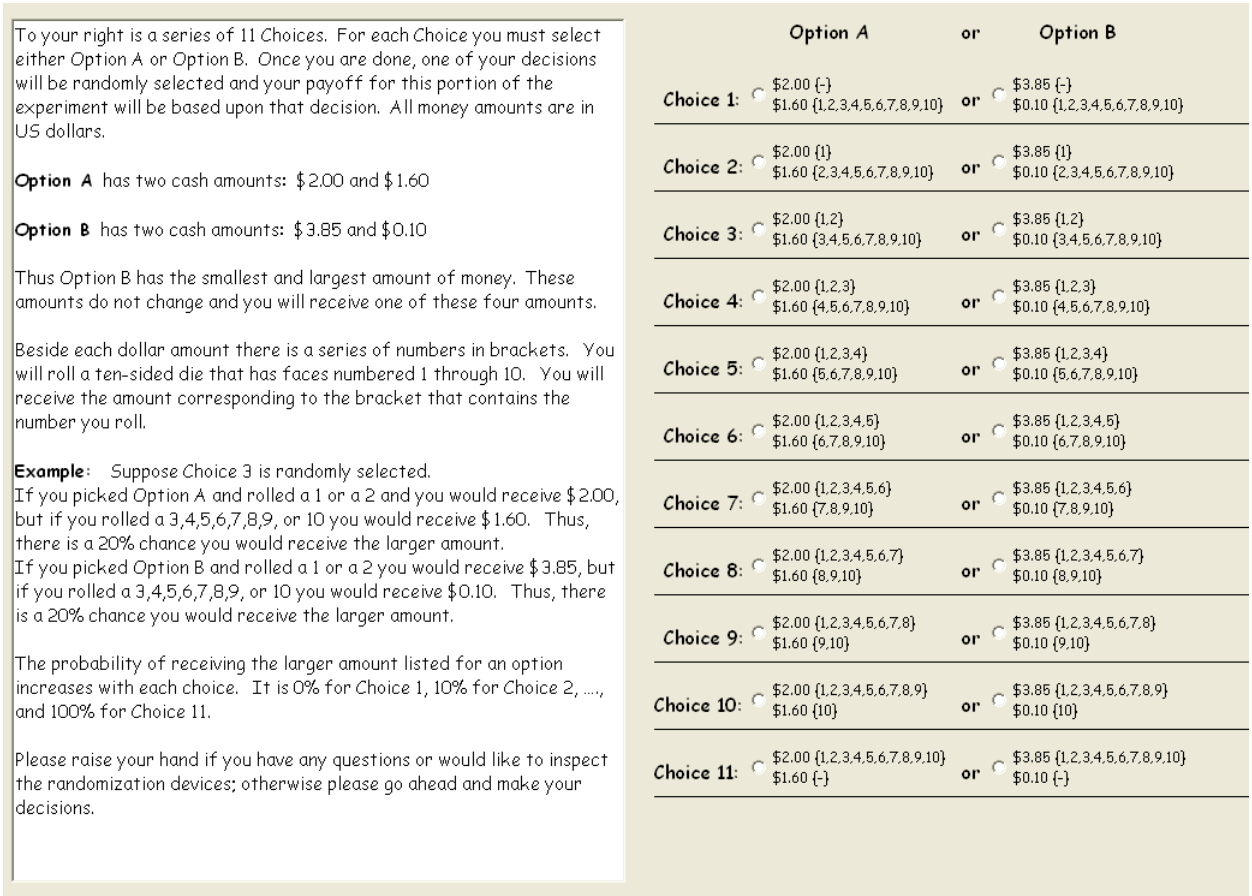
Holt and Laury developed the task shown in Table 1. A respondent is shown 10 binary comparisons, the rows of Table 1, and selects either Option A or Option B for each one. The payoffs for Option A are fixed at $2.00 and $1.60 while the payoffs for Option B are fixed at $3.85 and $0.10. In each successive row, the likelihood of receiving the larger payoff increases. In the final row there is no uncertainty and monotonicity alone is sufficient to lead a person to select Option B. In the other comparisons, the choice is dependent on the level of risk aversion. The original Holt and Laury design did not involve a comparison with 0 likelihood of receiving the larger payoff so that monotonicity would be sufficient to lead a person to select Option A. The main difference between the current study and that of Holt and Laury is the inclusion of a choice where there is no likelihood of receiving the maximum payoff, thus providing an additional check on comprehension assuming subjects prefer more money to less. Figure 1 shows the screen for the modified Holt and Laury task (H&L).

To identify a respondent's level of risk aversion one need only determine the point at which subjects switch from preferring option A to preferring Option B going down the table. The last column of Table 1 provides the implied CRRA parameter consistent with someone first selecting Option B on that decision. For example, a risk neutral person would select Option A in the first four rows of Table 1 (five rows including the 0 likelihood of the larger payoff in Figure 1) and Option B in the last 6 rows.

Table 1. The Binary Comparions of Holt and Laury (2002)

Option A				Option B				Implied Range of CRRA Risk Parameter for Switching from A to B
Chance	Payoff	Chance	Payoff	Chance	Payoff	Chance	Payoff	
1/10	$2.00	9/10	$1.60	1/10	$3.85	9/10	$0.10	
2/10	$2.00	8/10	$1.60	2/10	$3.85	8/10	$0.10	$r \leq -0.95$
3/10	$2.00	7/10	$1.60	3/10	$3.85	7/10	$0.10	$-0.95 \leq r \leq -0.49$
4/10	$2.00	6/10	$1.60	4/10	$3.85	6/10	$0.10	$-0.49 \leq r \leq -0.15$
5/10	$2.00	5/10	$1.60	5/10	$3.85	5/10	$0.10	$-0.15 \leq r \leq 0.15$
6/10	$2.00	4/10	$1.60	6/10	$3.85	4/10	$0.10	$0.15 \leq r \leq 0.41$
7/10	$2.00	3/10	$1.60	7/10	$3.85	3/10	$0.10	$0.41 \leq r \leq 0.68$
8/10	$2.00	2/10	$1.60	8/10	$3.85	2/10	$0.10	$0.68 \leq r \leq 0.97$
9/10	$2.00	1/10	$1.60	9/10	$3.85	1/10	$0.10	$0.97 \leq r \leq 1.37$
10/10	$2.00	0/10	$1.60	10/10	$3.85	0/10	$0.10	$1.37 \leq r$

Figure 1. Screen Image of Implemented Holt and Laury Task



In the current study as well as the original study by Holt and Laury, subjects were informed in advance that only one choice would be randomly selected to determine the payoff after they had made their selection for each comparison. In the current study, the random selection was determined by the roll of a die.[6] Once a comparison was selected subjects rolled a ten sided die to determine their actual payoff based upon they option that had been selected. The information presented to subjects during the experiment indicated what payoff would result from each possible roll of the die. For example, if there was a 4/10 chance of receiving the larger payoff the numbers {1,2,3,4} were displayed beside this payoff and the numbers {5,6,7,8,9,10} were displayed by the smaller payoff. This was explained to subjects in the directions, which were visible throughout the experiment (see Figure 1). Subjects went through a practice trial, complete with dice rolls, after making their initial choices for each of the comparisons. After the practice trial, subjects could adjust their responses prior to the determination of their payoff.

2.2 Deal or No Deal task

This task is modeled on the popular game show Deal or No Deal.[7] While shown in many countries with varying rules, the basic format is similar. Once a contestant is selected a number of briefcases holding various amounts of money are displayed. The distribution of amounts is known, but the contestant does not know the content of any briefcase. At the first stage the contestant selects a single brief case which is set aside. This is the only briefcase from which the contestant can collect the amount of money inside. The game then proceeds to a series of rounds in which the contestant opens other briefcases revealing the amounts of money inside. At the end of each round, an offer is made that the contestant can accept in exchange for the set aside

[6] The comparisons were numbered one through eleven. A 12-sided die was rolled to determine which comparison was used. Subjects were informed that if they rolled a 12, they would simply reroll the die. Thus each of the 11 comparisons was equally likely to be selected.
[7] See Deck et al. (2008) for a detailed discussion of the game show.

briefcase (Deal) or can reject and thus move on to the next round (No Deal). The game ends when either the contestant takes the deal or has opened all of the remaining briefcases and is paid the amount in the briefcase that was originally set aside.

The laboratory version of Deal or No Deal (DOND) is similar but not identical to the game show. One difference is that subject do not set aside an initial case, but rather receive the last remaining briefcase. A total of 12 cases are presented with cash amounts varying from $0.01 to $100.00. The number of cases and the dollar amounts are smaller than in the game show where there are twenty something cases and prizes upwards of $1,000,000 depending on the version of the show.

Figure 2. Screen Image of Implemented Deal or No Deal Task

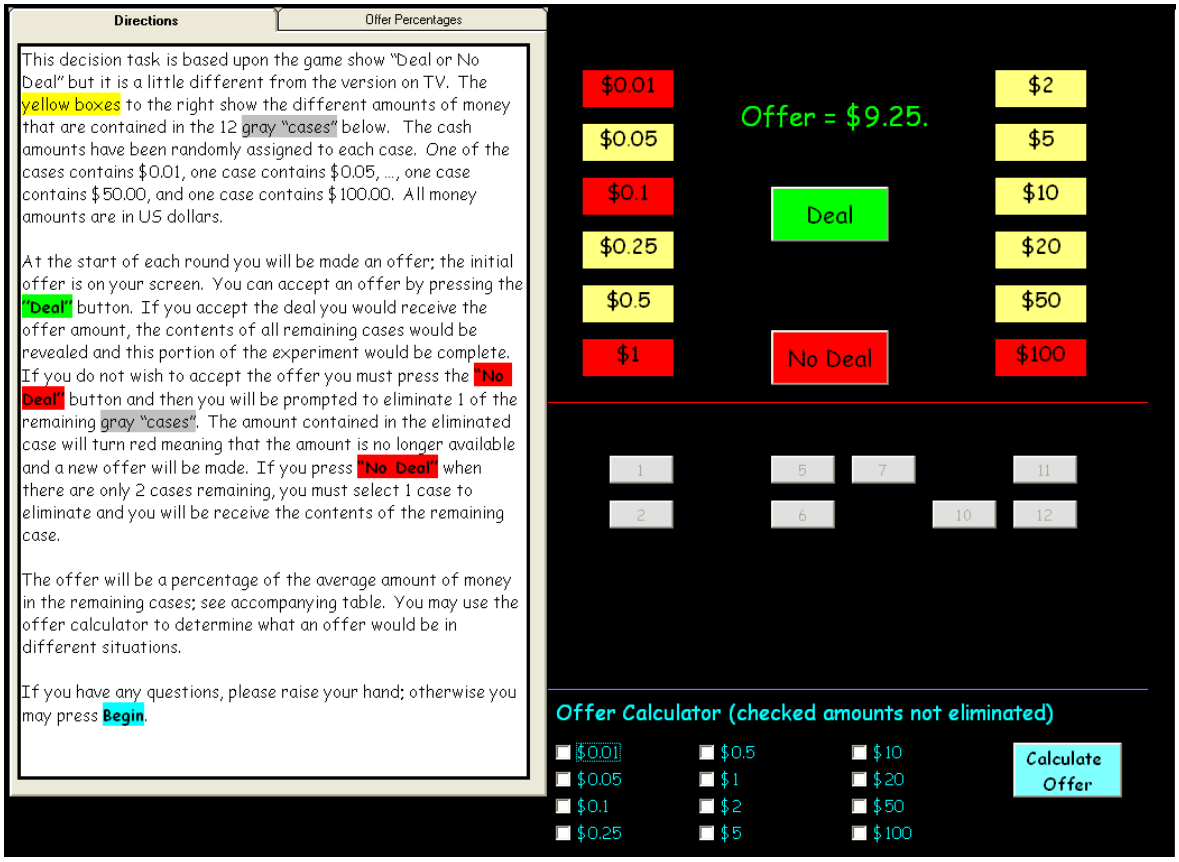


Figure 2 presents a sample image of the subject's screen. The amounts of money are shown on the top right, with amounts in red having been eliminated in earlier rounds. The gray boxes on the right represent the cases; each randomly assigned to contain one of the specified amounts. Before any cases have been opened the offer is $2.99. In subsequent rounds the offer is a predetermined percentage of the expected value of the remaining cases. Table 2 gives the percentage, which were available to the subjects on the "Offer Percentages" tab (see Figure 2). In the game show contestants do not know how the offer is determined and it is not a simple percentage of expected value. The ability to use a deterministic offer function is an advantage of the laboratory as researches cannot know how respondents imagine offers to be generated when the process is unknown. Another difference between the laboratory version and the game show is that game show contestants open multiple briefcases prior to being made an offer in early rounds whereas laboratory subjects were given an offer after each round. As shown in Figure 2, the directions are displayed on the left hand side of the screen throughout the experiment. After pressing "Begin" subject go through an unpaid practice game before going through the paid task.

Following Deck et al. (2008), one can estimate a measure of risk aversion by observing what offers a person accepts and rejects. Consider a person with only two reaming briefcases *i* and *j* containing the amounts B_i and B_j and an offer O_{ij}. The person should accept the offer if the utility of the offer, $u(O_{ij})$, exceeds the expected utility of rejecting it, $u(B_i)/2+u(B_j)/2$. With three remaining briefcases *i, j* and *k* and an offer O_{ijk} acceptance implies that

$$u(O_{ijk}) > \frac{1}{3}\max[u(O_{ij}), \frac{u(B_i)}{2} + \frac{u(B_j)}{2}] + \frac{1}{3}\max[u(O_{ik}), \frac{u(B_i)}{2} + \frac{u(B_k)}{2}] + \frac{1}{3}\max[u(O_{jk}), \frac{u(B_j)}{2} + \frac{u(B_k)}{2}] \cdot$$

This formulation assumes that the person will make the optimal decision in the final round. And its extension to earlier rounds is intuitive. The decision to continue provides some lower bound

on the degree of risk aversion while the decision to accept an offer provides an upper bound. Given the offer percentages provided in Table 2, a risk neutral person would reject offers when more than two cases remain and would accept the offer when exactly two briefcases remain. A person who is risk loving would never accept an offer and a person who is risk averse would accept prior to reaching the round with two briefcases remaining.[8] Unlike the Holt and Laury procedure where the degree of risk aversion can be determined by the switching point, in this procedure the stopping point can imply a different levels of risk aversion depending on the dollar amounts in the unopened briefcases. The estimation technique follows that of Deck et al. (2008); a series of possible risk parameters are considered and a subject is found to be consistent with a given risk parameter if that parameter value would lead to the same choices as those observed for the subject.

Table 2. Offer Percentages by Round

Round	1	2	3	4	5	6	7	8	9	10	11	12
Offer as Percentage of Expected Value	19%	65%	74%	80%	84%	88%	91%	94%	97%	99%	101%	_

2.3 Survey Instrument

The survey instrument collected three types of information from each subject.[9] First it collected demographic information such as age, gender, ethnicity, and parent's education. The second portion of the survey instrument collected measures of individual characteristics as developed in the psychology literature including the Five Factor Model of Personality (Costa and

[8] Given that this method provides bounds on risk attitudes, a person could be barely risk seeking and still stop with two cases remaining just as someone who is barely risk averse might continue until two cases remain. This is true of the Holt and Laury procedure as well.

[9] The survey is available from the researchers upon request.

McRae, 1992) and the Risk Attitudes Scale of Weber et al. (2002).[10] The final portion of the survey provided additional measures of risk aversion that have been used in previous economic analysis.

The Five Factor Model (FFM) of personality specifies that five traits (i.e., extraversion, agreeableness, conscientiousness, neuroticism, and openness) are fundamental and universal. In particular, there is evidence that the FFM subsumes competing trait models of personality (see Costa and McCrae, 1992; Gill and Hodgkinson, 2007). As such, the FFM is one of the most commonly used personality taxonomies in the management and psychology literatures. Research has consistently shown that the "Big 5" traits (i.e., the traits included in the FFM) are stable across adulthood (McCrae and Costa, 1990) and predict a variety of work- (e.g., task performance, citizenship behaviors, job satisfaction, and training proficiency) and non-work- (e.g., creativity, life satisfaction, smoking, personality disorders, decision-making) related attitudes, behaviors, and phenomena (Malouff, Thorsteinsson, and Schutte, 2006; Saulsman and Page, 2004; Barrick and Mount, 1991). Furthermore, research has shown that the Big 5 traits are related to judgment and decision-making across a variety of contexts, including jury decisions (Clark, Boccaccini, Caillouet, and Chaplin, 2007), entrepreneurial business ventures (Wooten, Timmerman, and Folger, 1998), and decisions to engage in risky health-related behaviors (Trobst, Wiggins, Costa, Herbst, McCrae, and Masters, 2000). The Big 5 are purported to affect decision making by influencing confidence/overconfidence in decisions, sensitivity to information from the environment (McElroy and Down, 2007), and heuristic biases (Trobst et al., 2000). In other words, there is evidence that personality, as operationalized by the FFM, can be used to explain why different people approach certain tasks and situations in different ways.

[10] For a general discussion of the need to incorporate psychological measures into economics see Borghans, Duckworth, Heckman, and ter Weel (2008).

Consistent with previous research, personality trait markers for the FFM are measured via the International Personality Item Pool (Goldberg, 1999). This measure assesses each of the Big 5 traits with ten statements to which the respondents can strongly disagree, disagree, be neutral, agree, or strongly agree using a five point Likert scale. For example, statements regarding *neuroticism* include "I get stressed out easily" and "I seldom feel blue"; *agreeableness* statements include "I insult people" and "I feel little concern for others"; *extraversion* statements include "I am the life of the party" and "I start conversations"; *conscientiousness* statements include "I am always prepared" and "I shirk at my duties"; and *openness* statements include: "I spend time reflecting on things" and "I am quick at understanding things".

Scholars have suggested that it is appropriate to consider risk attitudes as a personality trait (Weber, 1998). Personality researchers have also noted that, while traits typically shape patterns of behavior across situations, there is also a need to recognize aspects of the situation that may elicit certain trait-influenced responses (Mischel and Shoda, 1995). With this in mind, Weber and colleagues developed the Domain-Specific Risk-Taking (DOSPERT) scale. DOSPERT assesses willingness to engage in risky decision-making across a variety of domains (e.g., social, recreational, health, safety, gambling, ethical, and investments). Supporting the use of a domain specific measure of risk, research has demonstrated that risk-taking is highly domain specific (Weber et al., 2002; Hanoch, Johnson, and Wilke, 2006). For example, a study by Weber et al. (2002) demonstrated that people are not consistently risk averse or risk seeking across the six content domains assessed by the scale. In addition, research has provided evidence for the validity of this measure by demonstrating that it is related to sensation seeking, dispositional risk taking, intolerance for ambiguity, social desirability, performance on gambling tasks, and risky health decisions (see Blaise and Weber, 2006; Weber et al., 2002). As such, DOSPERT has been

described as one of the most useful measures of risk propensity across a number of everyday situations (Harrison, Young, Butow, Salkeld, and Solomon, 1995).

Consistent with previous research, Weber et al.'s (2002) risk attitudes scale is used to assess risk across different situations (i.e., Social, Health and Safety, Ethical, Investment, Recreational, and Gambling). Similar to the measure of the FFM, DOSPERT measures each dimension using a series of statements. The likelihood of engaging in various activities is measured with a 5 point Likert scale with responses ranging from Highly Unlikely to Highly Likely. Statements for the *social domain* include "Approaching your boss to ask for a raise" and "Admitting your tastes differ from those of your friends"; statements for the *health and safety domain* include "Engaging in unprotected sex" and "Not wearing a seatbelt while in the front seat"; statements for the *ethical domain* include "Illegally copying a piece of software" and "Forging someone's signature"; statements for the *investment domain* include "Investing ten percent of your annual income in a modest growth mutual fund" and "Investing ten percent of your income in government bonds"; statements for the *recreational domain* include "Trying bungee jumping at least once" and "Vacationing in a third world country without reservations"; and statements for the *gambling domain* include "Betting a day's income on the outcome of a sporting event" and "Gambling a week's income at a casino."

A priori, there is no specific reason to suggest which and how the different risk attitudes will relate to the behavior of individuals performing the tasks of DOND and H&L. Based on the literature, there is no specific guide for predicting if the tasks will be perceived as gambling or investing, for example. Therefore this paper takes an agnostic approach and performs the analyses with no priors regarding the relationship between the different risk attitudes scales and the degree of risk aversion under the different elicitation methods. There are specific features of

each elicitation method that could cause subjects to perceive the tasks differently, thus changing the relative importance of different personality characteristics. For example, DOND is a dynamic game while H&L is static. This change may systematically alter behavior but the maintained assumption here is that this behavioral response is due to a change in the personality domain that is driving behavior (i.e., perhaps dynamic games are more likely to be perceived as gambling).

Following Nicholson et al. (2005), the FFM is estimated while incorporating the DOSPERT attitudes. While Nicholson et al. (2005) utilize Structural Equation Model (SEM) regression, the current analysis uses the Partial Least Squares (PLS) method because of the relatively small sample size and strong correlation among survey items for each domain.[11] In the model, the Big Five Factors of Personality are specified as unobserved characteristics (i.e., latent variables) that determine the domain-specific risk attitudes which are also specified as latent variables. Each unobserved characteristic reveals itself to researchers through a series of survey items, which serve as indicators of the latent construct (see Bollen & Lennox, 1991). For example, the extent to which someone agrees with the statement "I get irritated easily" reflects that person's neuroticism. These observable items are termed manifest variables.

Formally, let LV_{ij} denote a latent variable for individual i and characteristic j and let MV_{ijk} denote its manifest variables. Each of the K manifest variables are measured by a 5-point Likert scale. Every manifest variable reflects the latent variable in the sense that $MV_{ijk} = \pi_{jk0} + \pi_{jk1} LV_{ij} + u_{jk}$, which looks like a classical linear model except that it cannot be estimated because the latent variable is not observed. Latent variables are estimated as weighted

[11] For methodological details, refer to Wold (1985), Fornell and Brookstein (1982), Chin (1995), and Tenenhaus et al. (2005). The method is well known in fields outside economics such as psychology, marketing, and chemistry. It is useful particularly when researchers wish to minimize measurement error when assessing unobservable or theoretical constructs, such as personality traits, work attitudes, and perceptions of different social contexts.

means of corresponding manifest variables by some procedure of iteration and convergence criteria.[12]

The structural or path model specifies relationships among latent variables. For simplicity, suppose that there are two latent variables, LV_1 (e.g. neuroticism) and LV_2 (e.g. ethical risk attitude). A causal relationship or path should be built based on some theoretical background: $LV_{i2} = \alpha_0 + \alpha_1 LV_{i1} + v_i$. Once the latent variables are replaced with the estimates, the above linear equation is estimated by OLS.

The estimation results are generally consistent with those of Nicholson et al. (2005); when the estimates are significant, Extraversion and Openness motivate risk taking while Neuroticism, Conscientiousness and Agreeableness depress risk taking. There is only one exception; Neuroticism motivates risk taking in the social domain.[13] Table 3 provides the Partial Least Squares results.

Table 4 shows how DOSPERT attitudes, elicited by the PLS method from the survey items, are related to demographic characteristics. The six DOSPERT measures are jointly estimated as dependent variables by the Seemingly Unrelated Regression method. The results are consistent with results previously reported in the literature (Weber, Blais, & Betz, 2002). Results indicate that men are more prone to take risk in the context of recreation, health/safety, and gambling. The willingness to take risk seems to be decreasing with age across all the domains,

[12] An alternative estimate of the latent variable is the arithmetic mean of its manifest variables. That is, $LV_{ij} = MV_{ij} = \frac{1}{K}\sum_{k=1}^{K} MV_{ijk}$.

[13] One may be concerned here since the estimates, although they are overall consistent with expectation, are not significant. This is in part due to our small sample size; Nicholson et al. use 1,699 individuals. We can avoid the problem of small sample by using simply the arithmetic means of manifest variables instead of the estimated latent measures from the PLS method; they are strongly correlated. The results below change little if the means of manifest variables are used for the analysis.

Table 3. Partial Least Squares Estimation of Big Five Factor Model of Risk Attitudes

	Social	Recreation	Health & Safety	Gambling	Ethical	Investment
Agreeableness	-0.0466	0.0422	-0.0744	-0.2093	-0.2367	0.0153
	(0.4662)	(0.4276)	(0.6508)	(1.5222)	(2.1372)	(0.0974)
Conscientiousness	-0.1817	-0.0354	-0.0878	0.0363	-0.2268	0.1694
	(1.9689)	(0.2622)	(0.8604)	(0.3134)	(1.6756)	(1.5925)
Extraversion	0.3812	0.1917	0.3282	0.1176	0.1932	0.1495
	(3.9602)	(1.7053)	(3.3164)	(0.9814)	(1.3381)	(1.2724)
Neuroticism	0.2916	0.1209	0.2169	-0.0839	0.1599	-0.0710
	(2.7632)	(0.7290)	(1.1689)	(0.6436)	(0.8111)	(0.5939)
Openness	0.1307	0.2876	0.2358	0.2534	-0.0076	0.1363
	(1.2575)	(2.1857)	(1.9351)	(2.3384)	(0.0452)	(1.1334)

* The number of observations is 75 survey respondents. The t statistic, computed by bootstrapping, is present in parentheses. The model is estimated by *SmartPLS*®, which is available at http://www.smartpls.de/.

Table 4. Estimated DOSPERT Measures and Demographic Characteristics: Seemingly Unrelated Regression Results

	Social	Recreation	Health & Safety	Gambling	Ethical	Investment
Male	-0.143	0.474***	0.350**	0.703***	-0.040	0.268
	(0.260)	(0.161)	(0.166)	(0.242)	(0.235)	(0.164)
White	-0.571	0.348	-0.595**	0.217	-0.094	0.616**
	(0.470)	(0.291)	(0.301)	(0.438)	(0.424)	(0.297)
Asian	-1.083*	0.359	-1.309***	0.557	-0.293	1.246***
	(0.587)	(0.364)	(0.376)	(0.548)	(0.531)	(0.371)
Age	-0.025	-0.026**	-0.020*	-0.021	-0.030	-0.0001
	(0.017)	(0.011)	(0.011)	(0.016)	(0.016)	(0.011)
Mom - HS Graduate	-0.301	0.017	-0.518	-0.180	-0.575	-0.142
	(0.674)	(0.418)	(0.431)	(0.629)	(0.609)	(0.426)
Mom - Some College	-0.421	-0.092	-0.425	-0.163	-0.753	-0.063
	(0.635)	(0.394)	(0.407)	(0.593)	(0.574)	(0.401)
Constant	4.198***	2.680***	3.596***	1.942**	3.668***	2.938
	(0.915)	(0.567)	(0.586)	(0.853)	(0.826)	(0.578)
R squared	0.065	0.206	0.260	0.151	0.072	0.174

although the effects are only significant in recreation and health/safety. Interestingly, race plays different roles across different domains. Caucasians are more willing to take risk in investments while they are more risk averse in the health/safety domains. Asians in this sample have similar

traits as Caucasians. It seems that mother's education decreases the willingness to take risk across all the domains, although not statistically significant.

The survey instrument also measured the degree of risk aversion directly albeit based upon hypothetical responses. Following (Dohmen et al., 2005), subjects were asked how much of $100,000 in lottery winnings they would invest in an asset that would either double or halve in value over the next two years. Each subject selects a response from a list of options; therefore an interior choice identifies an upper and lower bound for the CRRA parameter.[14] Additionally, respondents completed questions regarding a hypothetical scenario in which they could accept a new job that would either double their income or cut it in by some fraction with equal probability.[15] These questions are presented as part of the National Longitudinal Survey of Youth (NLSY) (see Spivey, 2007) and the Health and Retirement Survey (HRS) (see Barsky et al., 1997).

3. Results

The results are presented in three stages. First, the individual risk measures are presented separately and compared with previously reported measures of risk preferences. The general result is that there is considerable heterogeneity across subjects. Next, responses are compared within subject across elicitation methods. As before, these is considerable variation across elicitation methods for the same subject's implied risk parameter. Finally, the personality characteristics are utilized to explain within subject variation.

[14] Assuming the CRRA function, the response bounds the participant's risk aversion parameter. There were five possible responses leading to six risk intervals with the five cutoff values of r = 0.558, 0.72, 1, 1.636, and 4.91.
[15] Again assuming the CRRA function, the possible responses lead to four intervals with three cutoffs of r =1, 2, and 3.76.

3.1 Individual Risk Attitudes by Elicitation Method.

Table 5 compares the results of the current study with those of Holt and Laury. As evidenced by the table, subjects in the current study were similar to those studied by Holt and Laury (the null hypotheses of no difference cannot be rejected at any standard level of significance based upon two-sample Kolmogorov-Smirnov test).[16]

Table 5. Comparison of Risk Attitudes in Holt and Laury Task.

Number of "Safe Choices"	0-1	2	3	4	5	6	7	8	9-10
Holt and Laury (2002)	0.01	0.01	0.06	0.26	0.26	0.23	0.13	0.03	0.01
Current Study	0.01	0.04	0.11	0.17	0.28	0.26	0.08	0.06	0.01

The number of safe choices corresponds to the design of Holt and Laury (2002). The current study included an additional comparison with no chance of receiving the larger payoff and thus the number of "safe choices" in the current study is actually one greater than what is reported in this table. That is the label 0-1 includes 0-2 safe choices in the current study. Therefore, this table directly compares risk attitudes between the studies.

Figure 3 compares the risk attitudes of the subjects in the Deal or No Deal task with those of contestants on the actual game show as reported in Deck et al. (2008).[17] The general result is that the subjects tended to be far more risk loving than the game show contestants.[18] There are at least three potential explanations for this result. One is the size of the stakes which are

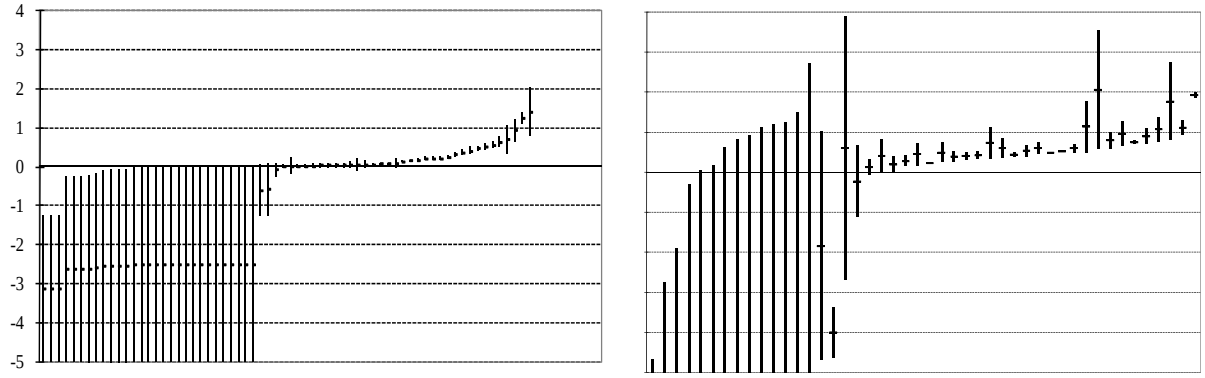
[16] In both studies some subjects were not consistent with a single switching point from Option A to Option B. Individual responses were examined in such cases. Holt and Laury (2002) add the number of safe to determine the "switching" point. In the current study, this is addressed in two ways. First, if a subject were to select Option A five times and then Option B once followed by Option A once and then Option B for the remainder of the choices was treated as if she had selected Option A six times and then switched to Option B, consistent with Holt and Laury. Second, if a subject made a single choice inconsistent with a unique switching rule and not covered by the first rule above, that single choice was considered to be an error. For example, if a subject chose Option A, then Option B, then Option A four times before switching to Option B for the remainder, this subject was classified as having chosen Option A for six times. There were 11 subjects that made inconsistent decisions. Eight of them were reclassified as described and three were too erratic to be classified and therefore are omitted from subsequent analyses.

[17] For five subjects bounds for DOND could not be computed. For three of these subjects behavior was inconsistent between rounds and two of the subjects accidentally stopped immediately.

[18] This is consistent with the finding of Baltussen, Post, Thaler, and van den Assem (2008).

considerable larger on the game show. Holt and Laury (2002) among others found that a dramatic increase in the stakes lead to more risk averse behavior.

Figure 3. Deal or No Deal Risk Attitude Bounds in the Lab (Left) and on Television (Right)



Another difference between the formats is the presence of an audience; one might have greater concern for looking foolish and earning a low pay off on television than in the laboratory. A third difference is that subjects knew how offers would be generated. Knowing that the offer as a percentage of expected value would increase in subsequent rounds or simply knowing that one was being offered a substantial amount less than the expected value in most rounds may have induced people to continue further than they would have without that information.

Table 6 compares the implied risk attitude of subjects based upon the survey responses with what has been reported previously. The general result is that the respondents tend to be less risk averse than what has been previously reported. Possible explanations for the differences are the demographic composition of the samples to the degree that such traits impact risk attitudes and the comparison respondents draw between these questions and other questions in either survey which might impact responses.

Table 6. Comparison of Survey Responses of Economic Risk.

Lottery Investment Question						
Investment Amount	0%	20%	40%	60%	80%	100%
Dohmen et al. (2005)	≈60%	≈18%	≈13%	≈6%	≈2%	≈1%
Current Study	9.3%	16.0%	33.3%	22.7%	10.7%	8.0%

Accepting Risky Job Questions				
Risk Type	Very Strongly Risk Averse	Strongly Risk Averse	Moderately Risk Averse	Weakly Risk Averse
HRS - Barsky et al. (1997)	64.6%	11.6%	10.9%	12.8%
NLSY - Spivey (2007)	46%	12%	17%	25%
Current Study	20.8%	36.1%	25%	18.1%

3.2 Comparison of Risk Attitudes by Elicitation Method within Subjects.

As with previous research, the results of the different elicitation techniques are troublesome. Not only do the same subjects differ with regard to their estimated level of risk aversion; attitudes are only weakly correlated between elicitation techniques.[19]

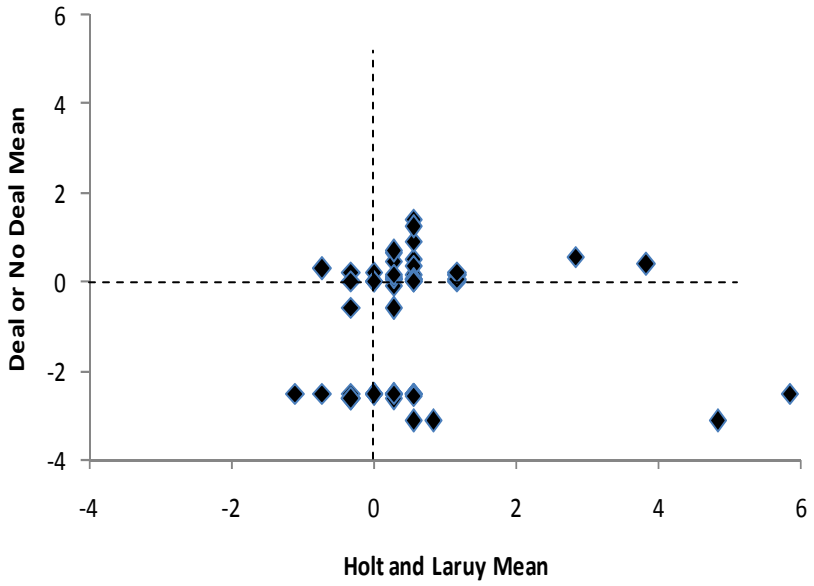
Figure 4 provides a scatter plot of the midpoint for the risk attitude of each subject under the Holt and Laury task and the Deal or No Deal task.[20] If the risk parameter were the same under both elicitation methods, the observations would lay on (or near) the 45 degree line. They do not. Subjects in the top left and bottom right of this plot actually switch from being risk loving to being risk averse or vice versa. The correlation between the two tasks is 0.008 (p-value

[19] One potential difference in the two paid tasks is the relative size of the stakes. The average payment in the Deal or No Deal task was approximately six times that of the average payment in the Holt and Laury task. However, evidence suggests that this is not problematic. While the current data does not address this concern, the original study by Holt and Laury (2002) compared behavior within subjects at different wealth levels. 93 subjects in that study made decisions with the stakes used in the current study, then decisions with stakes 20 times greater, and then decisions with the low stakes again. There is substantial correlation between the implied risk attitudes at the two stake levels (correlation = 0.64 between average low stakes response and the 20 times stakes response) suggesting the change in rankings of risk attitudes is not merely the result of changing stakes. Further, the typical finding is that increases in stakes lead to more risk aversion, the opposite pattern to what is observed here. Thus, the behavioral shift attributed to changing the task is understated.

[20] A lower bound of -5 is used for subjects who went all of the way in Deal or No Deal. For two subjects, one bound is missing for the Holt and Laury task; these bounds were imputed using the average distance of the intervals for the properly bounded subjects. The figure excludes subjects whose behavior could not be characterized.

= 0.9494). The correlation between the job and lottery survey measures of risk is -0.103 (p-value = 0.3889).[21] The greatest correlation between two of the four measures is 0.242 (p-value = 0.0420) for the Holt and Laury procedure and the job survey. No other pair of measures is significantly correlated even at the 10% level.

Figure 4. Plot of CRRA Risk Parameters in Holt and Laury and Deal or No Deal Tasks



The analysis of the midpoint is informative but one must be cautious since the actual risk parameter could lie anywhere in the interval. However the data clearly showed that risk aversion varies across different elicitation methods within subjects.[22] Fifty percent of the subjects definitely were less risk averse or more risk loving in DOND than in H&L because interval of consistent risk parameters for DOND was strictly below the interval of consistent risk parameters for H&L. Thirteen percent of subjects definitely were more risk averse in DOND. For the

[21] Correlations for the job and lottery risk surveys are based upon rank.
[22] This is based upon the 67 subjects for whom bounds could be computed for both DOND and H&L.

remainder of the subjects, the two intervals from DOND and H&L had some overlap. Interestingly, those who were less risk averse in DOND are more likely to be male and younger.

3.3 Explaining Within Subject Variation with Personality Characteristics.

To explain the apparent inconsistency between risk measures, the analysis now turns to the individual characteristics from the psychology literature.[23] The estimation assumes that the risk aversion parameter, γ_i, is normally distributed and *iid* across individuals, $\gamma_i = X_i\beta + \varepsilon_i$ and $\varepsilon_i \sim N(0, \sigma^2)$. The mean is assumed to depend upon the estimated latent variables for the domain-specific risk attitudes as well as demographic characteristics. Initially the specification allowed for heterogeneity in σ, but no explanatory variable turns out to be significant in determining it except for the intercept.[24] The likelihood function is

$$L = \prod_{i=1}^{N} \left\{\Pr(\gamma_{Li} \le \gamma_i \le \gamma_{Ui})\right\}^{U_i L_i} \left\{\Pr(\gamma_i \le \gamma_{Ui})\right\}^{(1-U_i)L_i} \left\{\Pr(\gamma_{Li} \le \gamma_i)\right\}^{U_i(1-L_i)}$$
$$= \prod_{i=1}^{N} \left\{\Phi(\frac{\gamma_{Ui} - X_i\beta}{\sigma}) - \Phi(\frac{\gamma_{Li} - X_i\beta}{\sigma})\right\}^{U_i L_i} \left\{\Phi(\frac{\gamma_{Ui} - X_i\beta}{\sigma})\right\}^{U_i(1-L_i)} \left\{1 - \Phi(\frac{\gamma_{Li} - X_i\beta}{\sigma})\right\}^{(1-U_i)L_i}$$

where γ_U and γ_L are the upper and lower bounds of the CRRA parameter, respectively. U and L are indicator functions for the existence of the upper and lower bounds, respectively. The maximum likelihood estimation results are presented in Table 7.[25]

[23] Shor (2007) and Schmitt et al. (2005) examine a similar issue in simple allocation games. Shor (2007) examines how attitudes towards distributive and procedural justice impact behavior in the ultimatum and dictator game. Schmitt et al. (2005) consider Briggs-Myers personality types impact behavior in the ultimatum game with pre-commitment.

[24] In order to control for a possible wealth effect, the amount of prize money that the subject had earned during participation in any previous portion of the experiment was included, but the variable turned out to be insignificant. An indicator variable of whether the subject had played DOND prior to H&L was included to see if there is any effect of learning or experience. The variable was also insignificant and it is dropped from the final specification.

[25] The results are based upon 65 usable observations. Two observations are lost because of missing demographic information and bounds for DOND and H&L could not be computed for eight subjects.

Table 7. Impact of Personal Characteristics on Risk Attitudes Across Elicitation Methods

	DOND	H&L	Lottery Survey	Job Survey
Social	0.043	-0.114	-0.256^{++}	-0.096
	(0.083)	(0.110)	(0.155)	(0.198)
Recreation	-0.194	-0.009	-0.830^{+++}	-0.566^{+}
	(0.152)	(0.209)	(0.287)	(0.356)
Health and Safety	0.172	0.274	-0.065	0.453
	(0.156)	(0.221)	(0.299)	(0.381)
Gambling	-0.161^{++}	-0.062	-0.039	-0.181
	(0.090)	(0.126)	(0.169)	(0.221)
Ethical	0.055	-0.259^{++}	0.045	0.149
	(0.093)	(0.131)	(0.180)	(0.231)
Investment	-0.005	-0.495^{+++}	-0.310	-0.211
	(0.124)	(0.177)	(0.252)	(0.313)
Male	-0.0002	0.534**	0.824**	1.071**
	(0.183)	(0.268)	(0.366)	(0.482)
White	-0.169	-1.621***	-1.020	-0.615
	(0.321)	(0.471)	(0.662)	(0.869)
Asian	-0.041	-0.701	-0.889	0.526
	(0.489)	(0.679)	(0.941)	(1.214)
Age	0.023*	-0.003	-0.007	0.048
	(0.012)	(0.016)	(0.023)	(0.030)
Mom - HS Graduate	-1.031*	-0.424	0.311	0.122
	(0.561)	(0.647)	(0.827)	(1.064)
Mom - Some College	-0.927*	-0.280	0.207	0.437
	(0.537)	(0.611)	(0.776)	(1.001)
Constant	0.662	4.148***	6.040***	2.201
	(0.867)	(1.190)	(1.651)	(2.011)
Standard Deviation (σ)	0.557***	0.875***	1.195***	1.476***
	(0.072)	(0.076)	(0.120)	(0.181)
Number of Observations	68	70	73	71
Log Likelihood	-123.9	-172.8	-147.7	-90.23
McFadden's pseudo R squared	0.087	0.110	0.093	0.076

Note: The one-tailed test of H_0: $\beta \geq 0$ and H_1: $\beta < 0$ is done for the DOSPERT scales. +, ++, and +++ denote significance at the 10%, 5%, and 1% levels, respectively. For the other variables, the two-tailed t test of H_0: $\beta = 0$ and H_1: $\beta \neq 0$ is done. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Given that there is no reason to believe that higher scores for the social, recreational, health and safety, ethical, gamble, and investment domains should increase risk aversion, one-tailed test for the non-positive impacts of DOSPERT measures on the risk aversion parameter are used.

The results are striking. Behavior in the Deal or No Deal task correlates with a person's attitude towards gambling, but gambling attitudes do not impact behavior in the Holt and Laury task.[26] It appears that subjects view the Deal or No Deal task as gambling, subjects who indicated willingness to gamble appear less risk averse in Deal or No Deal. On the other hand, the Holt and Laury procedure correlates with a subject's attitude towards investments. The more likely a person is willing to invest "income in a very speculative stock" the less risk averse they will appear as measured by the Holt and Laury task. This is not true for Deal or No Deal; subjects are not viewing that task as an investment. The Holt and Laury task is also associated with ethical attitudes but to a smaller degree and significance than investment attitudes. Interestingly, the survey questions about investing lottery winnings are not associated with either gambling or investing, but are associated with social and recreation risk attitudes. Responses to the job choice survey are not associated with any of the six risk attitude measures.

Given the results presented in Table 7, an individual's implied level of risk aversion will vary across tasks based upon their personality characteristics. The results show cross-sectional relationships between risk aversion and psychological measures. Given that psychological measures are significantly different within individuals as well as across individuals, this variation

[26] The Holt and Laury procedure is a comparison of two lotteries while Deal or No Deal is a comparison of a fixed amount and a lottery. This distinction may in part explain why people view the tasks differently. The change in the way subjects view the tasks could also be due to the visual presentations, the word choices in the task directions, or familiarity with the popular game show.

explains how one person could appear more risk averse than someone else in one task and less risk averse than that same person in another task.[27]

Table 8 shows how risk taking attitudes change across different domains within subjects. It is not surprising to find that the attitudes are correlated between different domains since they should be fundamentally rooted in risk aversion in general. Indeed, in many cases, the hypothesis of independency can be rejected. It is, however, also true that attitudes are not perfectly or strongly correlated, consistent with Cohen (1988).

Table 8. Within-Subject Correlations Between Domain-Specific Risk Taking Attitudes

	Social	Recreation	Health and Safety	Gambling	Ethical
Recreation	0.2077				
	(0.0738)				
Health and Safety	0.3525	0.4889			
	(0.0019)	(0.0000)			
Gambling	0.1788	0.3066	0.4136		
	(0.1248)	(0.0075)	(0.0002)		
Ethical	0.2354	0.2353	0.3818	0.2762	
	(0.0420)	(0.0421)	(0.0001)	(0.0164)	
Investment	-0.0048	0.2244	0.0797	0.1710	-0.1136
	(0.9676)	(0.0529)	(0.4965)	(0.1425)	(0.3318)

Note: Spearman correlation test p-values are in parentheses.

The other demographic information is revealing as well. Previous studies have tended to report that women are more risk averse then men (see Charness and Gneezy, 2007). For example, Weber et al. (2002) found that women were more risk averse across all domains except for social risk. Weber et al. (2002) suggested that this is because women have different perceptions of the

[27] One might explicitly measure the gap between two risk measures, for example, $\gamma_{i,H\&L}$ from H&L and $\gamma_{i,DOND}$ from DOND. The above MLE method can be used to estimate $\beta_{H\&L} - \beta_{DOND}$ where the upper and lower bounds for the dependent variable are $\gamma^{U}_{i,H\&L} - \gamma^{L}_{i,DOND}$ and $\gamma^{L}_{i,H\&L} - \gamma^{U}_{i,DOND}$, respectively. For the current sample the results of this estimation are qualitatively in harmony with those in Table 7.

activities' benefits and risks relative to men. In addition, McCrae (2002) reported gender differences across more general personality traits (e.g., neuroticism, openness, and conscientiousness) associated with the FFM. In the current research, the results indicate that, after controlling for risk attitudes, gender is significant for the Holt and Laury task and the hypothetical survey elicitation methods. However, the data suggest that it is men who are more risk averse. Age and mother's education impact behavior, but only in DOND. Curiously, ethnicity matters but only for the H&L procedure. Caucasian respondents were more willing to take what is perceived as an investment risk.

4. Conclusions

Risk is ubiquitous and as such much attention has been given to trying to measure risk. This paper does not attempt to resolve the ongoing debate about how to model risk (CRRA, CARA, Prospect Theory, etc.). Rather this paper asks a more fundamental question; can risk be reduced to a problem of payoffs and probabilities? The results suggest that the general answer is no; respondents view different risky situations differently. Models that examine risk based purely on probabilities and outcomes cannot capture the subtlety of the context in which the decision is made. The experimental version of Deal or No Deal as implemented in this study is viewed as gambling whereas the Holt and Laury procedure as implemented in this study is viewed as a financial decision. It is well known that bidders act as if they are more risk averse in single unit first price sealed bid auctions experiments than in single unit Dutch clock auction experiments with independent private values even though those environments are strategically equivalent. Perhaps this can be explained by the way subjects view those tasks. A reasonable hypothesis for further research is that bidding in the Dutch auction, in which the bidder watches potential profits grow while risking a payoff of zero, is impacted by a respondent's attitude

towards gambling while bidding in a first price sealed bid auction is not. As mentioned above, Dave, Eckel, Johnson, and Rojas report different results when comparing the Holt and Laury task and the Eckel and Grossman (2002) task which fixes probabilities and changes payoffs. Bruner (2007) does something similar but does not find that the elicitation method changes behavior substantially. One difference in the two studies is how the alternative task is presented to the respondents. Bruner (2007) presents the two tasks in table format. Dave et al. (2007) present the task as selecting one lottery from a set of 6 possibilities. Perhaps this change triggers how the respondents view the problem and thus leads different personality traits to become relevant in the decision making process.

More broadly, this paper demonstrates how personality measures can be used to predict economic behavior. The use of such measures has received relatively little attention in economics as evidenced by the following quote:

> The lack of familiarity of economists with these personality measures is one reason for their omission from most economic studies. Another reason is that many economists have yet to be convinced of their predictive validity, stability or their causal status, believing instead that behavior is entirely situationally determined. …Without evidence that there is value in knowing which personality traits are most important in predicting outcomes, there is little incentive to include sufficiently broad and nuanced personality measures in empirical studies. – Borghans, Duckworth, Heckman, and ter Weel (2008, p. 4)

Based upon the current results it is clear that personality impacts risk aversion. However, it remains to be determined if these or other personality characteristics have explanatory power for other economic behavior. Clearly, more research is warranted in this area.

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