Deal or No Deal: Risk Aversion in a Field Experiment with Very High Stakes

Current Version: November 2005

Abstract

We utilize data from an Australian television game show involving high stakes and sequential lottery choices to show that risk aversion increases with increasing stakes. Our estimates of risk aversion are lower than that found in other game show papers or other empirical work. Importantly, we also find considerable heterogeneity in people's willingness to bear risk. A special feature of the game show enables the high stakes testing of prospect theory. Our data provides support for this theory.

Journal of Economic Literature Classification: C13, C23, C25, C93, D81, D82.

Keywords: Decision Theory, Expected Utility, Game Shows, Risk Aversion, Calibration Theorem, Field Experiment, Prospect Theory, Loss Aversion.

1 Introduction

The analysis of decisions under uncertainty is fundamental to modern economics and finance. This paper contributes to a recently developing empirical literature that adopts the central research question: How risk averse are individuals? Subsidiary questions regarding risk aversion include its heterogeneity and how it varies with individual characteristics (especially wealth and gender). While the theoretical literature on risk aversion and expected utility theory is large and long-standing, the literature *explicitly* testing for risk aversion is comparatively small. Such empirical tests as exist, either in laboratory or field experiments involving real stakes, have mostly been confined to small cash values. There has been a recent debate doubting the applicability of such estimates when extrapolated to high real stakes (see Rabin (2000) and Segal (2005)). The current paper exploits an Australian game show data-set to estimate the risk aversion of contestants who face an environment of very high stakes.

"Deal or No Deal" is a half-hour TV game show in which contestants make a series of choices between a sure thing and a lottery.[1] It is ideal for studying a range of issues relating to economic decision making. The show consists of a chosen contestant faced with 26 suitcases, randomly containing amounts ranging from 50 cents to $200,000 dollars. There are up to nine rounds in the main stage of the game. Before commencing play, the contestant selects a suitcase and it is then placed aside, unopened. In each of the following rounds, the contestant removes a number of suitcases, depending upon which round is being played; they are opened and the amounts revealed. The prizes contained in these suitcases can no longer be won. The contestant is then offered an amount by the "Bank" (the producers): "the Deal". The choice facing the contestant is to take the bank offer, at which point the game ends (modulo a possibility discussed next) or to reject it and continue playing the game into at least the next round (i.e., to take the lottery choice). If the contestant chooses to play on, the process is repeated. Even if the contestant at some stage accepts an offer from the Bank, the contestant is still asked to go through the motions

[1] We use data from the Australian version of this show, although the show has now been syndicated in over 30 countries.

of removing suitcases, just to see what might have transpired. One of two supplemental rounds may then appear at the end of the show. First, when only two suitcases are left, the contestent may be offered a "Chance" round, allowing the contestant to exchange the certain amount that they've already won for a pick of one of the two remaining suitcases. Second, when all suitcases have been revealed, the contestant may be given the option of swapping the certain amount that they have won for the "SuperCase", which is a lottery in which one of eight prizes may be won. Both these possibilities are entirely at the discretion of the producers.

Our paper investigates two fundamental issues. First, we explore the willingness of contestants to take risks with large monetary gambles. Second, we assess whether contestants exhibit loss aversion. Regarding the first issue, we find that, while on average most contestants on Deal or No Deal are probably risk averse, their willingness to bear risk is greater than had previously been found in studies of US game shows. Moreover, many contestants are willing to take very risky gambles, even when the stakes are high. There is a high degree of heterogeneity between contestants in terms of risk aversion. The Deal or No Deal data also support previous empirical findings that people become more risk averse as stakes rise (see Holt and Laury (2002) and Harrison et. al. (2003)). Any discussion of how risk aversion increases with increasing stakes leads automatically to a consideration of the Rabin 'Calibration Theorem' (see Rabin (2000) and Rabin and Thaler (2001)). This states that any rejection of even, small-stakes gambles over a certain range of initial wealth implies absurd levels of risk aversion with respect to high-stakes gambles.[2] Conversely, starting with 'sensible' levels of risk aversion in high-stakes gambles, when faced with small-stakes gambles agents should be roughly risk neutral or even risk loving (see Watt (2002)).[3] From this point of view our results, revealing mild risk-loving behavior for low wealth levels, appear to be consistent with the type of behavior which the 'Rabin critique' finds so anomolous.

[2] The lower bound on risk aversion obtained from this type of reasoning enables comparisons with other types of data, such as for example the elasticity of labor supply (Chetty (2005)).

[3] Since it is widely considered (from laboratory experiments) that individuals exhibit risk aversion in small-stakes environments (see for example the survey of risk aversion in the experimental auction literature by Bajari and Hortascu (2005)), the 'Rabin critique' is thought to have implications for the validity of standard expected utility models.

As contestents progress through the game, they become more wealthy on average[4] and so tend to exhibit increasing risk aversion. We find risk-loving behavior more likely with low stakes gambles (see also LeRoy (2003)) - although it is certainly not confined to low stakes gambles. Of course, the repeated nature of the game may also have led to a reduction in risk aversion in the early rounds (Samuelson (1963)), as might the possible occurrence of future Chance or Super-Case rounds.

The theoretical and scientific attraction of expected utility theory is that it posits a consistent preference relation regardless of changes in the 'frame' of the decision, especially with respect to changes in a decision-maker's wealth. Prospect theory (which implies loss aversion[5]) is a well-known example of a theory of decision-making under uncertainty where that is not the case. This is also true of some attempts to 'clarify' the Rabin critique by making distinctions between theory versus models, or between end-state wealth and income models (or some hybrid of the two) (see for example Cox and Sadiraj (2004)).[6] The Deal or No Deal game show is ideally structured to test the second issue (concerning 'loss aversion') as some contestants face a reversal of the framing of their choice when they participate in either the Chance round or the Supercase round described above. In the "normal" rounds, contestants face the prospect of swapping their rights to the lottery for a sure amount of money. In contrast, in the Chance and Supercase rounds, contestants face the prospect of exchanging a certain amount of money *already won* via the "Deal" agreed to earlier for a gamble. Approximately 40 percent of the contestants in our data set participate in one of these "special" rounds. We find that contestants exhibit a considerably higher level of risk aversion in both the Chance and Supercase rounds than in the normal rounds. Assuming the validity of an underlying assumption that contestents are characterizable by some type of non-expected utility model, this appears to provide some support for a kind of preference

[4] Of course, while this is true on average, it is possible for an individual contestant to become less wealthy during the course of the game if their Bank Offers decline due to the removal of high-value suitcases.

[5] 'Loss aversion' is where a person's welfare will fall more as a result of losing a specified amount of money than it rises when they win the same amount of money. People who are loss averse will be willing to take large risks to avoid losses but will tend to be risk averse with potential gains. See generally Kahnemann and Tverskey (1979).

[6] Other responses to the Rabin critique include Watt (2002), LeRoy (2003) and Palacios-Huerta et. al. (2003).

reversal or framing effect.[7] Notably, other game show studies in the literature do not involve such a reversal of the choice framework, and so were not able to test this behavioral effect.

On the important issue of the variation in risk aversion with agent characteristics, we find, consistent with much of the pre-existing literature, that attributes like *ex ante* wealth and gender have no significant effect.[8] The one recent exception to the lack of significance of agent heterogeneity is Cohen and Einav (2005), who utilize a large car insurance data set to structurally estimate (and hence control for) risk aversion and attributes long thought to influence risk aversion.

Researchers have, to date, largely relied upon three methods to study the magnitude and variability (with stakes) of risk aversion. First, researchers have tested risk aversion by running experiments in which people face actual monetary gambles.[9] Given the funding limits of such studies, many (though not all) of these studies were perforce small-stakes. The second method is to rely upon responses to surveys (see the discussion at the beginning of Camerer (1995)). This permits the consideration of people's attitudes to gambles involving much larger sums – but such studies are limited to hypothetical choices and there is no sound reason for thinking that what people say they will do when faced with high stakes is what they in fact will do (see Holt and Laury (2002) and the discussion in Hartog et. al. (2000)). Finally, there is the use of 'field experiments,' or situations of data generation outside the direct control of the researcher in which people are faced with large gambles. This includes a small game show literature as well as a small literature utilizing experiments conducted in developing countries. Collectively, these studies have found that people are generally (though only moderately) risk averse in high stakes environments, and that they become more risk averse as the stakes of the gamble increase (though again, only mildly).

Most of the game show papers are limited in their direct comparability to this paper

[7] The empirical literature on preference reversals and risk aversion is still developing, owing largely to the difficultly of disentangling such effects from others such ask, for example, incentive effects. See for example the recent survey of the experimental 'endowment effect' literature by Plott and Zeiler (2005).

[8] For a survey of the literature of the effect of gender on risk aversion see Crossen and Gneezy (2004). Meyer and Meyer (2004) have suggested in a recent survey that, properly calibrated, most of the empirical literature on risk aversion is in fact, and contrary to surface appearance, consistent with each other.

[9] See for example the survey of the laboratorial auction literature by Bajari and Hortascu (2005), and also Holt and Laury (2002), Harrison et. al. (2003) and Goeree et. al. (2003).

because they involve strategic interaction rather than, as is the case with Deal or No Deal, pure decision theoretic considerations. Papers concerning strategic game shows focus on disjunction and possible means of reconcilation between actual play and the theoretically prescribed optimal play, an issue resolved in laboratorical experiments via quantal response equilibrium models (see McKelvey and Palfrey (1995)).[10] A game show paper that focuses explicitly on measuring risk aversion is Gertner (1993), utilizing data from the show 'Card Sharks.' Gertner finds a very high coefficient of risk aversion. Further, Gertner finds that individual player behaviour is inconsistent with expected utility theory. Fullenkamp, Tenorio and Battalio (2003) consider lottery games and find both risk aversion and that it varies with the size of the stakes. Hersch and McDougall (1997) consider the same type of data for lottery games and finds that income is not a significant determinant, a finding replicated in this paper. Beetsma and Schotman (2001) consider the show 'Lingo' and find evidence of risk aversion. An advantage of the current paper compared to other game show papers (i.e., Jeopardy, which requires strong general knowledge) is that Deal or No Deal requires no especial skills in order to succeed.

Finally, two papers transport the experimental lab to the developing world. Binswanger (1980) takes a basic risk aversion experimental design (a one-shot lottery) to illiterate peasants in India (so that the payments are very large relative to the average income level of the participants). He finds only moderate risk aversion in his high-stakes environment, and also finds (matching results in this paper), that risk aversion varies little or not at all in agent characteristics (he finds only a very mild increase in risk aversion with wealth). Similarly, Kachelmeier and Shehata (1992) seek to extract participant certainty equivalents using lottery experiments in China. Like us, they find risk-seeking behavior for low stakes and/or low probability of gain lotteries. This risk-seeking behavior weakens with increasing stakes. Like us, they find little variation in risk preferences with other agent characteristics, including wealth.

Section 2 outlines the Deal or No Deal game show and section 3 describes the data it

[10] Three papers consider the show 'The Price is Right:' Bennett and Hickman (1993), Berk, Hughson and Vandezande (1996) and Healy and Noussair (19??). A paper by Metrick (1995) examines data from the game show 'Jeopardy.' None of them explicitly test for risk aversion (as opposed to implying it (or not) via choice of model).

generates. Section 4 gives the estimates on the bounds of risk aversion for the contestants and section 5 presents the results on the variation of risk aversion with stakes. Section 6 tests prospect theory and section 7 introduces the more realistic case of 'noisy' decision making, which permits point estimation rather than just bounds estimaton. Section 8 briefly discusses dynamic issues, while section 9 concludes.

2 Description of 'Deal or No Deal' Gameshow

The TV game is comprised of three stages. The first two stages reduce the contestant pool from 150 to one - the "contestant".

In Stage 1, the 150 members of the studio audience are sorted into 6 groups of 25. One of those groups is chosen at random. An additional, 26th person is chosen at random from the remaining pool of 125. These 26 people progress to Stage 2. Stage 2 is a trivia contest between the 26 people who were selected during Round 1. Participants in Stage 2 answer three simple questions. Of the Stage 2 participants that answer the most questions correctly, the chosen contestant is the person with the fastest reaction time. The contestant then moves on to Stage 3, which is the segment of the game that is of interest for this paper.

Stage 3 starts with 26 numbered suitcases, each of which contains a concealed, pre-determined money prize. The 26 unique money prizes range from 50 cents to a maximum of \$200,000, with most of the values falling below \$10,000. The schedule of prizes is contained in Appendix 1. The schedule of prizes remains the same in each show, although the amount allocated to each numbered suitcase is determined randomly before the start of each show.

At the start of Stage 3, the contestant chooses one suitcase, which is set aside. If the contestant plays Stage 3 to its ultimate conclusion, the contestant will win the prize contained in that suitcase. The remaining 25 suitcases are given to the 25 unsuccessful participants in Stage 2 ("the suitcase contestants").

Next, in Round 1 of the game, the contestant chooses six suitcases, from the remaining 25, for removal. As the contestant nominates each suitcase for removal, the money prize contained in that suitcase is revealed by the suitcase contestant holding it. Once a money prize has been revealed, it is removed from the game and can no longer be won. Before each suitcase is opened, the suitcase contestant holding it is given an opportunity to guess the prize within their suitcase. Any suitcase contestant guessing correctly wins $1,000. These events have no impact on our experiment.

After the frist six suitcases have been removed, the "Bank" (ie the producers of the gameshow) makes an offer to the contestant via the host of the gameshow: the "Bank Offer". The Bank Offer is a cash prize - determined, in part, by which money prizes remain available to be won in the 20 remaining unopened suitcases. The contestant can either accept this offer by choosing "Deal", or continue to the next round of Stage 3 by choosing "No Deal". When making this and all future decisions, the contestant is fully aware of which prizes remain available to be won.

If "Deal" is chosen, the contestant wins the money offered by the Bank but forfeits the right to continue playing Stage 3.

If "No Deal" is chosen, then the contestant moves to Round 2 of the game and must nominate a further five suitcases for removal from the 19 unopened cases still held by suitcase contestants. The contestant may not nominate the suitcase originally set aside. After the money prizes contained in these five suitcases are revealed, the contestant receives a second, revised Bank Offer. If, after the second Bank Offer, the contestant chooses "No Deal", a further four suitcases must be removed (Round 3). The Bank then makes a third Bank Offer based on the remaining 11 suitcases.[11]

The contestant again chooses either "Deal" or "No Deal". If "No Deal" is chosen, the contestant moves to a fourth Round and must nominate a further three suitcases for removal. After their removal, the Bank makes a fourth offer, based on the remaining 8 unopened suitcases. The contestant again chooses "Deal" or "No Deal". If "No Deal" is chosen, two more suitcases must be removed in Round 5, after which a fifth Bank Offer is made. If "No Deal" is chosen after the fifth offer, the game enters a phase (Rounds 6-9) in which suitcases held by the suitcase contestants are removed one by one. After the removal of each suitcase, a new Bank Offer is made.

When only one unopened suitcase held by a suitcase contestant remains, the contestant

[11] The suitcase originally chosen by the contestant and the 10 unopened cases still held by suitcase contestants.

must either accept the 9th Bank Offer or choose their own suitcase over the suitcase held by the single remaining suitcase contestant.

If the contestant accepts a Bank Offer, s/he continues to nominate suitcases for removal "as if" s/he were still playing Stage 3. This heightens tension allowing TV viewers to imagine "what might have been." It also gives all suitcase contestants an opportunity to guess the value of the prize in their suitcase, thereby winning $1,000.

Once the contestant has accepted a Bank Offer, one of two supplementary rounds may be played, at the discretion of the producers.

The Chance Round After a contestant has accepted a Bank Offer and made a deal, a "Chance" round may be introduced by the Bank. If it is offered, the Chance round will appear when only two cases remain to be opened: the suitcase originally set aside by the contestant and the last remaining case held by a suitcase contestant. In the Chance round, the Bank offers the contestant a chance to retract their "Deal" decision. If the contestant accepts, they forfeit all winnings from their previously made deal, and instead take home whatever is inside their selected briefcase. Since only two prize outcomes remain, the Chance round represents a choice between a 50-50 gamble between two prizes vs the prize already won. The Chance round is only ever offered when the two remaining prizes differ by a large magnitude, highlighting the contrast between the risky and the safe options.[12] Accepting the "Chance" offer is not compulsory. If the contestant declines to take the "Chance", they will still leave with the money prize that they accepted when the deal was made.

The SuperCase Round After a contestant has accepted a Bank Offer and made a deal, the SuperCase feature may be introduced by the Bank. If it is offered, The SuperCase round is played after all suitcases have been opened. If the contestant elects to take the SuperCase option, they will win whatever cash amount is revealed to be inside the SuperCase, and forfeit their previously struck deal. In each game that it is offered, one

[12] For example, in one game, the contestant faced a choice between a certain offer of $15,100 and a gamble between $10 and $75,000. The person chose the sure amount of money.

of the following cash values will be selected at random, and placed inside the SuperCase: \$0.50, \$100, \$1 000, \$2 000, \$5 000, \$10 000, \$20 000, or \$30 000.[13]

3 Data

3.1 Summary Statistics

We have data for 102 episodes from the second and third series of the show. Table 1 contains descriptive statistics. The mean value of prizes won in these episodes is \$15,810 with a standard deviation of \$18,541. The minimum prize won was \$1 and the maximum \$105,000. Not surprisingly, the Bank Offers in the initial rounds were generally low relative to the expected value of the remaining suitcases. Given that there is only one contestant per show, the producers have a strong incentive to ensure that each contestant plays at least a few rounds. In our sample, no contestants accepted an offer in rounds 1, 2 or 3, and only one contestant accepted in the fourth round. A total of 91 contestants played until at least round 6.

The 26 suitcases that are available to be won at the beginning of each game have a mean of \$19,112 and standard deviation of \$44,576. This seems to indicate that contestants are successfully managing risk, in simultaneously reducing the mean and standard deviation of their winnings, on average.[14] However, such a conclusion is too simplistic. As will be shown in the next section, a high proportion of contestants displays risk-loving behaviour.

The standard deviation of winnings is reduced by two factors that boost the earnings of contestants with a low expected value of remaining suitcases in later rounds. First, winnings are boosted, on average, by the highly generous offers made in later rounds - particularly to contestants with only low valued cases remaining in play. Second, the SuperCase round is usually only offered to contestants who have struck a low Deal, and

[13] The mean and standard deviation of the SuperCase option are \$8,510 and \$11,000 respectively. The Supercase was offered 24 times, with the contestants having accepted deals ranging from \$2,100 to \$17,800. For example, in one game, the contestant had previously accepted a Deal of \$6,350. After all suitcases had been revealed, the contestant was offered the SuperCase option. The contestant accepted, and won \$20,000.

[14] Indeed, the pseudo-Sharpe ratio for the outcomes in our sample is 0.85 - a considerable improvement over the counterpart of 0.42 facing contestants before the game begins.

usually gives these contestants a high probability of increasing their winnings.

We have data on three personal characteristics of each contestant: gender; age; and the postcode in which they reside.[15] Forty eight percent of contestants in the sample were male. The age of contestants varied from 18 to 66 years, with a mean of 32 and standard deviation of 10. For each postcode, we obtained average income data from the 2001 Australian Census, and used this as a proxy for individual wealth.

Table 1: Descriptive Statistics

Statistics	Obs	Mean	Standard Deviation	Min	Max
Prize won	102	$15,810	$18,541	$1	$105,000
Bank Offer	741	$8,717	$9,783	$1	$105,000
Gender (male = 1)	728	0.48	0.49		
Age	728	32	9.7	18	66
Individual income	720	$421	$86	$250	$650
Household income	720	$920	$200	$450	$1,750
Family income	720	$1,089	$256	$550	$1,750

3.2 Strengths and Limitations of the Data

Strengths Two important advantages of our data are that they describe decisions with both high stakes and real financial consequences. Notably, Holt and Laury (2002) find evidence that people's risk aversion is different when there are real stakes as opposed to hypothetical choices. Further, several studies (Binswanger 1980, Kachelmeir 1982 and Holt and Laury 2002) find that risk aversion increases along with the stakes of a gamble. It is important to stress that the stakes in Deal or No Deal are higher than any feasible experiment and almost any other game shows. The mean prize won by contestants is almost $16,000 with the highest prize being $105,000.[16]

Deal or No Deal also offers contestants very simple, stark choices. Almost all other game shows that have been studied by economists involve some element of skill, whether it

[15] Postcodes in Australia are analagous to Zip Codes in the U.S.

[16] Put another way, to perform this experiment from scratch would have required a total prize pool of approximately $1.6 million.

be knowledge of trivia, skill in word games or an ability to compute the odds in a game of chance involving cards. The only skill needed in Deal or No Deal is the comparison of a gamble with a certain offer: precisely the computational capacity in which economists are interested when studying decision making under uncertainty.

Finally, the format of Deal or No Deal is ideal for testing Prospect Theory as many contestants face a change of framing in the final round of the game. This feature is not present in other gameshows based on lottery choices.

Limitations The possibility of selection bias in the contestant pool is an issue for this paper, as it is for all studies based upon game show data. The process of selecting the contestant in Stages 1 and 2 is likely to mitigate this problem.

As outlined earlier, there are two stages in the selection of the contestant. First, 26 people are randomly chosen from the audience. It is not clear that the people who volunteer for quiz show audiences are systematically more risk averse or more risk seeking than the broader population. They may be more extroverted, on average, than the general population. They may have more free time, on average. Even if this were true, these qualities have not been shown to be correlated with risk aversion.

In the second stage, the 26 people randomly chosen from the audience compete to become the contestant by participating in a very simple trivia quiz in which the emphasis is on speed. There is no reason to think that there is any correlation between reaction time in a simple quiz and risk aversion.

The fact that the contestant is, in effect, randomly chosen from the audience via a two-stage process means that it is simply not possible for the producers of the show to engage in as much vetting of contestants as they would if contestants were chosen directly via an application process.

The artificial environment of the gameshow could potentially increase or decrease people's risk aversion. On the one hand, the excitement of being on television, surrounded by lights and a screaming audience could make people more prone to risk taking or to errors of judgement. On the other hand, some people may become more risk averse when in front of a national audience and carefully avoid doing anything embarrassingly foolish. The possibility that these factors are roughly in balance, on average, is consistent with earlier studies of game shows which have found that contestants display levels of risk aversion broadly in line with participants in experimental studies.

4 Risk Aversion

4.1 Set up

Each contestant plays up to nine rounds in Stage 3, with almost all contestants playing six or more rounds in our sample. Each decision in each round provides a bound on the risk aversion of the decision-maker. In order to calculate the risk aversion bounds implied by the decision made in each round by each contestant, we solve for the risk aversion parameter for the CRRA and CARA utility functions that would leave the contestant indifferent between the bank offer and a $1/n$ chance of winning each of the n remaining suitcases.

For the CRRA parameters, we solve for each contestant and each round, the γ such that:

$$\frac{(BO_r + w)^{1-\gamma}}{1-\gamma} = \frac{1}{n}\sum_{i=1}^{n_r}\frac{(SC_{i,r} + w)^{1-\gamma}}{1-\gamma} \tag{1}$$

where w is wealth, BO_r is the bank offer in round r, $SC_{i,r}$ is the value remaining in suitcase i and n_r is the number of remaining suitcases for that contestant in round r. This will provide a bound, rather than a point estimate, of γ. If the contestant rejects BO_r, then the γ that indicates indifference is the upper bound of the person's CRRA parameter: they must be no more risk averse than this. If the contestant accepts BO_r, then γ will be a lower bound.

Similarly, to calculate estimates of the bounds of the CARA parameters, we solve for each contestant and each round the σ such that:

$$\frac{-\exp(-\sigma * BO_r)}{\sigma} = \frac{1}{n}\sum_{i=1}^{n_r}\frac{-\exp(\sigma * SC_{i,r})}{\sigma} \tag{2}$$

where σ is the coefficient of absolute risk aversion. There is no need to include wealth in the CARA calculation as it cancels out.

4.2 Minimum Upper Bound on CARA and CRRA estimates

In each round that the contestant rejects an offer, we have an upper bound on that person's CARA and CRRA parameters. We know that the person's risk aversion parameter can be no higher than that person's lowest upper bound. The mean CARA minimum upper bound for the 102 contestants is -0.0000078. The mean CRRA minimum upper bound where wealth is set at 0 is 0.062. The impact of including wealth on the CRRA minimum upper bounds is discussed in the following section.

Both of these values are very low compared to other experimental/game show results. Moreover, since these represent only bounds, the true value of the parameters may be even lower. Figures 1 and 2 contain the distribution of contestants' CARA and CRRA minimum upper bounds, respectively.

Figures 1 and 2 reflect not just the low mean level of risk aversion, but also the high degree of heterogeneity across contestants. Of the 102 contestants in our sample, 33 had a negative risk aversion minimum upper bound, indicating risk-loving behaviour. These people rejected at least one offer that was greater than the expected value of the remaining suitcases. The lighter colored bars in each diagram represent people whose minimum upper bound indicates risk-loving behaviour. Importantly, only 59 people were made at least one offer that was greater than the expected value of the remaining suitcases. In other words, 56 percent of contestants that received one or more offers greater than expected value rejected at least one of those offers.

This risk-loving behavior was not confined to low stakes gambles. Many of the 33 people that rejected at least one offer greater than the expected value of the remaining suitcases rejected more than one such offer. In total, 49 Bank Offers that were greater than the expected value of the remaining suitcases were rejected. Of these 49 rejected offers, 10 were for values greater than $10,000. Out of a sample of 102 contestants, 8 rejected at least one offer greater than expected value of more than $10,000. Three contestants rejected such offers of more than $20,000. This represents a sizeable minority of the sample who exhibit risk-loving behavior with very large stakes.

Figure 1: Distribution of CARA Minimum Upper Bounds

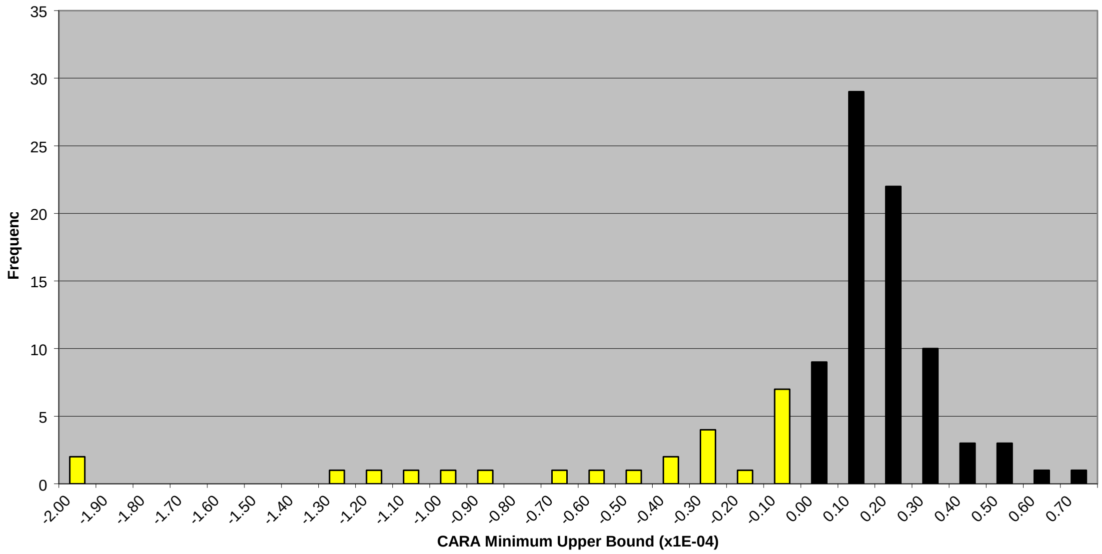
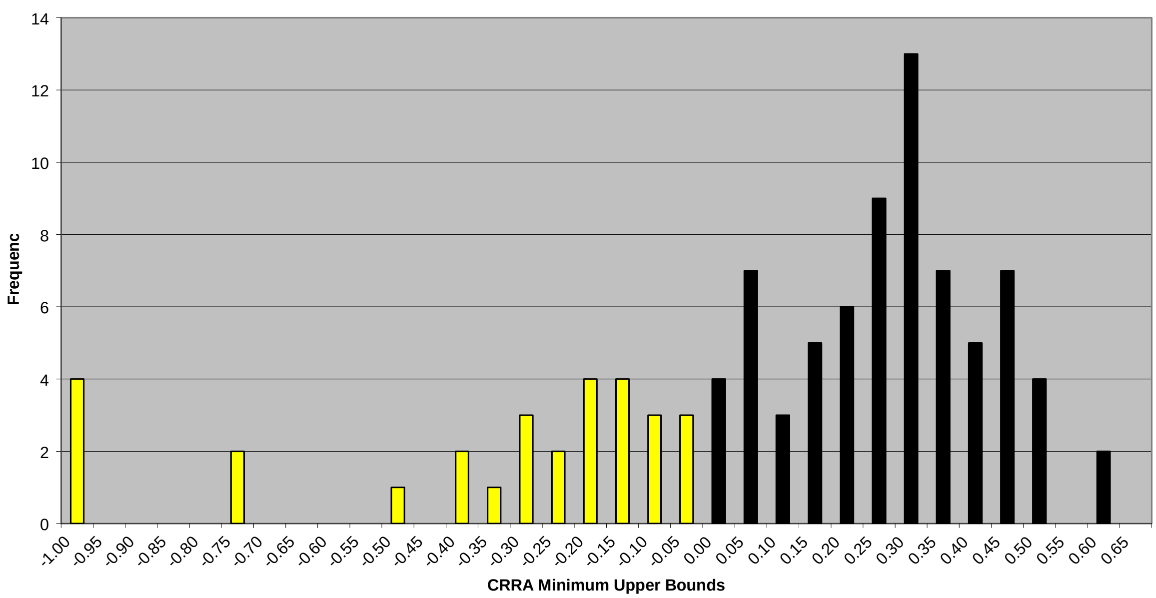


Figure 2: Distribution of CRRA Minimum Upper Bounds (Wealth = \$0)



4.3 Sensitivity of the CRRA Estimates to the Inclusion of Wealth

The CRRA utility function is based upon a person's wealth. Therefore, in order to estimate that parameter in the context of a lottery choice, we would ideally know a person's total wealth after each possible lottery outcome.

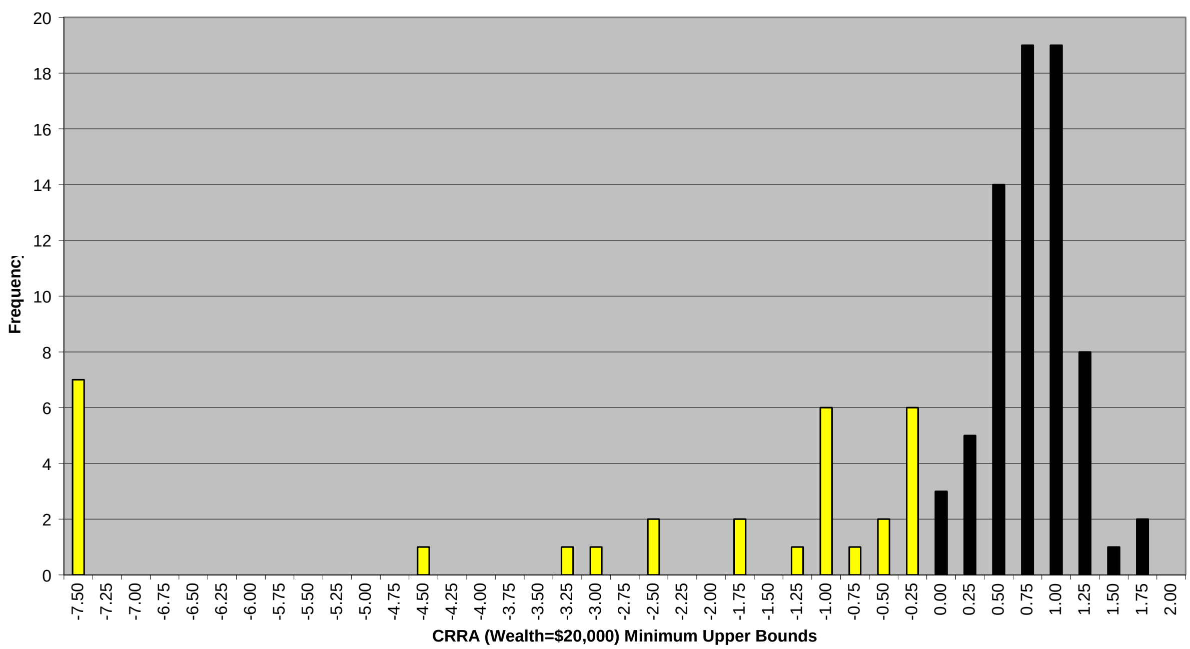
Rabin (2000) shows that if risk aversion arises from the concavity of the utility function, then the presence of risk aversion in low stakes gambles implies implausibly high levels of risk aversion in high stakes gambles. One example that Rabin gives is a risk averse person who turns down a gamble involving a 50% chance of losing $100 and a 50% chance of winning $105 for any level of lifetime wealth less than $350,000. We know nothing about this person's risk aversion for wealth levels above $350,000. We know that, from an initial wealth level of $340,000, the person will turn down a 50-50 bet of losing $4,000 and gaining $635,670.

A similar effect occurs with small stakes gambles and varying wealths levels with CRRA utility. The level of risk aversion necessary to justify the observed behaviour in Deal or No Deal is highly sensitive to wealth levels. Consider a person with a CRRA parameter of -0.5 and wealth of zero. This person will be indifferent between a gamble of ($100, 0.5) and a certain $63. If this person faced the same gamble, but had a wealth level of $100, the person would be indifferent between a gamble of ($100, 0.5) and a certain $54.20. A person with a CRRA parameter of -0.5 and a wealth level of $10,000 would be indifferent between ($100, 0.5) and $50.20.

Now consider it from the perspective of observing behaviour on Deal or No Deal. A person with CRRA utility and zero wealth would be indifferent between $55 and ($100,0.5, $1,0.5) if their risk aversion parameter was -0.15. Choices involving this level of risk are commonly observed on the show. If the person had a wealth level of $1,000, then the risk aversion parameter for indifference between $55 and ($100,0.5, $1,0.5) would need to be -3.89. A wealth level of $10,000 would require a risk aversion parameter of -37.13 for indifference. A similar effect occurs with risk averse people.

We do not have direct data on contestants' wealth levels. However, in order to see how sensitive the CRRA parameters that imply indifference are to wealth, we assume that contestants all have wealth $20,000 before playing the game. The CRRA minimum upper bounds become considerably more divergent, as can be seen from Figure 3. The mean minimum upper bound is now -1.32, even though the same number of people are risk loving as before (since that depends only on whether they have rejected a Bank Offer greater than the expected value of the remaining suitcases). Seven contestants have a CRRA parameter less than -10 when a wealth level of $20,000 is assumed.

Figure 3: Distribution of CRRA Upper Bounds - Wealth = $20,000



4.4 Inconsistency in decision-making

Of the 102 contestants, 11 played the game through to its conclusion without accepting any offers. Therefore, all other contestants rejected at least one Bank Offer and accepted at least one Bank Offer. For these people, the lowest upper bound (which could be thought of as the most generous offer rejected) and the highest lower bound (which could be thought of as the least generous offer accepted) represent a band within which the risk aversion parameter lies.

We define inconsistency as a situation in which a person's lowest upper bound is lower than their highest lower bound. This represents a situation in which a person has accepted an offer that was less generous (in terms of risk) than an offer that they had previously rejected. Twenty-four of the 91 contestants that accepted at least one offer displayed at least one instance of inconsistency in their decision making when the CARA utility function was used to measure risk, while 26 displayed at least one instance of inconsistency when the CRRA functional form was used (with zero wealth). This level of inconsistency is common in field experiments and laboratory experiments involving this type of decision making (see Cameror and Ho (1999)). We take account of this inconsistency in some of our estimations by adopting a model that encompasses noisy decision making.

5 Variation of Risk Aversion with Increasing Stakes

Previous studies have found that risk aversion increases with rising stakes. (see Binswanger 1980, Kachelmeier and Shehata 1992, Holt and Lawry 2002). Our results confirm this. Table 2 shows the results for all rounds, $1 - 9$, of a probit regression where the dependent variable is whether or not a Bank Offer is accepted. The higher is the Bank Offer relative to the expected value of the remaining suitcases, the more likely is the person to accept. The marginal effect of this ratio is 0.36. The standard deviation of the values of the remaining suitcases is not statistically significant.[17] We also found scale effects. The higher is the offer, the more likely is a person to accept. The marginal effect of a change in the offer of $10,000 is 0.05. Of the personal characteristics, only age was statistically significant. The model was better at approximating the effects of age when a quadratic, rather than linear, form was used.

[17] Results not shown. The standard deviation of the values of the remaining suitcases was also not statistically significant in any of the other specifications for which results are reported.

Table 2 also includes results from a panel probit regression where each contestant's decisions are treated as a separate group. The results are robust to the panel specification. The ratio of the offer to expected value remains statistically significant, as do the scale effects. Age remains the only personal characteristic that is statistically significant.

Table 2: Probit Results for Rounds 1-9

	Accept Offer = 1		Accept Offer = 1 Panel Specification		
Independent Variables	Coefficient	z	Coefficient	z	Marginal Effect
Constant	-1.35	-1.90	-1.33	-1.79	
Offer (per \$10,000)	0.295	4.78	0.301	4.60	0.05
Offer/Expected Value Gamble	2.32	11.72	2.36	11.80	0.36
Gender (Male = 1)	0.06	0.42	0.06	0.42	0.01
Age	-0.80	-2.12	-0.81	-2.10	-0.12
Age^2	$8.2E-4$	1.65	$8.3E-4$	1.64	$1.3E-4$
Income (weekly, per \$1,000)	-0.27	-0.34	-0.31	-0.37	-0.04
Obs	720		720		
Groups			99		
Pseudo R^2	35.77				

Gender has been found a significant determinant of risk aversion in most studies in which it was testable. In order to check the robustness of our initial finding with respect to gender, we also included it as an interaction dummy. The results are contained in Table 3. We interact gender with the offer and with the ratio of the offer to the expected value of the remaining suitcases. Males are more likely to have increasing risk aversion as the stakes of the gamble rise. They are also less likely than females to accept an offer for a given ratio between the offer and the expected value (ie to be less risk averse).

Table 3: Probit Results for Rounds 1-9, with Gender Interaction Dummy Variables

	Accept Offer = 1		Accept Offer = 1 Panel Specification		
Independent Variables	Coefficient	z	Coefficient	z	Marginal Effect
Constant	-1.74	-2.59	-1.74	-2.50	
Offer (per \$10,000)	0.218	3.26	0.224	3.22	0.03
Offer/Expected Value Gamble	2.53	10.90	2.58	10.88	0.38
Age	-0.07	-1.83	-0.07	-1.82	-0.01
Age^2	$6.8E-4$	1.35	$7.0E-4$	1.35	$1.0E-4$
Gender*Offer (Male = 1)	0.41	3.10	0.42	3.05	0.62
Gender*Ratio (Male = 1)	-0.31	-1.54	-0.31	-1.49	-0.05
Obs	728		728		
Groups			100		
Pseudo R^2	37.43				

Table 4 shows the likelihood of our model correctly predicting the decision for each observation. Of the 740 offers made, 619 were rejected and 121 accepted. Our model correctly predicts 597 of the rejections (96%) and 46 of the acceptances (38%). This represents a 20% improvement over a baseline model that predicts rejection in all rounds. An alternative benchmark that separately predicts each round individually does no better as there is a greater than 50% chance of accepting in only rounds 8 and 9 and it is only slightly higher than 50% in that round (51% and 52%, respectively).

Table 4: Hit-Miss Table for Rounds 1-9

	Estimated Equation			Constant Probability		
	Dep= 0	Dep= 1	Total	Dep= 0	Dep= 1	Total
P(Dep=1)<=0.5	597	76	672	619	122	740
P(Dep=1)>0.5	22	46	68	0	0	0
Total	619	122	740	619	122	740
Correct	597	46	643	619	0	619
%Correct	96.45	37.70	86.77	100.00	0	83.54
%Incorrect	3.55	62.30	13.23	0	100.00	16.46
Total Gain	-3.55	37.70	3.24			
%Gain		37.70	19.67			

Tables 5 and 6 show the probit results and hit-miss table when the data for estimation is confined to rounds 6-9. Rounds 1-5 are relatively uninformative since the Bank Offers are typically set low enough to ensure rejection. Given that there is only one contestant per show, it is necessary for there to be at least 5 rounds to create a meaningful half hour TV program. Almost all of the interesting choices occur in rounds 6-9.

Focusing on rounds 6-9 reduces the sample size to 236. However, both the ratio of the Bank Offer to the expected value of the remaining suitcases and the size of the Bank Offer remain statistically significant. As before, age is the only statistically significant personal characteristic. The results are once again robust to the panel specification when focusing on the final four rounds. Gender and income remain statistically insignificant.

Our model now correctly predicts 49% of acceptances, although the prediction rate for rejections falls to 81%. Overall, the model represents a 25% improvement over the baseline case in rounds 6-9.

Table 5: Probit Results for Rounds 6-9

	Accept Offer = 1		Accept Offer = 1 Panel Specification		
Independent Variables	Coefficient	z	Coefficient	z	Marginal Effect
Constant	0.33	0.32	0.36	0.34	
Offer (per $10,000)	0.165	2.45	0.168	2.37	0.6
Offer/Expected Value Gamble	1.29	5.16	1.35	5.34	0.51
Gender (Male = 1)	−0.022	−0.12	−0.022	−0.12	−0.009
Age	−0.10	−1.94	−0.10	−1.84	−0.039
Age^2	0.0012	1.71	0.0012	1.61	$4.7E-4$
Income (weekly, per $1,000)	−0.14	−0.13	−0.25	−0.23	−0.53
Obs	230		230		
Groups			89		
Pseudo R^2	11.64				

Table 6: Hit-Miss Table for Rounds 6-9

	Estimated Equation			Constant Probability		
	Dep=0	Dep=1	Total	Dep=0	Dep=1	Total
P(Dep=1)<=0.5	108	51	159	134	103	237
P(Dep=1)>0.5	26	52	78	0	0	0
Total	134	103	237	134	103	237
Correct	108	52	160	134	0	134
%Correct	80.60	50.49	67.51	100.00	0	56.54
%Incorrect	19.40	49.51	32.63	0	100.00	43.46
Total Gain	−19.40	50.49	10.97			
%Gain		50.49	25.24			

The results in Table 7 include interaction dummies with gender for rounds 6-9. The interaction dummies remain statistically significant and once again indicate that males are more likely to become risk averse as the stakes increase but that males are also less likely than females to be swayed by a positive bank offer-expected value ratio. The explanatory power of the model increases with the inclusion of the dummy interaction variables with the R-squared increasing from 11.64 to 15.32 (ie comparing Tables 5 and 7, both of which deal with Rounds 6-9).

Table 7: Probit Results for Rounds 6-9 With Gender Interaction Dummy Variables

	Accept Offer = 1		Accept Offer = 1 Panel Specification		
Independent Variables	Coefficient	z	Coefficient	z	Marginal Effect
Constant	−0.08	−0.09	−0.08	−0.09	
Offer (per $10,000)	0.103	1.48	0.104	1.50	0.41
Offer/Expected Value Gamble	1.55	5.41	1.57	5.43	0.61
Age	−0.09	−1.73	−0.09	−1.72	−0.04
Age^2	0.001	1.51	0.001	1.49	$4.2E-4$
Gender*Offer	0.61	3.10	0.61	2.97	0.24
Gender*Ratio	−0.42	−1.98	−0.42	−1.96	−0.16
Obs	233		233		
Groups			90		
R-squared	15.32				

6 Testing Prospect Theory

6.1 Description of Theory

Prospect theory asserts that people will generally be risk averse in lottery choices involving gains and risk seeking in lottery choices involving losses. In particular, prospect theory suggests a utility function that is (i) defined on deviations from the reference point (not on overall wealth); (ii) is concave for gains and convex for losses; and (iii) is steeper for losses than gains. This results in the well known s-shaped utility function.

In the Chance and SuperCase rounds, the framing of the choice faced by the contestant changes. In rounds 1-9, the contestant chooses whether or not to swap his/her right to a lottery for a sure amount of money. The contestant "owns" the right to keep removing suitcases until only the suitcase initially nominated remains and to receive Bank Offers after each round of this process. Each time a Bank Offer is made, the contestant is being asked to sell this lottery.

In the Chance and SuperCase rounds, the choice is reversed. Specifically, the contestant has already accepted a Deal and is being asked to swap his/her sure winnings for a gamble. In other words, the contestant is now being asked to buy a new lottery. If the contestant's current winnings become the reference point (as suggested by prospect theory), then accepting either the Chance or SuperCase will mean accepting a positive probability of suffering a loss relative to the reference point and a positive probability of enjoying a gain relative to the reference point. Specifically, consider the Chance round in which a person will face a choice between the 2 remaining suitcases or a sure amount of money. The Chance round is only offered when the values in the 2 remaining suitcases are highly divergent, with one being considerably higher than the previously agreed Deal and one considerably lower. In the Chance round, the contestant chooses between a 50-50 chance of losing or gaining relative to the reference position vs the status quo. A person with an s-shaped utility function that is steeper for losses than gains will be less likely to accept a Chance round (or SuperCase) gamble.

6.2 Summary of the Chance and SuperCase Rounds

Of the 102 episodes in our sample, the Chance (SuperCase) round appeared in 20 (24) of them. Table 8 presents a summary of the Chance rounds in our sample. When the Chance round appeared, the mean value of the already accepted deal was $9,824. The minimum previously accepted deal was $480 and the highest $44,200. The mean of the two remaining suitcases was almost always higher than the previously accepted deal - usually considerably higher. The mean of the two suitcases in the 20 Chance rounds was $18,229, almost double the mean of the prize that the contestants had already won. Notwithstanding this, in only 7 Chance rounds was the suitcase gamble accepted.

Table 8: Chance Round Summary

Deal Previously Accepted	Expected Value of Remaining Cases	Remaining Suitcases		Option chosen by contestant Chance/Certain Amount	Prize Won
$11,200	$25,000	$50,000	$1	**Chance**	$1
$14,760	$17,500	$25,000	$10,000	**Chance**	$10,000
$44,200	$50,000	$100,000	$10	Certain Amount	$44,200
$8,230	$12,875	$25,000	$750	**Chance**	$25,000
$6,800	$8,500	$15,000	$2,000	**Chance**	$2,000
$17,700	$52,500	$100,000	$5,000	**Chance**	$100,000
$10,000	$12,625	$25,000	$250	Certain Amount	$10,000
$7,380	$25,375	$50,000	$750	Certain Amount	$7,380
$15,150	$37,505	$75,000	$10	Certain Amount	$15,150
$9,990	$37,500	$75,000	$1	Certain Amount	$9,990
$4,500	$6,000	$10,000	$2,000	**Chance**	$2,000
$14,999	$37,510	$75,000	$25	Certain Amount	$14,999
$1,200	$1,010	$2,000	$25	Certain Amount	$1,200
$3,999	$4,250	$7,500	$1,000	Certain Amount	$3,999
$1,000	$1,040	$2,000	$75	Certain Amount	$1,000
$14,730	$25,025	$50,000	$50	**Chance**	$50
$1,100	$1000	$2,000	$1	Certain Amount	$1,100
$480	$378	$750	$5	Certain Amount	$480
$8,000	$7,510	$15,000	$25	Certain Amount	$8,000
$1,010	$1,505	$3,000	$10	Certain Amount	$1,000

In the Supercase round (in unreported results), we observe the mean value of the previously accepted deal was \$8,750, with a minimum of \$2,100 and a maximum of \$17,800. The mean and standard deviation of the SuperCase is \$8,510 and \$11,000, respectively. In only 10 SuperCase rounds was the SuperCase chosen.

6.3 The Effect of Chance and SuperCase Rounds on Willingness to Accept

Tables 9 and 10, in the context of our Probit model, show the impact of the Chance and SuperCase rounds on the willingness of a contestant to accept an offer. In the Chance and Supercase rounds, the offer represents the status quo. When the loss function is steeper than the gain function (as it is in the s-shaped utility function posited by Kahnemann and Tverskey), it will make a contestant unlikely to accept a gamble in the Chance or Supercase rounds if the prize already won becomes the reference point.

This is unlikely to arise from the concavity of the contestant's utility function since contestants verge on risk neutral on average in our sample, with a relatively high proportion displaying risk loving behaviour. Further, in probit regressions, dummies for the Chance and Supercase rounds are highly statistical significant, with the dummies having a high marginal effect. This suggests that contestants become much more prone to rejecting the gamble in the Chance and Supercase rounds which is consistent with a steep loss function.

Table 9 contains the results of a Probit for rounds 1-9 that includes dummies for whether the decision is made during a Chance or Supercase round. A further variable, "high cases remaining" is also included. The highcase variable is the proportion of remaining suitcases that are higher than that round's Bank Offer. This captures a possible rule of thumb - that the contestant takes account of how many remaining suitcases are above the Bank Offer for that round. This game has a dynamic component. A contestant who rejects an offer does so knowing that s/he will receive another offer at the end of the next round of play. The degree to which the next offer could potentially fall will depend upon the skewness of the remaining prizes. For example, consider a contestant who has been made a Bank Offer in a later round and need only remove one suitcase if s/he decides to reject the offer. If only one high suitcase remains, then the contestant faces a $1/n$ chance of losing that suitcase - but eliminating that suitcase would result in a significantly lower Bank Offer at the end of the round. In contrast, if the remaining prizes have a more even distribution and there are several high values, then the contestant faces a higher chance of choosing one of those suitcases, but smaller decrease in the next Bank Offer should that occur. The highcases variable is significant at the one percent level in both the probit using data from all 9 rounds and the probit using data from rounds 6-9 (Table 11). As expected, the marginal effect of this variable is higher in rounds 6-9.

The Chance and Supercase dummy variables and the highcase variable are all statistically significant at the one percent level. Further, the Chance and Supercase dummies have a high marginal effect. Males are less likely to accept an offer in the Chance and Supercase rounds (ie more likely to take the gamble by giving up their already won prize) and are also less likely to be affected by the high case rule of thumb.

Table 10 compares the predictive power of the model against the benchmark. The model performs considerably better than the model in the previous section, correctly predicting 54% of acceptances and representing an overall 34% improvement on the benchmark model.

Table 9: Probit Results Incorporating the Chance and SuperCase Rounds for Rounds 1-9

	Accept Offer = 1		Accept Offer = 1 Panel Specification		
Independent Variables	Coefficient	z	Coefficient	z	Marginal Effect
Constant	-1.66	-2.12	-1.66	-2.23	
Offer (per $\$10,000$)	0.38	4.45	0.37	4.29	0.04
Offer/Expected Value Gamble	3.14	9.94	3.08	9.79	0.32
CHANCE dummy	2.78	5.38	2.76	5.22	0.81
SuperCase dummy	4.06	4.18	4.01	4.11	0.95
High Cases/Cases Remaining	-2.54	-2.84	-2.51	-2.69	-0.26
Age	-0.08	-1.86	-0.08	-1.89	-0.008
Age^2	$7.4E-4$	1.27	$7.4E-4$	1.30	$7.8E-5$
Gender*Offer (Male = 1)	0.27	1.80	0.26	1.87	0.03
Gender*Ratio (Male = 1)	-0.67	-2.10	-0.64	-2.04	-0.07
Gender*Chance (Male = 1)	-1.65	-2.42	-1.62	-2.37	-0.05
Gender*SC (Male = 1)	-2.39	-2.02	-2.30	-1.96	-0.05
Gender*HighcaseRemaining (Male= 1)	1.84	1.84	1.77	1.74	0.18
Obs	728		728		
Groups			100		
Pseudo R^2	48.32				

Table 10: Hit-Miss Table Incorporating the Chance and SuperCase Rounds for Rounds $1-9$

	Estimated Equation			Constant Probability		
	Dep= 0	Dep= 1	Total	Dep= 0	Dep= 1	Total
P(Dep=1)<= 0.5	594	56	650	619	122	741
P(Dep=1)> 0.5	25	66	91	0	0	0
Total	619	122	741	619	122	741
Correct	594	66	660	619	0	619
%Correct	95.96	54.10	89.07	100.00	0	83.54
%Incorrect	4.04	45.90	10.93	0	100.00	16.46
Total Gain	-4.04	54.10	5.53			
%Gain		54.10	33.61			

Tables 11 and 12 test the same model as outlined in Tables 9 and 10, but using data from rounds 6-9. As discussed, almost all of the difficult choices faced by contestants are in rounds 6-9. Once again, most variables are statistically significant at the one percent level and the Chance and Supercase dummies have a high marginal effect. Even though the sample size is considerably reduced when focusing on rounds 6-9, the significance of the gender-interaction variables is as high as in the full sample probit. The results in Table 11 are robust to panel specification.

As shown in Table 12, the model now correctly predicts almost 70% of acceptances and, notwithstanding the loss of accuracy on the rejections, represents a 44% overall improvement on the benchmark. In unreported results, when the model is applied to rounds 7-9, where contestants have an approximately 50% chance of accepting, the model correctly predicts 75% of acceptances.

Table 11: Probit Results Incorporating the Chance and SuperCase Rounds for Rounds $6-9$

	Accept Offer = 1		Accept Offer = 1 Panel Specification		
Independent Variables	Coefficient	z	Coefficient	z	Marginal Effect
Constant	-0.73	-0.69	-0.70	-0.73	
Offer	0.25	2.89	0.24	3.01	0.09
Offer/Expected Value Gamble	2.34	6.13	2.10	5.85	0.90
CHANCE dummy	2.18	4.18	2.16	4.16	0.59
SuperCase dummy	3.01	3.01	3.07	3.17	0.66
High Cases/Cases Remaining	-2.04	-2.09	-2.17	-2.29	-0.81
Age	-0.08	-1.45	-0.07	-1.44	-0.03
Age^2	$8.6E-4$	1.12	$7.7E-4$	1.14	$3.6E-4$
Gender*Offer (Male = 1)	0.42	2.05	0.40	2.09	0.019
Gender*Ratio (Male = 1)	-0.70	-2.06	-0.68	-2.17	-0.28
Gender*Chance (Male = 1)	-1.60	-2.38	-1.53	-2.28	-0.33
Gender*Supercase (Male = 1)	-2.17	-1.78	-2.04	-1.77	-0.47
Gender*High Cases Remaining (Male= 1)	1.68	1.56	1.66	1.62	0.65
Obs	233		233		
Groups			90		
Pseudo R^2	25.67				

Table 12: Hit-Miss Table Incorporating the Chance and SuperCase Rounds for Rounds 6-9

	Estimated Equation			Constant Probability		
	Dep= 0	Dep= 1	Total	Dep= 0	Dep= 1	Total
P(Dep=1)<= 0.5	107	31	138	134	103	237
P(Dep=1)> 0.5	27	72	99	0	0	0
Total	134	103	237	134	103	237
Correct	107	72	179	134	0	134
%Correct	79.85	69.90	75.53	0	100.00	56.54
%Incorrect	20.15	30.10	24.47	100.00	0	43.46
Total Gain	−20.15	69.90	18.99			
%Gain			43.69			

7 Risk Aversion Estimates

To model risk aversion behavior in their sample of lottery choice participants, Holt and Laury (2002) use a power-expo utility function with a noise parameter, μ.[18] They define the probability of choosing one of two options as being the ratio of the utility levels from that option compared to the sum of the utility of the two options (ie the risky and the non-risky):

$$Pr(ChooseOptionA) \ = \frac{U_A^{1/\mu}}{U_A^{1/\mu} + U_B^{1/\mu}} \tag{3}$$

The noise parameter indicates how far from a fifty-fifty choice the person will be for any given difference in U_A and U_B. The higher is μ, the more likely is the person to choose the option with the higher utility.

In performing this estimation, we use either: (a) the actual decisions made by each contestant j in each round; or (b) the probability of contestant j in round r choosing accept from the earlier probits. Therefore, we have an equation based on either the actual

[18] This follows Duncan Luce (1959).

decision or our probit estimates (probhat) for each round of each contestant, with BO_r = bank offer and $SC_{i,r}$ being suitcase i of n_r total suitcases:

$$PRobHat_{j,r}\ orDecision_{j,r} = \frac{\left(\frac{1}{n}\sum_{i=1}^{n_r}\frac{1-\exp(-\alpha * SC_{i,r}^{1-q})}{\alpha}\right)^{1/\mu}}{\left(\frac{1}{n}\sum_{i=1}^{n_r}\frac{1-\exp(-\alpha * SC_{i,r}^{1-q})}{\alpha}\right)^{1/\mu} + \left(\frac{1-\exp(-\alpha * BO_r^{1-q})}{\alpha}\right)^{1/\mu}} + \epsilon_{i,r} \quad (4)$$

where $\epsilon_{i,r}$ is the error for person j in round r. We have 740 observations (ie 740 contestant/round decisions) and, therefore, 740 equations, with 3 parameters to estimate: the noise parameter μ, and the two power-expo parameters α and q.

When the LHS variable is the actual decision, the MLE estimates are $\alpha = 0.00000001$, $q = -0.26$, $\mu = 0.45$. As α approaches zero, the power-expo utility function, as normalized, will approach CRRA, with q being the coefficient of relative risk aversion. Therefore, our MLE estimates with noise indicate risk loving behaviour, on average. When the LHS variable is probhat, then the MLE estimates are $\alpha = 0.00000001$, $q = -0.11$, $\mu = 0.30$.

We also calculated MLE estimates using the CRRA utility function rather than the power-expo utility function. Using the CRRA with the noise-estimation function is well-defined where $\gamma < 1$, since the CRRA function is positive over this range.[19] Given that contestants are not highly risk averse, the MLE estimate falls within this range. The MLE estimates using the CRRA utility function when the LHS is probhat, are: $\gamma = -0.19$, $\mu = 0.375$. When the LHS is the actual decision (accept = 1), the estimates are: $\gamma = 0.01$, $\mu = 0.425$.

8 Dynamic Issues

There are two elements to the contestant's decision that have a dynamic aspect. The first of these dynamic elements will bias our estimates towards being too risk-loving. The second element will have an offsetting effect.

[19] If the value of the utility function is negative, it would not be possible to raise it to the power of $1/\mu$.

The first dynamic element of a contestant's decision-making is that the contestant trades off this round's bank offer against the possibility of a higher bank offer in the following round. The true trade-off faced by the contestant is not between the current Bank Offer and the remaining suitcases but, rather, between this round's offer and the contestants expectation of next round's offer (and the offers in all following rounds). This will depend not just on the distribution of the remaining suitcases, but also on the contestant's expectations of the behaviour of the bank conditional on each possible combination of suitcases in following rounds. To the contestant, this will be a stochastic variable.

Table 13 contains two regressions that seek to explain the bank's offer by the distribution of the remaining suitcases and the round of play. As expected, the bank offer increases with the expected value of the remaining suitcases. In the sample as a whole, an increase in the standard deviation of the remaining suitcases reduces the offer, but it increases it in rounds 6-9. This positive relationship between the bank's offer and the standard deviation holds true for each of rounds 6-9 individually. Of the individual characteristics, only age is statistically significant.

The round of play is significant, both in the sample as a whole and in rounds 6-9. This premium from continuing to play may explain part of the contestants' willingness to bear risk.

Table 13: Determinants of the Bank's Offer

	Rounds 1-9		Rounds 6-9	
	Coefficient	t-statistic	Coefficient	t-statistic
Constant	−8275.62	−8.54	−8232.78	−2.93
Expected value	0.71	26.73	0.56	13.67
Standard deviation	−0.06	−3.66	0.13	4.35
Round	1512.76	19.38	1086.43	3.48
Age	38.90	2.62	41.82	0.87
Gender	295.99	0.99	549.67	1.35
Income	−2.28	−1.34	−0.35	−0.10
Obs	720		230	
R-Squared	0.85		0.91	

Table 14 contains the average of the ratio of the bank offer to the expected value of the remaining suitcases by round. As expected, the ratio increases in later rounds as the offers become more tempting.

Table 14: Ratio of the Bank Offer to the EV of Remaining Cases

Round	Ratio of the Bank Offer to the Expected Value of the Remaining Cases				
	Obs	Mean	St Dev	Minimum	Maximum
1	102	0.17	0.09	0.01	0.48
2	102	0.31	0.10	0.09	0.72
3	102	0.41	0.16	0.14	1.08
4	101	0.57	0.17	0.16	1.04
5	97	0.72	0.24	0.29	2.09
6	91	0.88	0.28	0.27	1.82
7	73	1.07	0.44	0.07	2.18
8	49	1.10	0.46	0.25	2.17
9	23	1.03	0.28	0.60	1.63

Table 14 confirms the "round premium" effect described in Table 13. The ratio of the Bank Offer to the expected value of the remaining suitcases rises in each successive round, except between rounds 8 and 9. For rounds 7,8 and 9, the ratio of the Bank Offer to the expected value of the remaining case is, on average, greater than one. This round premium effect will make contestants less likely to accept a given Bank Offer, all other things equal. Therefore, this will bias our estimates of contestants' risk aversion downwards, making them appear less risk averse than they really are.

We test for this by recalculating the MLE estimates contained in section 7 by scaling up the value in the remaining suitcases in the early rounds so as to reflect the fact that offers in future rounds will be more generous, on average, than in the current round. Offers in future rounds will still be based on the future distribution of suitcases and, therefore, on the current distribution of suitcases. However, the current value of current suitcases is higher than is reflected in the current round offer, given the round premium. In effect, it is as though the each suitcase that remains in the current round contains more than its face value.

To calculate how much to increase the current value of suitcases, we construct a weighted average of future round premiums given how likely the contestant is to progress to each future round, on average. For example, of contestants playing Round 1, 97 will progress to Round 5, 91 to Round 6 and so on. This hazard rate can be combined with the average increase in the ratio of the offer to the expected value of the remaining suitcases to arrive at how much the contestant can expect that ratio to increase, based on their likelihood of progressing to each round. The adjustment factors for each round are:

- Round 1, 5.82;
- Round 2, 3.19;
- Round 3, 2.41;
- Round 4, 1.77;
- Round 5, 1.43;
- Round 6, 1.21; and
- Round 7, 1.02.

After having scaled the remaining suitcases for each contestant and each round, we obtain new MLE estimates for the CRRA parameters. Where the LHS variable is probat, we obtain: $\gamma = -0.14$ (as compared to $\gamma = -0.19$ without the scaling) and $\mu = 0.425$. When the LHS is the actual decision, we obtain: $\gamma = 0.06$ (compared to $\gamma = 0.01$ without the scaling) and $\mu = 0.40$. As expected, contestants appear more risk averse when this round premium effect is included.

Somewhat suprisingly, including the round premium effect has quite a small impact on the parameter estimates. This is attributable to the fact that vast majority of difficult decisions are faced in rounds $7-9$, when the round premium effect has largely become irrelevant. The ratio of the offer to the expected value of the remaining suitcases rises to 1.07 in round 7, and stays at that level for the final three rounds. Most of the risk-loving decisions that we witness are taken in these final three rounds and, therefore, this adjustment does not affect their impact on the parameters.

The second dynamic aspect of the contestant's decision relates to the possibility of a Chance or SuperCase appearing. This offsets the bias introduced by the first dynamic aspect of contestants' decision-making. In later rounds, the chance and supercase rounds act as "insurance", making any given "Deal" more enticing. This offsets the first dynamic aspect of the contestant's decision, making the contestant more willing to accept low offers. Therefore, this effect will result in our earlier calculations of the risk aversion necessary for indifference to be too high (ie not risk loving enough). A simple example illustrates this point.

Consider a risk-neutral contestant in the penultimate round of play. Let us assume that in this example, the contestant knows that the bank offer in each round will be the expected value of the remaining suitcases. The contestant faces three suitcases: ($50,000; $200, $100). First, consider the contestant's behaviour if there is no chance round. If the contestant plays on, she has a 1/3 chance of each of the following pairs: ($50,000; $100), ($50,000, $200) and ($200, $100). These pairs have expected values of $25,100; $25,050 and $150 respectively - for an overall expected value of $16,800. In this situation, a risk-neutral contestant will be indifferent between playing on and a Bank Offer of $16,800 (= the expected value of the remaining cases).

Now, consider the situation in which there is a probability, p, of the Chance round being offered if the two remaining suitcases (ie after the Deal has been accepted and s/he has "hypothetically" removed one more case) are highly divergent with a mean greater than the accepted bank offer. This is precisely the situation in which the Chance round is offered. Now, if the contestant opts for "No Deal" and plays on, she faces the following prospect:

$$\frac{1}{3} * (\$50,000, 0.5; \$100, 0.5) + \frac{1}{3} * (\$50,000, 0.5; \$200, 0.5) + \frac{1}{3} * (\$200, 0.5; \$100, 0.5) \quad (5)$$

As before, the expected value of playing on is $\$16,800$. The expected value of accepting any offer less than $\$25,000$ is higher now. Suppose the contestant is offered $\$x < \$16,800$. If she accepts $\$x$, she now faces the following prospect.

$$p * \frac{1}{3} * (\$50,000, 0.5; \$200, 0.5) + p * \frac{1}{3} * (\$50,000, 0.5; \$100, 0.5) + \left[\frac{2(1-p)+1}{3}\right] * \$x \quad (6)$$

In other words, the contestant has p probability of being offered the chance round if she draws either ($50,000, $100) or ($50,000, $200). If not, she is left with $\$x$. The probability of being left with $\$x$ is $\frac{2(1-p)+1}{3}$. The higher is p, the lower $\$x$ needs to be to make accepting the deal worthwhile. For example, if $p = 1/2$, then a risk neutral contestant will be willing to accept $\$12,700$ (as opposed to $\$16,800$ without chance insurance). More starkly, if $p = 1$, then the contestant will accept any offer greater than $150.

9 Conclusion

This paper presents results of a simple lottery-choice for a game show that allows us to measure the degree of risk aversion in a context of both very high and wide-ranging (possible) payoffs. In addition, a feature of the game is especially convenient for testing non-expected utility theories relating to loss aversion and other reference point theories.

Using their decisions during the course of an episode, we are able to construct bounds for each conestant's CRRA and CARA risk aversion parameters. We find that, on average, the upper bounds for contestants' CRRA parameter are 0.06 and for the CARA paramter are -7.8E-06. These results are supported by MLE estimates based on a model that introduces noise into contestants' decisions. We calculate MLE estimates with both the CRRA and the power-expo utility functions. Even with adjustments for selection, for the dynamic nature of the game, and for the possible insurance aspect that an end-feature of the game might provide contestants (the 'Chance' or 'SuperCase' rounds), our estimates are still considerably lower than what is reported in the literature in a variety of contexts (other game shows, experiments, empirics with finance data).

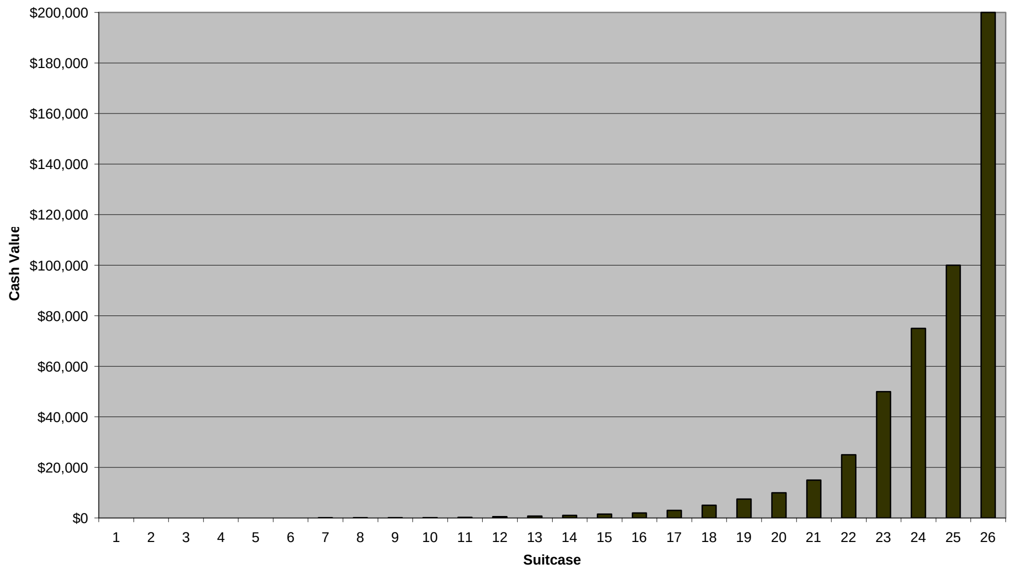
In addition to finding a low mean level of risk aversion, we find a high degree of heterogeneity. Of the 56 people that receive at least one Bank Offer greater than the expected value of the remaining suitcases, 33 reject at least one of those offers. These risk-loving decisions are not confined to low stakes gambles. The mean Bank Offer greater than expected value that is rejected is $6,000. Moreover, eight people reject at least one offer greater than expected value of more than $10,000. A significant minority of our sample displays risk-loving behavior with high stakes gambles.

Like Holt and Laury (2002), we confirm that risk aversion is increasing in the stakes of the lottery, and our results are consistent with standard calibrations of expected utility theory (and with non-expected utility theories, for that matter).

Finally, we are able to exploit a special feature of the game show that sometimes appears at the final decision-stage and which reverses the choice faced by contestants up till that time - instead of being offered a sure thing in exchange for a lottery, contestants who are entitled to end the show with money already earned are offered a lottery in exchange for that sure-thing. We find that the reversal of framing has a significant impact on people's willingness to bear risk, and that their high level of risk aversion during the Chance and SuperCase rounds is consistent with Prospect Theory.

A Appendix

Schedule of prizes: $0.50; $1; $2; $5; $10; $25; $50; $75; $100; $150; $250; $500; $750; $1,000; $1,500; $2,000; $3,000; $5,000; $7,500; $10,000; $15,000; $25,000; $50,000; $75,000; $100,000; $200,000.



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