Deal or No Deal?

Decision making under risk in a large-payoff game show

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Abstract

We examine the risky choices of contestants in the popular TV game show "Deal or No Deal" and related classroom and laboratory experiments. Contrary to the traditional view of expected utility theory, the choices can be explained in large part by previous outcomes experienced during the game. Risk aversion decreases after earlier expectations have been shattered by unfavorable outcomes or surpassed by favorable outcomes. Our results point to reference-dependent choice theories such as prospect theory, and suggest that path-dependence is relevant, even when the choice problems are simple and well-defined and large real monetary amounts are at stake.

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A WIDE RANGE OF THEORIES OF RISKY CHOICE have been developed, including the normative expected utility theory of von Neumann and Morgenstern and the descriptive prospect theory of Kahneman and Tversky (1979). Although risky choice is fundamental to virtually every branch of economics, empirical testing of these theories has proven to be difficult.

Many of the earliest tests such as those by Allais (1953), Ellsberg (1961) and the early work by Kahneman and Tversky were based on either thought experiments or answers to hypothetical questions. With the rising popularity of experimental economics, risky choice experiments with real monetary stakes have become more popular, but because of limited budgets most experiments are limited to small stakes. Some experimental studies try to circumvent this problem by using small nominal amounts in developing countries, so that the subjects face large amounts in real terms; see, for example, Binswanger (1980, 1981) and Kachelmeier and Shehata (1992). Still, the stakes in these experiments are typically not larger than one month's income and thus do not provide evidence about risk attitudes regarding prospects that are significant in relation to lifetime wealth.

Non-experimental empirical research is typically plagued by what amount to "joint hypothesis" problems. Researchers cannot directly observe risk preferences for most real-life problems, because the true probability distribution is not known to the subjects and the subject's beliefs are not known to the researcher. For example, to infer the risk attitudes of investors from their investment portfolios, one needs to know what their beliefs are regarding the joint return distribution of the relevant asset classes. Were investors really so risk averse that they required an equity premium of 7 percent per year, or were they surprised by unexpectedly many favorable events or worried about catastrophic events that never occurred? An additional complication arises because of the difference between risk and uncertainty: real-life choices rarely come with precise probabilities.

In order to circumvent these problems, some researchers analyze the behavior of contestants in TV game shows, for example "Card Sharks" (Gertner, 1993), "Jeopardy!" (Metrick, 1995), "Illinois Instant Riches" (Hersch and McDougall, 1997), "Lingo" (Beetsma and Schotman, 2001), "Hoosier Millionaire" (Fullenkamp *et al.*, 2003) and "Who Wants to be a Millionaire?" (Hartley *et al.*, 2005). The advantage of game shows is that the amounts at stake are larger than in experiments and that the decision problems are often simpler and better defined than in real life.

The game show we use in this study, "Deal or No Deal", has such desirable features that it almost appears to be designed to be an economics experiment rather than a TV show. We will describe the rules of the game in detail later, but here is the essence of the game. A contestant is shown 26 briefcases that each contain a hidden amount of money, ranging from €0.01 to €5,000,000 (in the Dutch edition). The contestant picks one of the briefcases and then owns its unknown contents. Next, she selects 6 of the other 25 briefcases to open. Each opened briefcase reveals one of the 26 prizes that are *not* in her own briefcase. The contestant is then given a "bank offer" - the opportunity to walk away with a sure amount of money - and asked the simple question: "Deal or No Deal?" If she says "No Deal", she has to open five more briefcases, followed by a new bank offer. The game continues in this fashion until the contestant either accepts a bank offer, or rejects all offers and receives the contents of her own briefcase. The bank offers depend on the value of the unopened briefcases; if the contestant opens high-value briefcases, the bank offer falls.

This game show seems well-suited for analyzing risky choice. The stakes are very high and wide-ranging: contestants can be sent home as multimillionaires or practically empty-handed. Unlike other game shows, "Deal or No Deal" involves only simple stop-go decisions ("Deal" or "No Deal") that require minimal skill, knowledge or strategy, and the probability distribution is simple and known with near-certainty. Finally, the game show involves multiple game rounds, and consequently seems particularly interesting for analyzing path-dependence, or the role of earlier outcomes. Thaler and Johnson (1990) conclude that risky choice is affected by prior outcomes in addition to incremental outcomes due to decision makers incompletely adapting to recent losses and gains. Although "Deal or No Deal" contestants never have to pay money out of their own pockets, they can suffer significant "paper" losses if they open high-value briefcases (causing the expected winnings to fall), and such losses may influence their subsequent choices.

We examine the games of 151 contestants from the Netherlands, Germany and the US in 2002-2007. The game originated in the Netherlands (and these original episodes formed the basis of the first analysis of the game in our initial draft), and is now broadcast around the world. Although the game format of "Deal or No Deal" is generally similar across all editions, there are some noteworthy differences. For example, in the daily versions from Italy, France and Spain, the banker knows the amounts in the briefcases and may make informative offers, leading to strategic interaction between the banker and the contestant. In the daily edition from Australia, special game options known as "Chance" and "Supercase" are sometimes offered at the discretion of the game-show producer after a contestant has made a "Deal". These options would complicate our analysis, because the associated probability distribution is not known, introducing a layer of uncertainty in addition to the pure risk of the game. For these reasons, we limit our analysis to the games played in the Netherlands, Germany and the United States. However, several other research groups have started investigating editions from other countries, including Australia (Mulino *et al.*, 2006; De Roos and Sarafidis, 2006), Italy (Bombardini and Trebbi, 2005; Blavatskyy and Pogrebna, 2006a, b), Mexico (Deck *et al.*, 2006) and the UK (Andersen *et al.*, 2006). These papers have different foci than ours and provide complimentary analyses of this interesting game.

The three editions we use have a very similar game format, apart from substantial variation in the amounts at stake. While the average prize that can be won in the Dutch edition is roughly €400,000, the averages in the German and US edition are roughly €25,000 and €100,000, respectively. At first sight, this makes the combined data set useful for separating the effect of the stakes on risky choice from the effect of prior outcomes; within one edition, prior outcomes are strongly confounded with stakes. However, cross-country differences in culture, wealth and contestant selection procedure may confound the effect of stakes across the three editions. To analyze the isolated effect of stakes on risky choice, we conduct a series of classroom and laboratory experiments with a homogeneous student population. The experiments also shed some light on the effect of the distress of decision making in the limelight.

The findings of our analysis are difficult to reconcile with expected utility theory. The contestants' choices appear to be driven in large part by the previous outcomes experienced during the game. Risk aversion seems to decrease after earlier expectations have been shattered by opening high-value briefcases, consistent with a "break-even effect". Similarly, risk aversion seems to decrease after earlier expectations have been surpassed by opening low-value briefcases, consistent with a "house-money effect".

The orthodox interpretation of expected utility of wealth theory does not allow for these effects, because subjects are assumed to have the same preferences for a given choice problem irrespective of the path traveled before arriving at this problem. Our results point in the direction of reference-dependent choice theories, such as prospect theory, and indicate that path-dependence is relevant, even when large real monetary amounts are at stake. We therefore explore a version of prospect theory with a path-dependent reference point as an alternative to expected utility theory.

Of course, we must be careful with rejecting expected utility theory and embracing alternatives like prospect theory. We find that the standard implementation of expected utility theory is unable to explain the choices of losers and winners. A better fit could be achieved with a nonstandard utility function that has risk seeking segments and depends on prior outcomes. Therefore, this study does not reject or accept any theory. Rather, our main finding is the important role of reference-dependence and path-dependence, phenomena that are not standard in typical implementations of expected utility but are common in prospect theory.

The remainder of this paper is organized as follows. In Section I, we describe the game show in greater detail. Section II discusses our data material. Section III provides a first analysis of the risk attitudes in "Deal or No Deal" by examining the bank offers and the contestants' decisions to accept ("Deal") or reject ("No Deal") these offers. Section IV analyzes the decisions using expected utility theory with a general, flexible-form expo-power utility function. Section V analyzes the decisions using prospect theory with a simple specification that allows for partial adjustment of the subjective reference point that separates losses from gains. This specification explains a material part of what expected utility theory leaves unexplained. Section VI reports results from a series of classroom and laboratory experiments in which students play "Deal or No Deal". The experiments confirm the important role of previous outcomes and suggest that the isolated effect of the amounts at stake is limited and that our results are not driven by the distress of decision making in the limelight. Finally, Section VII offers concluding remarks and suggestions for future research.

I. Description of the game show

The TV game show "Deal or No Deal" was developed by the Dutch production company Endemol and was first aired in the Netherlands in December 2002. The show soon became very popular and was exported to dozens of other countries, including Germany and the US. The following description applies to the Dutch episodes of "Deal or No Deal". Except for the monetary amounts, the episodes from the German and US editions used in this study have a similar structure.

Each episode consists of two parts: an elimination game based on quiz questions in order to select one finalist from the audience and a main game in which this finalist plays "Deal or No Deal". Audience members have not been subject to an extensive selection procedure: players in the national lottery sponsoring the show are invited to apply for a seat and tickets are subsequently randomly distributed to applicants. Only the main game is subject of our study. Except for determining the identity of the finalist, the elimination game does not influence the course of the main game. The selected contestant has not won any prize before entering the final.

The main game starts with a fixed and known set of 26 monetary amounts ranging from €0.01 to €5,000,000 that have been randomly allocated over 26 numbered and closed briefcases. One of the briefcases is selected by the contestant and this briefcase is not to be opened until the end of the game.

The game is played over a maximum of nine rounds. In each round, the finalist chooses one or more of the other 25 briefcases to be opened, revealing the prizes inside. Next, a "banker" tries to buy the briefcase from the contestant by making her an offer. Contestants have a few minutes time to evaluate the offer and to decide between "Deal" and "No Deal" and may consult a friend or relative who sits nearby.[2] The remaining prizes and the current bank offer are displayed on a scoreboard and need not be memorized by the contestant. If the contestant accepts the offer ("Deal"), she walks away with this sure amount and the game ends; if the contestant rejects the offer ("No Deal"), the game continues and she enters the next round.

In the first round, the finalist has to select six briefcases to be opened and the first bank offer is based on the remaining 20 prizes. The numbers of briefcases to be opened in the maximum of eight subsequent rounds are 5, 4, 3, 2, 1, 1, 1 and 1. Accordingly, the number of prizes left in the game decreases to 15, 11, 8, 6, 5, 4, 3 and 2. If the contestant rejects all nine offers she receives the prize in her own briefcase. Figure 1 illustrates the basic structure of the main game.

[INSERT FIGURE 1 ABOUT HERE]

To provide further intuition for the game, Figure 2 shows a typical example of how the main game is displayed on the TV screen. A close-up of the contestant is shown in the center and the original prizes are listed to the left and the right of the contestant. Eliminated prizes are shown in a dark color and remaining prizes are in a bright color. The bank offer is displayed at the top of the screen.

[INSERT FIGURE 2 ABOUT HERE]

As can be seen on the scoreboard, the initial prizes are highly dispersed and positively skewed. During the course of the game, the dispersion and the skewness generally fall as more and more briefcases are opened. In fact, in the ninth round, the distribution is perfectly symmetric, because the contestant then faces a 50/50 gamble with two remaining briefcases.

Bank behavior

Although the contestants do not know the exact bank offers in advance, the banker behaves consistently according to a clear pattern. Four simple rules of thumb summarize this pattern:

Rule 1. Bank offers depend on the value of the unopened briefcases: when the lower (higher) prizes are eliminated, the average remaining prize increases (decreases) and the banker makes a better (worse) offer.

Rule 2. The offer typically starts at a low percentage (usually less than 10 percent) of the average remaining prize in the first round and gradually increases to 100 percent in the later rounds. This strategy obviously serves to encourage contestants to continue playing the game and to gradually increase excitement.

Rule 3. The offers are not informative, that is, they cannot be used to determine which of the remaining prizes is in the contestant's briefcase. Only an independent auditor knows the distribution of the prizes over the briefcases. Indeed, there is no correlation between the percentage bank offer and the relative value of the prize in the contestant's own briefcase.

Rule 4. The banker is generous to losers by offering a relatively high bank offer. This pattern is consistent with path-dependent risk attitudes. If the game-show producer understands that risk aversion falls after large losses, he may understand that high offers are needed to avoid trivial choices and to keep the game entertaining to watch. Using the same reasoning, we may also expect a premium after large gains; this, however, does not occur, perhaps because with large stakes, the game already is entertaining.

Section III gives descriptive statistics on the bank offers in our sample and Section IV presents a simple model that captures the above rules of thumb. The key finding is that the bank offers are highly predictable.

II. Data

We examine all "Deal or No Deal" decisions of 151 contestants appearing in episodes aired in the Netherlands (51), Germany (47), and the United States (53).

The Dutch edition of "Deal or No Deal" is called "*Miljoenenjacht*" (or "Chasing Millions"). The first Dutch episode was aired on December 22, 2002 and the last in our sample dates from January 1, 2007. In this time span, the game show was aired 51 times, divided over eight series of weekly episodes and four individual episodes aired on New Year's Day. A distinguishing feature of the Dutch edition is the high amounts at stake: the average prize equals roughly €400,000 (€391,411 in episode 1 – 47 and €419,696 in episode 48 – 51). Contestants may even go home with €5,000,000. The fact that the Dutch edition is sponsored by a national lottery probably explains why the Dutch format has such large prizes. The large prizes may also have been preferred to stimulate a successful launch of the show and to pave the way for exporting the formula abroad. Part of the 51 shows were recorded on videotape by the authors and tapes of the remaining shows were obtained from the Dutch broadcasting company *TROS*.

In Germany, a first series of "*Deal or No Deal - Die Show der GlücksSpirale*" started on June 23, 2005 and a second series commenced on June 28, 2006.[3] Apart from the number of prizes, the two series are very similar. The first series, however, uses only 20 instead of 26 prizes and it is played over a maximum of 8 game rounds instead of 9. Because these 8 rounds are exactly equal to round 2 – 9 of the regular format in terms of the number of remaining prizes and in terms of the number of briefcases that have to be opened, we can analyze this series as if the first round has been skipped. Both series have the same maximum prize (€250,000) and the averages of the initial set of prizes are practically equal (€26,347 vs. €25,003 respectively). In the remainder of the paper we will consider the two German series as one combined subsample. The first series was broadcasted weekly and lasted for 10 episodes, each with two contestants playing the game sequentially instead of one. The second series was aired either once or twice a week and lasted for 27 episodes, bringing the total number of German contestants in our sample to 47. Copies of the first series were obtained from TV station *Sat.1* and from Endemol's local production company *Endemol Deutschland GmbH*. The second series was recorded by a friend of the authors.

In the United States, the game show debuted on December 19, 2005, for 5 consecutive nights and returned on TV on February 27, 2006. This second series lasted for 34 episodes until early June 2006. The 39 episodes combined covered the games of 53 contestants, with some contestants starting in one episode and continuing their game in the next. The regular US format has a maximum initial prize of $1,000,000 (roughly €800,000) and an average of $131,478 (€105,182). In the games of 6 contestants however, the top prizes and averages were larger to mark the launch and the finale of the second series. All US shows were recorded by the authors. US Dollars are translated into Euros by using a rate of €0.80 per $.

For each contestant, we collected data on the eliminated and remaining prizes, the bank offers and the "Deal or No Deal" decisions in every game round, leading to a panel data set with a time-series dimension (the game rounds) and a cross-section dimension (the contestants).

We also collected data on each contestant's gender, age and education. Age and education are often revealed in an introduction talk or in other conversations during the game. The level of education is coded as a dummy variable, with a value of 1 assigned to contestants with a bachelor degree level or higher (including students) or equivalent work experience. Although a contestant's level of education is usually not explicitly mentioned, it is often clear from the stated profession. We estimate the missing values for age based on the physical appearance of the contestant and other information revealed in the introduction talk, for example, the age of children.

However, age, gender and education do not have significant explanatory power in our analysis. In part or in whole, this may reflect a lack of sampling variation. For example, during the game, the contestant is permitted to consult with friends, family members or her spouse, and therefore decisions in this game are in effect taken by a couple or a group, mitigating the role of the individual contestant's age, gender or education. For the sake of brevity, we do not report the effect of contestant characteristics in this study. Moreover, prior outcomes are random and unrelated to characteristics and therefore the characteristics probably would not affect our main conclusions about path-dependence, even if they would affect the level of risk aversion.

Table 1 shows summary statistics for our sample. Compared to the German and US contestants, the Dutch contestants on average accept lower percentage bank offers (76.3 percent vs. 91.8 and 91.4 percent) and play roughly three game rounds less (5.2 vs. 8.2 and 7.7 percent). These differences may reflect unobserved differences in risk aversion due to differences in wealth, culture or contestant selection procedure. In addition, increasing relative risk aversion (IRRA) may help to explain the differences. As the Dutch edition involves much larger stakes than the German and US editions, a modest increase in relative risk aversion suffices to yield sizeable differences in the accepted percentages. Furthermore, the observed differences in the number of rounds played are inflated by the behavior of the banker. The percentage bank offer increases with relatively small steps in the later game rounds and consequently a modest increase in relative risk aversion can yield a large reduction in the number of game rounds played. Thus, the differences between the Dutch contestants on the one hand and the German and US contestants on the other hand are consistent with moderate IRRA.

[INSERT TABLE 1 ABOUT HERE]

Cross-country analysis

Apart from the amounts at stake, the game show format is very similar in the three countries. Still, there are some differences in how contestants are chosen to play that may create differences in the contestant pool. In the Dutch and German shows there is a preliminary game in which contestants answer quiz questions, the winner of which gets to play the main game we study. One special feature of the Dutch edition is the existence of a "bail-out offer" at the end of the elimination game. Just before a last, decisive question, the two remaining contestants can avoid losing and leaving empty-handed by accepting an unknown prize that is announced to be worth at least €20,000 (approximately 5 percent of the average prize in the main game) and typically turns out to be a prize such as a world trip or a car. If the more risk-averse pre-finalists are more likely to exit the game at this stage, the Dutch finalists might be expected to be less risk averse on average. In the US, contestants are not selected based on an elimination game but rather the producer selects each contestant individually, and the selection process appears to be based at least in part on the appearance and personalities of the contestants. (The web site for the show tells prospective contestants to send a video of themselves and their proposed accompanying friends and relatives. The show also conducts open "casting calls".) Contestants (and their friends) thus tend to be attractive and lively. Another concern is that richer and more risk-seeking people may be more willing to spend time attempting to get onto high-stake editions than onto low-stake editions. To circumvent these problems, Section VI complements the analysis of the TV shows with a series of classroom and laboratory experiments that use a homogeneous student population.

III. Preliminary analysis

To get a first glimpse of the risk preferences in "Deal or No Deal", we analyze the offers made by the banker and the contestants' decisions to accept or reject the offers in the various game rounds.

Several notable features of the game can be seen in Table 2. First, the banker becomes more generous by offering higher percentages as the game progresses ("Rule 2"). The offers typically start at a tiny fraction of the average prize and approach 100 percent in the later rounds. The strong similarity between the percentages in the Dutch edition (Panel A), the German edition (Panel B) and the US edition (Panel C) suggest that the banker behaves in a similar way.[4] The numbers of remaining contestants in every round clearly show that the Dutch contestants tend to stop earlier and accept relatively lower bank offers than the German and US contestants do. Again, this may reflect the substantially larger stakes in the Dutch edition, or, alternatively, unobserved differences in risk aversion due to differences in wealth, culture or contestant selection procedure. Third, the contestants generally exhibit what might be called only "moderate" risk aversion. In the US and German sample, all contestants keep playing until the bank offer is at least half the expected value of the prizes in the unopened briefcases. In Round 3 in the Netherlands, 20 percent of the contestants (10 out of 51) do accept deals that average only 36 percent of the expected value of the unopened briefcases, albeit at stakes that exceed €400,000. Many contestants turn down offers of 70 percent or more of amounts exceeding €100,000. Fourth, there can be wide discrepancies, even within a country, in the stakes that contestants face. In the Dutch show contestants can be playing for many hundreds of thousands of euros, down to a thousand or less. In the later rounds, the contestant is likely to face relatively small stakes, as a consequence of the skewness of the initial set of prizes.

[INSERT TABLE 2 ABOUT HERE]

What is not apparent from this table, is the effect that the particular path a player takes can have on the choices he or she makes. To give an example of the decisions faced by an unlucky player consider poor Frank, who appeared in the Dutch episode of January 1, 2005 (see Table 3). In round 7, after several unlucky picks, Frank opens the briefcase with the last remaining large prize (€500,000) and he sees the expected prize tumble from €102,006 to €2,508. The banker then offers him €2,400, or 96 percent of the average remaining prize. Frank rejects this offer and play continues. In the subsequent rounds, Frank deliberately chooses to enter unfair gambles, to finally end up with a briefcase worth only €10. Specifically, in round 8, he rejects an offer of 105 percent of the average remaining prize; in round 9, he even rejects a certain €6,000 in favor of a 50/50 gamble of €10 or €10,000. We feel confident to classify this last decision as risk-seeking behavior, because it involves a single, simple, symmetric gamble with thousands of Euros at stake. Also, unless we are willing to assume that Frank would always accept unfair gambles of this magnitude, the only reasonable explanation for his choice behavior seems to be a reaction to his misfortune experienced earlier in the game.

[INSERT TABLE 3 ABOUT HERE]

In contrast, consider the exhilarating ride of Susanne, an extremely fortunate contestant who appeared in the German episode of August 23, 2006 (see Table 4). After a series of very lucky picks, she eliminates the last small prize of €1,000 in round 8. In round 9, she then faces a 50/50 gamble of €100,000 or €150,000, two of the three largest prizes in the German edition. While she was concerned and hesitant in the earlier game rounds, she decidedly rejects the bank offer of €125,000, the expected value of the gamble; a clear display of risk-seeking behavior.

[INSERT TABLE 4 ABOUT HERE]

Thus both unlucky Frank and lucky Susanne exhibit very low levels of risk aversion, even risk-seeking, whereas most of the contestants in the shows are at least moderately risk averse. Frank's behavior is consistent with a "break-even" effect, a willingness to gamble in order to get back to some perceived reference point. Susanne's behavior is consistent with a "house-money" effect, an increased willingness to gamble when someone thinks they are playing with "someone else's money".

To systematically analyze the effect of prior outcomes such as the extreme ones experienced by Frank and Suzanne, we first develop a rough classification of game situations in which the contestant is classified as "loser" or "winner" and analyze the decisions of contestants in these categories separately. Of course, there are numerous ways one could allocate players into winner and loser categories. The results we show are robust to other categorization schemes.

Our classification takes into account the downside risk and upside potential of rejecting the current bank offer. We classify a contestant as loser if her average remaining prize after opening one additional briefcase is low, even if the best-case scenario of eliminating the lowest remaining prize would occur. Using $\bar{x}_r$ for the current average, the average remaining prize in the best-case scenario is:

(1) $$BC_r = \frac{n_r \bar{x}_r - x_r^{\min}}{n_r - 1}$$

where n_r stands for the number of remaining briefcases in game round $r = 1, \cdots, 9$ and $x_r^{\min}$ for the smallest remaining prize. Similarly, winners are classified by the average remaining prize in the worst-case scenario of eliminating the largest prize:

(2) $$WC_r = \frac{n_r \bar{x}_r - x_r^{\max}}{n_r - 1}$$

where $x_r^{\min}$ stands for the smallest prize, respectively. We classify a contestant in a given game round as "loser" if BC_r belongs to the worst one-third for all contestants in that game round and as "winner" if WC_r belongs to the best one-third.[5] Game situations that satisfy neither of the two conditions (or both in rare occasions) are classified as "neutral".

Table 5 illustrates the effect of previous outcomes on the contestants' choice behavior. We see that, compared to contestants who are in the neutral category, both winners and losers have a stronger tendency to continue play. While 31 percent of all "Deal or No Deal" choices in the neutral group are "Deal" in the Dutch sample, the "Deal" percentage is only 14 percent for losers - despite the generous offers to losers ("Rule 4"). The low "Deal" percentage for losers suggests that risk aversion decreases when contestants were unlucky in selecting which briefcases to open. In fact, the strong losers in our sample generally exhibit risk-seeking behavior by rejecting bank offers in excess of the average remaining prize.

The low "Deal" percentage could be explained in part by the smaller stakes faced by losers and a lower risk aversion for small stakes, or increasing relative risk aversion (IRRA). However, the losers generally still have at least thousands or tens of thousands of Euros at stake and gambles of this magnitude are typically associated with risk aversion in other empirical studies (including other game show studies and experimental studies). Also, if the stakes would explain the low risk aversion of losers, we would expect a higher risk aversion for winners. However, the risk aversion seems to decrease when contestants are lucky and eliminated low-value briefcases. The "Deal" percentage for winners is 25 percent, below the 31 percent for the neutral group.

Interestingly, the same pattern arises in all three countries. The overall "Deal" percentages in the German and US editions are lower than in the Dutch edition, consistent with moderate IRRA and the large differences in the initial stakes. However, within every edition, the losers and winners have relatively low "Deal" percentages.

These results suggest that prior outcomes are an important determinant of risky choice. This would be inconsistent with the traditional interpretation of expected utility theory in which the preferences for a given choice problem do not depend on the path traveled before arriving at the choice problem. By contrast, path-dependence arises naturally in prospect theory. The lower risk aversion after misfortune is reminiscent of the break-even effect, or decision makers being more willing to take risk due to incomplete adaptation to previous losses. Similarly, the relatively low "Deal" percentage for winners is consistent with the house-money effect, or a lower risk aversion after earlier gains.

The analysis of "Deal" percentages is rather crude. It does not specify an explicit model of risky choice and it does not account for the precise choices (bank offers and remaining prizes) faced by the contestants. Furthermore, there is no attempt at statistical inference or controlling for confounding effects at this stage of our analysis. The next two sections use a structural choice model and a maximum-likelihood methodology to analyze the "Deal or No Deal" choices in greater detail.

[INSERT TABLE 5 ABOUT HERE]

IV. Expected Utility Theory

This section analyzes the observed “Deal or No Deal” choices with the standard expected utility of wealth theory. The choice of the appropriate class of utility functions is important, because preferences are evaluated on an interval from cents to millions. We do not want to restrict our analysis to the classic power utility function or exponential utility function, because it seems too restrictive to assume constant relative risk aversion (CRRA) or constant absolute risk aversion (CARA) for this interval. To allow for the plausible combination of increasing relative risk aversion (IRRA) and decreasing absolute risk aversion (DARA), we employ a variant of the flexible expo-power family of Saha (1993) that was used by Abdellaoui, Barrios and Wakker (2006) and Holt and Laury (2002):

$$u(x) = \frac{1 - \exp(-\alpha (W + x)^{1-\beta})}{\alpha} \tag{3}$$

In this function, three parameters are unknown: the risk aversion coefficients α and β, and initial wealth W. Interestingly, the classical CRRA power function arises as the limiting case where $\alpha \to 0$ and the CARA exponential function arises as the special case where $\beta = 0$. Theoretically, the correct measure of wealth should be life-time wealth, including the present value of future income. However, life-time wealth is not observable and it is possible that contestants do not integrate their existing wealth with the payoffs of the game. Therefore, we include initial wealth as a free parameter in our model.

We will estimate the three unknown parameters using a maximum likelihood procedure that measures the likelihood of the observed “Deal or No Deal” decisions based on the “stop value”, or the utility of the current bank offer, and the “continuation value”, or the expected utility of the unknown winnings when rejecting the offer. In a given round r, $B(x_r)$ denotes the bank offer as a function of the set of remaining prizes x_r. The stop value is simply:

$$sv(x_r) = u(B(x_r)) \tag{4}$$

Analyzing the continuation value is more complicated, because the game involves multiple rounds and the valuation has to account for the unknown bank offers and the optimal

"Deal or No Deal" decisions in all later rounds. We will elaborate on the continuation value, the bank offer model and the estimation procedure below.

Continuation value

The game involves multiple rounds and the continuation value has to account for the bank offers and optimal decisions in all later rounds. In theory, we can solve the entire dynamic optimization problem by means of backward induction, using Bellman's principle of optimality. Starting with the ninth round, we can determine the optimal "Deal or No Deal" decision in each preceding game round, accounting for the possible scenarios and the optimal decisions in subsequent rounds. This approach however assumes that the contestant takes into account all possible outcomes and decisions in all subsequent game rounds. Studies on backward induction in simple alternating-offers bargaining experiments suggest that subjects generally do only one or two steps of strategic reasoning and ignore further steps of the backward induction process; see, for example, Johnson *et al.* (2002) and Binmore *et al.* (2002). This pleads for assuming that the contestants adopt a simplified mental frame of the game.

Our video material indeed suggests that contestants generally look only one round ahead. The game-show host tends to stress what will happen to the bank offer in the next round should particular briefcases be eliminated and the contestants themselves often comment that they will play "just one more round" (although they often change their minds and continue play later on). We therefore assume a simple "myopic" frame. Using this frame, the contestant just compares the current bank offer with the unknown offer in the next round, ignoring the option to continue playing thereafter.

Given the current set of prizes (x_r), the statistical distribution of the set of prizes in the next round (x_{r+1}) is known:

(5) $$\Pr[x_{r+1} = y \mid x_r] = \binom{n_r}{n_{r+1}}^{-1} = p_r$$

for any given subset y of n_{r+1} elements from x_r. In words, the probability is simply one divided by the number of possible combinations of n_{r+1} out of n_r. Thus, using $\mathrm{X}(x_r)$ for all relevant subsets, the continuation value for a myopic contestant is given by:

(6) $$cv(x_r) = \sum_{y \in X(x_r)} u(B(y)) p_r$$

Given the cognitive burden of multi-stage induction, this frame seems the appropriate choice for this game. However, as a robustness check, we have also replicated our estimates using the rational model of full backward induction and have found that our parameter estimates and empirical fit did not change materially. In the early game rounds, when backward induction appears most relevant, the myopic model underestimates the continuation value. Still, the myopic model generally correctly predicts "No Deal", because the expected bank offers usually increase substantially during the early rounds. In the later game rounds, backward induction is of less importance, because fewer game rounds remain to be played and because the rate of increase in the expected bank offers slows down. For contestants who reach round nine, such as Frank and Susanne, the decision problem involves just one stage and the myopic model coincides with the rational model. The low propensity to "Deal" of losers and winners in later game rounds is therefore equally puzzling under the assumption of full backward induction.

Bank offers

To apply the myopic model, we need to quantify the behavior of the banker. Section I discussed the bank offers in a qualitative manner. For a contestant who currently faces remaining prizes x_r and percentage bank offer b_r in game round $r = 1, \cdots, 9$, we quantify this behavior using the following simple model:

(7) $$B(x_{r+1}) = b_{r+1} \bar{x}_{r+1}$$

(8) $$b_{r+1} = b_r + (1 - b_r) \rho^{(9-r)}$$

where ρ, $0 \leq \rho \leq 1$, measures the speed at which the percentage offer goes to 100 percent. Since myopic contestants are assumed to look only one round ahead, the model predicts only the offer in the next round. The bank offer in the first round need not be predicted, because it is shown on the scoreboard when the first "Deal or No Deal" choice has to be made. $B(x_{10}) = x_{10}$ and $b_{10} = 1$ refer to the prize in the contestant's own briefcase.

The model does not include an explicit premium for losers. However, before misfortune arises, the continuation value is driven mostly by the favorable scenarios and the precise percentage offers for unfavorable scenarios do not materially affect the results. After bad luck, the premium is included in the current percentage and extrapolated to future game rounds.

For each edition, we estimate the value of ρ by fitting the model to the sample of percentage offers made to all contestants in all relevant game rounds using least squares regression analysis. The resulting estimates are very similar for each edition: 0.832 for the Dutch edition, 0.815 for the first German series, 0.735 for the second German series and 0.777 for the US shows. The model gives a remarkably good fit. Figure 3 illustrates the goodness-of-fit by plotting the predicted bank offers against the actual offers. The results are highly comparable for the three editions in our study and therefore the figure shows the pooled results. For each individual sample, the model explains well over 70 percent of the total variation in the individual percentage offers. The explanatory power is even higher for monetary offers, with an R-squared of roughly 95 percent for each sample. Arguably, accurate monetary offers are more relevant for accurate risk aversion estimates than accurate percentage offers, because the favorable scenarios with high monetary offers weigh heavily on expected utility. On the other hand, to analyze risk behavior following losses, accurate estimates for low monetary offers are also needed. It is therefore comforting that the fit is good in terms of both percentages and monetary amounts. In addition, if ρ is used as a free parameter in our structural choice models, the optimal values are approximately the same as our estimates, further confirming the goodness.

[INSERT FIGURE 3 ABOUT HERE]

Since the principle behind the bank offers becomes clear after seeing a few shows, the bank offer model (7) - (8) is treated as deterministic and known to the contestants. Using a stochastic bank offer model would introduce an extra layer of uncertainty, yielding lower continuation values. For losers, the bank offers are hardest to predict, making it even more difficult to rationalize why these contestants continue play.

Maximum likelihood estimation

In the spirit of Becker *et al*. (1963) and Hey and Orme (1994), we assume that the "Deal or No Deal" decision of a given contestant $i = 1, \cdots, N$ in a given game round $r = 1, \cdots, 9$ is based on the difference between the continuation value and the stop value, i.e., $cv(x_{i,r}) - sv(x_{i,r})$, plus some error. The errors are treated as independent, normally distributed random variables with zero mean and standard deviation $\sigma_{i,r}$. Arguably, the error standard deviation should be higher for difficult choices than for simple choices. A natural indicator of the difficulty of a decision is the standard deviation of the utility of the outcomes used to compute the continuation value:

(9) $$\delta(x_{i,r}) = \sqrt{\sum_{y \in \mathrm{X}(x_{i,r})} (u(B(y)) - cv(x_{i,r}))^2 p_r}$$

We assume that the error standard deviation is proportional to this indicator, that is, $\sigma_{i,r} = \delta(x_{i,r})\sigma$, where σ is a constant noise parameter. As a result of this assumption, the simple choices effectively receive a larger weight in the analysis than difficult ones. We also investigated the data without weighting. The (unreported) results show that the weighting scheme does not materially affect the parameter estimates or the relative goodness of the models in our study. However, without weighting, the estimated noise parameters in the three editions strongly diverge, with the Dutch edition having a substantially higher noise level than the German and US editions. The increase in the noise level seems to reflect the higher difficulty of the decisions in the Dutch edition relative to the German and US editions; contestants in the Dutch edition typically face (i) larger stakes because of the large initial prizes and (ii) more remaining prizes because they exit the game at an earlier stage. The standard deviation of the outcomes (9) picks up these two factors and the deterioration of the fit provides an additional, empirical argument for our weighting scheme.

Given these assumptions, we may compute the likelihood of the "Deal or No Deal" decision as:

(10) $$l(x_{i,r}) = \begin{cases} \Phi\left(\dfrac{cv(x_{i,r}) - sv(x_{i,r})}{\delta(x_{i,r})\sigma}\right) & \text{if "No Deal"} \\ \Phi\left(\dfrac{sv(x_{i,r}) - cv(x_{i,r})}{\delta(x_{i,r})\sigma}\right) & \text{if "Deal"} \end{cases}$$

where $\Phi(\cdot)$ is the cumulative standard normal distribution function.

Aggregating the likelihood across contestants, the overall log-likelihood function of the "Deal or No Deal" decisions is given by:

(11) $$\ln(L) = \sum_{i=1}^{N} \sum_{r=2}^{R_i} \ln(l(x_{i,r}))$$

where R_i is the last game round played by contestant i.

To allow for the possibility that the errors of individual contestants are correlated, we perform a cluster correction on the standard errors (see, for example, Wooldridge, 2003). Note that the summation starts in the second game round ($r = 2$). The early German episodes with only eight game rounds effectively start in this game round and in order to align these episodes with the rest of the sample, we exclude the first round ($r = 1$) of the episodes with nine game rounds. Due to the very conservative bank offers, the choices in the first round are always trivial (no contestant in our sample ever said "Deal"); including these choices does not affect the results, but it would falsely make the early German episodes look more "noisy" than the rest of the sample.

The unknown parameters in our model (α, β, W, and σ) are selected to maximize the overall log-likelihood. To determine if the model works significantly better than a naïve model of risk neutrality, we perform a likelihood ratio test. Recall that we excluded the first game round for the episodes with nine game rounds to align them with the German episodes with only eight game rounds.

Results

Table 6 summarizes our estimation results. Apart from coefficient estimates and p-values, we have also computed the implied certainty equivalent as a fraction of the expected value, or certainty coefficient (CC), for 50/50 gambles of €0 or €10^z, z = 3, 4, 5, 6. These values help to interpret the coefficient estimates by illustrating the shape of the utility function. Notably, the CC can be interpreted as the critical bank offer (as a fraction of the expected value) that would make the contestant indifferent between "Deal" and "No Deal". If CC = 1, the contestant is risk neutral. When CC > 1, the contestant is risk seeking, and as CC approaches zero, the contestant becomes extremely risk averse. To help interpret the goodness of the model, we have added the "hit percentage", or the percentage of correctly predicted "Deal or No Deal" decisions.

In the Dutch sample, the risk aversion parameters α and β are both significantly different from zero, suggesting that IRRA and DARA are relevant and the classical CRRA power function and CARA exponential function are too restrictive to explain the choices in this game show. The estimated wealth level of €75,203 significantly exceeds zero. Still, given that the median Dutch household income is roughly €25,000 per annum, the initial wealth level seems substantially lower than life-time wealth and integration seems incomplete. This deviates from the classical approach of defining utility over wealth and is more in line with utility of income or the type of narrow framing that is typically assumed in prospect theory. A low wealth estimate is also consistent with Rabin's (2000) observation that plausible risk aversion for small and medium outcomes implies implausibly strong risk aversion for large outcomes if the outcomes are integrated with life-time wealth. Indeed, the estimates imply near risk neutrality for small stakes, witness the CC of 0.994 for a 50/50 gamble of €0 or €1,000, and increasing the wealth level would imply near risk neutrality for even larger gambles.

Rabin's point is reinforced by comparing our high stakes results with the laboratory experiments conducted by Holt and Laury (2002) using the lower stakes typical in the lab. Holt and Laury's subjects display significant risk aversion for modest stakes, which, as Rabin notes, implies extreme risk aversion for much larger stakes - behavior our contestants do not display. Indeed, contestants with Holt and Laury's estimated utility function would generally accept a "Deal" in the first game round, in contrast to the actual behavior we observe. We conclude, agreeing with Rabin, that expected utility of wealth models have difficulty explaining behavior for both small and large stakes.

The model also does not seem flexible enough to simultaneously explain the choices for losers and winners. The estimated utility function exhibits very strong IRRA, leading to an implausibly low CC of 0.141 for a 50/50 gamble of €0 or €1,000,000. Indeed, the model errs by predicting that winners would stop earlier than they actually do. If risk aversion increases with stakes, winners are predicted to have a stronger propensity to accept a bank offer, the opposite of what we observe, witness for example the "Deal" percentages in Table 3. However, strong IRRA is needed in order to explain the behavior of losers, who reject generous bank offers and continue play even with tens of thousands of Euros at stake. Still, the model does not predict risk seeking at small stakes, witness the CC of 0.946 for a 50/50 gamble of €0 or €10,000 – roughly Frank's risky choice in round 9. Thus, the model also errs by predicting that losers would stop earlier than they actually do.

Interestingly, the estimated coefficients for the German edition are quite different from the Dutch values. The optimal utility function reduces to the CARA exponential function ($\beta = 0$) and the estimated initial wealth level becomes insignificantly different from zero. Still, on the observed domain of prizes, the two utility functions exhibit a similar pattern of unreasonably strong IRRA and high risk aversion for winners. Again, the model errs by predicting that losers and winners would stop earlier than they actually do. These errors are so substantial in this edition that the fit of the expected utility model is not significantly better than the fit of a naive model that assumes that all contestants are risk neutral.

Contrary to the Dutch and German utility functions, the US utility function approximates the limiting case of the CRRA power function ($\alpha \approx 0$). The CC is again very high for small stakes. For larger stakes, the coefficient decreases but at a slower pace than in the other two countries, reflecting the relatively low propensity to "Deal" for US contestants with relatively large amounts at stake. The decreasing pattern stems from the estimated initial wealth level of €101,898, which yields near risk neutrality for small stakes. Still, initial wealth is not significantly different from zero, because a similar pattern can be obtained if we lower the value of beta relative to alpha and move in the direction of the CARA exponential function.

[INSERT TABLE 6 ABOUT HERE]

To further illustrate the effect of prior outcomes, Table 7 shows separate results for losers and winners (as defined in Section III). Confirming the high "Deal" percentages found earlier, the losers and winners are less risk averse and have higher CCs than the neutral group. The losers are in fact best described by a model of risk seeking, which is not surprising given that the losers in our sample often reject bank offers in excess of the average remaining prize. The same pattern arises in each of the three editions, despite sizeable differences in the set of prizes. For example, the Dutch losers on average face larger stakes than the contestants in the US and German neutral groups. Still, risk seeking (CC > 1) arises only in the loser group. Overall, these results suggest that the expected utility model fails to capture the strong effect of previous outcomes.

[INSERT TABLE 7 ABOUT HERE]

V. Prospect Theory

In this section, we use prospect theory to analyze the observed “Deal or No Deal” choices. Contestants are assumed to have a narrow focus and evaluate the outcomes in the game without integrating their initial wealth - a typical assumption in prospect theory. Furthermore, we will again use the myopic frame that compares the current bank offer with the unknown offer in the next round. Although myopia is commonly assumed in prospect theory, the choice of the relevant frame is actually more important than for expected utility theory in this game. As discussed in Section IV, the myopic frame seems appropriate for expected utility theory. However, for prospect theory, it can be rather restrictive. Prospect theory allows for risk seeking behavior when in the domain of losses and risk seekers have a strong incentive to look ahead multiple game rounds to allow for the possibility of winning the largest remaining prize. Indeed, contestants who reject high offers often explicitly state that they are playing for the largest remaining prize (rather than a high bank offer in the next round). Preliminary computations revealed that prospect theory generally performs better if we allow risk seekers to look ahead multiple game rounds. However, the improvements are limited, because risk seeking typically arises at the end of the game. At that stage, only few or no further game rounds remain and the myopic model gives a good approximation. Thus, we only report the results with the myopic model to be consistent with the previous analysis using expected utility theory.

The stop value and continuation value for prospect theory are defined in the same way as for expected utility theory, with the only difference that the expo-power utility function (3) is replaced by the prospect theory value function which is defined on changes relative to some reference point:

(12) $$v(x \mid RP) = \begin{cases} -\lambda(RP - x)^{\alpha} & x \le RP \\ (x - RP)^{\alpha} & x > RP \end{cases}$$

where $\lambda > 0$ is the loss-aversion parameter, RP is the reference point that separates losses from gains, and $\alpha > 0$ measures the curvature of the value function. The original formulation of prospect theory allows for different curvature parameters for the domain of losses ($x \le RP$) and the domain of gains ($x > RP$). To reduce the number of free parameters, we assume here that the curvature is equal for both domains.

Reference point specification

Kahneman and Tversky's original treatment of prospect theory equates the reference point with the status quo. Since "Deal or No Deal" contestants never have to pay money out of their own pockets, the reference point would then equal zero and contestants would never experience any losses. However, the authors recognize that "there are situations in which gains and losses are coded relative to an expectation or aspiration level that differs from the status quo." They point out that "a person who has not made peace with his losses is likely to accept gambles that would be unacceptable to him otherwise." This point is elaborated by Thaler and Johnson (1990), though neither team offers a formal model of how the reference point changes over time. One recent effort along these lines is Kőszegi and Rabin (2006).

The specification of the subjective reference point (or the underlying set of expectations) and how it varies during the game is crucial for our analysis as it determines which outcomes enter as gain or loss in the value function and with what magnitude. Slow adjustment or stickiness of the reference point can yield break-even and house-money effects or a lower risk aversion after losses and after gains. If the reference point adjusts slowly after losses, relatively many remaining outcomes are placed in the domain of losses, where risk seeking applies. Similarly, if the reference point sticks to an earlier, less favorable value after gains, relatively many remaining prizes are placed in the domain of gains, reducing the role of loss aversion.

Figure 4 illustrates these two effects using a 50/50 gamble of €25,000 or €75,000. Contestants in "Deal or No Deal" face this type of gambles in round 9. The figure shows the value function using the parameter estimates of Tversky and Kahneman (1992), or $\alpha = 0.88$ and $\lambda = 2.25$, and three alternative specifications for the reference point. In a neutral situation without prior outcomes, the reference point may equal the expected value (RP_N = €50,000). In this case, the contestant frames the gamble as losing €25,000 (€50,000 − €25,000) or winning €25,000 (€75,000 − €50,000). The certainty equivalent of the gamble is CE_N = €44,169, meaning that bank offers below this level would be rejected and higher offers would be accepted. The risk discount of €5,831 is caused by loss aversion, which assigns a larger weight to losses than to gains.

Now consider contestant L, who initially faced much larger stakes than €50,000 and incurred large losses before arriving at the 50/50 gamble in round 9. Suppose that L slowly adjusts to these earlier losses and places his reference point at the largest remaining prize (RP_L = €75,000). In this case, L does not frame the gamble as losing €25,000 or winning €25,000 but rather as losing €50,000 (€75,000 – €25,000) or breaking even (€75,000 – €75,000). Both prizes are placed in the domain of losses where risk seeking applies. Indeed, L would reject all bank offers below the certainty equivalent of the gamble, CE_L = €52,255, which includes a risk *premium* of €2,255.

Finally, consider contestant W, who initially faced much smaller stakes than €50,000 and incurred large gains before arriving at the 50/50 gamble. Due to slow adjustment, W employs a reference point equal to the smallest remaining prize (RP_W = €25,000) and places both remaining prizes in the domain of gains. In this case, W frames the gamble as one of either breaking even (€25,000 – €25,000) or gaining €50,000 (€75,000 – €25,000). Since loss aversion does not apply in the domain of gains, the risk aversion of W is lower than in the neutral case and W would rejects all bank below CE_W = €47,745, using a risk discount of €2,255, less than the value of €5,831 in the neutral case.

[INSERT FIGURE 4 ABOUT HERE]

It should be clear from the above examples that a proper specification of the reference point and its dynamics is essential for our analysis. In fact, without slow adjustment, prospect theory does not yield the path-dependence found in this study. Unfortunately, the reference point is not directly observable and prospect theory alone provides minimal guidance for selecting the relevant specification. We therefore need to give the model some freedom and rely on the data to inform us about the relevant specification. To reduce the risk of data mining and to simplify the interpretation of the results, we develop a simple structural model based on elementary assumptions and restrictions for the reference point.

If contestants were confronted with the isolated problem of choosing between the current bank offer and the risky bank offer in the next round, then it would seem natural to link the reference point to the current bank offer. The bank offer represents the sure alternative and the opportunity cost of the risky alternative. Furthermore, the bank offer is linked to the average remaining prize and therefore to current expectations regarding future outcomes. Interestingly, the Kőszegi and Rabin (2006) model, which endogenously determines the reference point as the optimal solution to the decision problem, also selects the bank offer as the relevant reference point in our framework, as shown in the Appendix. A simple specification would be $RP_r = \theta_1 B(x_r)$. If $\theta_1 = 0$, then the reference point equals the status quo ($RP_r = 0$) and all possible outcomes are evaluated as gains; if $\theta_1 > 0$, the reference point is strictly positive and contestant may experience (paper) losses, even though they never have to pay money out of their own pockets. A reference point below the current bank offer, or $\theta_1 < 0$, is conservative (pessimistic) in the sense that relatively few possible bank offers in the next round are classified as losses and relatively many possible outcomes are classified as gains. By contrast, an "optimistic" reference point, or $\theta_1 > 1$, involves many possible losses and few possible gains.

The actual game is dynamic and the bank offer changes in every round, introducing the need to update the reference point. However, due to slow adjustment, the reference point may be affected by earlier game situations. We may measure the effect of outcomes after earlier round j, $0 \leq j \leq r$, by the relative increase in the average remaining prize, or $d_r^{(j)} = (\bar{x}_r - \bar{x}_j)/\bar{x}_r$. For $j = 0$, $d_r^{(j)}$ measures the change relative to the initial average, or $\bar{x}_0$.

Ideally, our model would include this measure for all earlier game rounds (and possibly also interaction terms). However, due to the strong correlation between the lagged terms and the limited number of observations, we have to limit the number of free parameters. We restrict ourselves to just two terms: $d_r^{(r-2)}$ and $d_r^{(0)}$. The term $d_r^{(r-2)}$ is the longest fixed lag that can be included for all observations (our analysis starts in the second round) and measures recent changes; $d_r^{(0)}$, or the longest variable lag, captures all changes relative to the initial game situation. Adding these two lagged terms to the static model, our dynamic model for the reference point looks as follows:

$$RP_r = (\theta_1 + \theta_2 d_r^{(r-2)} + \theta_3 d_r^{(0)})B(x_r) \tag{13}$$

In this model, $\theta_2 < 0$ or $\theta_3 < 0$ implies that the reference points sticks to earlier values and that it is higher than the neutral value $\theta_1 B(x_r)$ after losses and lower after gains.

It is not immediately clear how strong the adjustment would be, or if the adjustment parameters would be constant, but it seems realistic to assume that the adjustment is always sufficiently strong to ensure that the reference point is feasible in the next round, i.e., not lower than the smallest bank offer possible and not higher than the largest bank offer possible. We therefore truncate the reference point at the minimum and maximum bank offer, i.e. $\min_{y \in X(x_r)} B(y) \leq RP_r \leq \max_{y \in X(x_r)} B(y)$. This truncation improves the empirical fit of our model and the robustness to the specification of the reference point and its dynamics.

Our complete prospect theory model involves five free parameters: loss aversion λ, curvature α, and the three parameters of the reference point model θ_1, θ_2 and θ_3. We estimate these parameters and the noise parameter σ with the same maximum likelihood procedure used for the expected utility analysis. We also apply the same bank offer model.

Our analysis ignores subjective probability transformation captured by prospect theory's weighting function and uses the true probabilities as decision weights. The fit of prospect theory could improve if we allow for probability transformation. If losers have a sticky reference point and treat all possible outcomes as losses, then they will overweight the probability of the smallest possible loss, strengthening the risk seeking that stems from the convexity of the value function in the domain of losses. Similarly, winners would overweight the probability of the largest possible gain, canceling the risk aversion that stems from the concavity of the value function in the domain of gains. Still, we prefer to focus on the effect of the reference point in this study and we ignore probability weighting for the sake of parsimony. This simplification is unlikely to be material, especially in the most important later rounds, because none of the relevant probabilities are small, which is when the decision weights in prospect theory most diverge from actual probabilities.

Results

Table 8 summarizes our results. For the Dutch edition, the curvature and loss aversion parameters are significantly different from unity. The curvature of the value function is needed to explain why some contestants reject bank offers in excess of the average remaining prize; loss aversion explains why the average contestant accepts a bank offer below the average prize. Both parameters take values that are comparable with the typical results in experimental studies. Indeed, setting these parameters equal to the Tversky and Kahneman (1992) parameter values does not change our conclusions.

The parameter θ_1 is significantly larger than zero, implying that contestants do experience (paper) losses, consistent with the idea that the reference point is based on expectations and that diminished expectations represent losses. The parameter is also significantly smaller than unity, indicating that the reference point generally takes a conservative value below the current bank offer.

The adjustment parameters θ_2 and θ_3 are significantly smaller than zero, meaning that the reference point tends to stick to earlier values and is higher (lower) than the neutral value after losses (gains). In magnitude, θ_2 is much larger than θ_3, suggesting that the effect of recent outcomes is much stronger than the effect of initial expectations. However, the changes in the average remaining prize during the last two game rounds are generally much smaller than the changes during the entire game, limiting the effect of the parameter value. In addition, in case of large changes, the reference point often falls outside the range of feasible outcomes. In these cases, the reference point is set equal to the smallest or largest possible bank offer (see above), further limiting the effect of the parameter value.

The slow adjustment of the reference point lowers the propensity of losers and winners to “Deal”. Not surprisingly, the prospect theory model yields substantially smaller errors for losers and winners and the overall log-likelihood is significantly higher than for the expected utility model. While the expected utility model correctly predicted 76 percent of the “Deal or No Deal” decisions, the hit percentage of the prospect theory model is as high as 85 percent.

The results for the German and US samples are somewhat different from the results for the Dutch sample, but still confirm the important role of slow adjustment. The difference seems related to the relatively large stakes and the associated high propensity to “Deal” in the Dutch edition. In the German and US samples, the reference point is substantially higher in relative terms than in the Dutch sample. The relatively high initial reference point helps explain why the German and US contestants stop in later rounds and demand higher percentage bank offers than the Dutch contestants. Relatively many outcomes are placed in the domain of losses, where risk seeking applies. In such a situation, a relatively high loss aversion is needed to explain “Deals”. Indeed, the loss aversion estimates are substantially higher than for the Dutch sample. Again, stickiness is highly significant. However, the most recent outcomes seem less important and the reference point now sticks primarily to the initial situation. This seems related to the German and US contestants on average playing more game rounds than the Dutch contestants. In later rounds, many briefcases have already been opened, but relatively few briefcases have been opened in the last few rounds. The last two game rounds therefore generally reveal less information in the German and US edition than in the Dutch edition. The model again materially reduces the errors for losers and winners and fits the data significantly better than the expected utility model in these two samples.

These results are consistent with our earlier finding that the losers and winners have a low propensity to “Deal” (see Table 3). Clearly, prospect theory with a dynamic but sticky reference point is a plausible explanation for this path-dependent pattern. Still, we stress that our analysis of prospect theory serves merely to explore and illustrate one possible explanation, and that it leaves several questions unanswered. For example, we have assumed homogeneous preferences and no subjective probability transformation. The empirical fit may improve even further if we would allow for heterogeneous preferences and probability weighting. Further improvements may come from allowing for a different curvature in the domains of losses and gains, from allowing for different partial adjustment after gains and losses, and from stakes-dependent curvature and loss aversion. We leave these issues for further research.

[INSERT TABLE 8 ABOUT HERE]

VI. Experiments

The previous sections have demonstrated the strong effect of prior outcomes or path-dependence of risk attitudes. Also, the amounts at stake seem to be important, with a stronger propensity to deal for larger stakes levels. Prior outcomes and stakes are however highly confounded within every edition of the game show: unfavorable outcomes (opening high-value briefcases) lower the stakes and favorable outcomes (opening low-value briefcases) raise the stakes. The stronger the effect of stakes, the easier it is to explain the weaker propensity to "Deal" of losers and the more difficult it is to explain the low "Deal" percentage of winners. To analyze the isolated effect of the amounts at stake, we conduct a series of experiments in which students at Erasmus University play "Deal or No Deal". The experiments also analyze the effect of decision making under distress. The TV studio is not representative of everyday life and one may ask if our results are driven by the distress of making decisions on national TV.

We consider three variations to the same experiment that all draw from the same student population. We manipulate the level of stakes by varying the monetary amounts by a factor of 10, and vary the "publicness" of the decision by comparing a classroom experiment that is designed to mimic the TV studio with an experiment in a quiet computerized laboratory.

All experiments use real monetary payoffs to avoid incentive problems (see, for example, Holt and Laury, 2002). In order to compare the choices in the experiments with those in the original TV show and to provide a common basis for comparisons between the three experiments, each experiment uses the original scenarios from the Dutch edition. At the time of the experiments, 40 episodes were available. The original monetary amounts are scaled down by a factor of 1,000 or 10,000, with the smallest amounts rounded up to one cent. Although the stakes are much smaller than in the TV show, they are still unusually high for experimental research. The "missing outcomes" for game rounds after a "Deal" in the original episode are selected randomly (but held constant across the experiments). Although the scenarios are predetermined, the subjects are not "deceived" in the sense that the game is not manipulated to encourage or avoid particular situations or behaviors. Rather, the subjects are randomly assigned to a scenario that is generated by chance at an earlier point in time (in the original episode). The risk that the students would recognize the original episodes seems small, because the scenarios are not easy to remember and the original episodes were broadcasted at least six months earlier. Indeed, the experimental "Deal or No Deal" decisions are statistically unrelated to which of the remaining prizes is in the contestant's own briefcase.

Base case experiment

We replicate the original game show as closely as possible in a classroom, using a game show host (a popular lecturer at Erasmus University) and live audience (the student subjects and our research team). The design of the classroom resembles a public tribune with a large stage in front of it. In addition, video cameras are pointed at the contestant, recording all her actions. The game situation (unopened briefcases, remaining prizes, bank offers) is projected on a computer monitor in front of the stage (for the host and the contestant) and on a large screen in front of the classroom (for the audience). This setup is intended to create the type of distress that contestants must experience in the TV studio. Our approach seemed effective, because the audience was very excited and enthusiastic during the experiment, applauding and shouting hints, and most contestants showed clear symptoms of distress.

In this first experiment, the original prizes and bank offers from the Dutch edition are divided by 10,000, resulting in an average prize of roughly €40 and a maximum of €500. Original prizes and offers are not available when a subject continues play in after a "Deal" in the original episode. In these cases, prizes are selected randomly and the bank offer is set according to the pattern observed in the original show.

We randomly selected 80 business or economics students from a larger population of students at Erasmus University who applied to participate in experiments during the academic year 2005-2006. Although each experiment requires only 40 subjects, 80 students were invited to guarantee a large audience and to ensure that a sufficient number of subjects would be available in the event that some subjects would not show up. Thus, approximately half of the students were selected to play the game. To control for a possible gender effect, we ensured that the gender of the subjects matched the gender of the contestants in the original episodes.

At the beginning of the experiment, we handed out the instructions to each subject, consisting of the original instructions to contestants in the TV show plus a cover sheet explaining our experiment. Next, the games started. Each individual game lasted about 5 to 10 minutes, and the entire experiment (40 games) lasted roughly 5 hours, equally divided in an afternoon session with one half of the subjects and games and an evening session with the other half.

The overall level of risk aversion in this experiment is lower than in the original TV show. Contestants on average stop in round 6.90 vs. 5.20 for the TV show and accept higher percentage bank offers. Still, the changes seem modest given that the initial stakes are 10,000 times smaller than in the TV show. In the TV show, contestants generally become risk neutral or risk seeking when "only" thousands or tens of thousands remain at stake. In the experiment, the stakes are much smaller, but the average contestant is clearly risk averse. This suggests that the effect of stakes on risk attitudes in this game is relatively weak. By contrast, the effect of prior outcomes is even stronger than in the TV show, witness the lower "Deal" percentages of losers and winners.

The first column of Table 9 shows the maximum likelihood estimation results. The estimated utility function exhibits the same pattern of extreme IRRA as for the original shows, but now at a much smaller scale, e.g., with a CC of 0.072 for a 50/50 gamble of €0 or €1,000. It follows from Rabin's (2000) observations that plausible levels of risk aversion require much lower initial wealth levels for small-stake gambles than for large-stake gambles. Indeed, initial wealth is estimated to be €11 in this experiment, roughly a factor of 10,000 lower than for the original TV episodes. Given the extreme IRRA, it is not surprising that the model errs by predicting that the losers and winners would stop earlier than they actually do. As for the original shows, prospect theory with a sticky reference point fits the data substantially better than the expected utility model, both in terms of the log-likelihood and the hit percentage.

Large-stake experiment

The modest change in the choices in the first experiment relative to the large-stake TV show suggests that the effect of stakes is limited in this game. Of course, the classroom experiment is not directly comparable with the TV show, for example because the experiment is not broadcasted on TV and uses a different type of contestants (students). Our second experiment therefore investigates the effect of stakes by replicating the first experiment with larger stakes.

The experiment uses the same design as before, with the only difference that the original monetary amounts are divided by 1,000 rather than by 10,000, resulting in an average prize of roughly €400 and a maximum of €5,000 – extraordinary large amounts for experiments. For this experiment, 80 new subjects were drawn from the same population, excluding students involved in the first experiment.

Based on the strong IRRA in the first experiment, we would expect a much higher risk aversion in this experiment. However, the average stop round and the accepted bank offers are surprisingly similar to those of the base case experiment. Therefore, the isolated effect of stakes seems much weaker than suggested by the estimated IRRA in the individual experiments.

The second column of Table 9 displays the maximum likelihood estimation results. With increased stakes but similar choices, the expected utility model needs a different utility function to rationalize the choices. In fact, the estimated utility function seems scaled in proportion to the stakes, so that the 50/50 gamble of €0 or €1,000 now involves the same CC as the 50/50 gamble of €0 or €100 in the base-case experiment. By contrast, for prospect theory, the estimated parameters are roughly the same as for the base case and a substantially better fit is achieved relative to the implementation of expected utility theory.

In both experiments, risk aversion is strongly affected by prior outcomes, which are strongly related to stakes *within* the experiments, but stakes do not materially affect risk aversion *across* the experiments. Since the stakes are increased by a factor of 10 and all other experimental and subject conditions are held constant, the only plausible explanation seems that prior outcomes rather than stakes are the main driver of risk aversion in this game.

Laboratory experiment

The two classroom experiments replicate the distressful situation in the TV studio as closely as possible. To investigate the role of distress, we conducted a third experiment in the quiet environment of a computerized laboratory, without the stressors (show host, audience and cameras). The laboratory experiment was run in two 20-minute sessions, each with 20 students sitting behind 20 computer terminals simultaneously. Both sessions consisted of 10 minutes of instructions (the same as in the classroom experiment) and 10 minutes to play the game. Each computer monitor has a sunken screen and dividers to mitigate the ability to see what other subjects are doing.

The overall level of risk aversion in this experiment falls compared to the classroom experiments. Contestants on average stop later (round 7.93) and accept higher percentage bank offers.

The third column of Table 9 exhibits our maximum likelihood estimation results. The estimated utility function now implies a CC as high as 1 for the 50/50 gamble of €0 or €1,000.

This suggests that subjects adopt less conservative strategies in the absence of distress, consistent with the experimental findings in Mano (1994). Furthermore, as in the classroom experiments, the risk attitudes are strongly determined by prior outcomes, with a relatively high propensity to deal for losers and winners. Not surprisingly, prospect theory with a sticky reference point fits the data substantially better than expected utility theory. This shows that our path-dependent pattern is not restricted to the TV studio.

[INSERT TABLE 9 ABOUT HERE]

VII. Conclusions

The behavior of contestants in game shows cannot always be generalized to what an ordinary person does in her everyday life when making risky decisions. While the contestants have to make decisions in just a few minutes in front of millions of viewers, many real-life decisions involving large sums of money are neither made in a hurry nor in the limelight. Still, we believe that the choices in this particular game show are worthy of study, because the decision problems are simple and well-defined, and the amounts at stake are very large. Furthermore, prior to the show, contestants have had considerable time to think about what they might do in various situations and during the show they were stimulated to discuss those contingencies with a friend or relative who sits in the audience. In this sense, the choices may be more deliberate and considered than might appear at first glance. Indeed, it seems plausible that our contestants have given more thought to their choices on the show than to some of the other financial choices they have made in their lives such as selecting a mortgage or retirement savings investment strategy.

What does our analysis tell us? First, we observe, on average, what might be called “moderate” levels of risk aversion. Even when hundreds of thousands of Euros are at stake, many contestants are rejecting offers in excess of 75 percent of expected value. In an expected utility of wealth framework, this level of risk aversion for large stakes is hard to reconcile with the same moderate level of risk aversion found in small-stake experiments - both ours, and those conducted by other experimentalists. Second, although risk aversion is moderate on average, the offer people accept varies greatly among the contestants; some demonstrate strong risk aversion by stopping in the early game rounds and accepting relatively conservative bank offers, while others exhibit clear risk-seeking behavior by rejecting offers above the average remaining prize and thus deliberately entering “unfair gambles”. While some of this variation is undoubtedly due to individual differences in risk attitudes, a considerable part of the variation can be explained by the outcomes experienced by the contestants in the previous rounds of the game. Most notably, risk aversion generally decreases after prior expectations have been shattered by eliminating high-value briefcases or after earlier expectations have been surpassed by opening low-value briefcases. This path-dependent pattern occurs in all three editions of the game, despite sizeable differences in the initial stakes across the editions. "Losers" and "winners" generally have a weaker propensity to "Deal" and a stronger prosperity to "No Deal" than their "neutral" counterparts.

The lower risk aversion of game show losers and winners is also hard to explain with expected utility theory and points in the direction of reference-dependent choice theories such as prospect theory. Indeed, our findings seem consistent with the break-even effect (losers becoming more willing to take risk due to incomplete adaptation to prior losses), and the house-money effect, (a low risk aversion for winners due to incomplete adaptation to prior gains). A simple version of prospect theory with a sticky reference point explains the "Deal or No Deal" decisions in our sample substantially better than expected utility theory. These findings suggest that reference-dependence and path-dependence are important, even when the decision problems are simple and well-defined, and large real monetary amounts are at stake.

Of course, we must be careful with rejecting expected utility theory and embracing prospect theory. We use the flexible expo-power utility function, which embeds the most popular implementations of expected utility theory, and find that this function is unable to provide an explanation for the choices of losers and winners in this game show. However, a (nonstandard) utility function that has risk seeking segments and depends on prior outcomes could achieve a better fit. Such exotic specifications blur the boundary between the two theories, and we therefore do not reject or accept one of the two. Rather, our main finding is the important role of reference-dependence and path-dependence, phenomena that are often ignored in implementations of expected utility.

To investigate the isolated effects of the amounts at stake and the distress produced by having to make decisions in the limelight, we conducted a series of classroom and laboratory experiments with a homogeneous student population. In our classroom experiment designed to mimic the TV studio, a tenfold increase of the stakes does not materially affect the choices, while the break-even effect and house-money effect are strong at both stakes levels. Furthermore, the same path-dependent effects occur in our quiet laboratory experiment, suggesting that our results are not driven by decision making under distress.

This study has focused on episodes from the Netherlands, Germany and the United States, because these episodes have a very similar game format. For further research it would be interesting to collect more international data in order to obtain more degrees of freedom to analyze the effect of prior outcomes in greater detail and to examine the role of the cultural, social or economic background of the contestant. It would also be interesting to further extend our classroom and laboratory experiments. While the stakes are much smaller, experiments do allow the researcher to control contestants, rules and situations, and to more closely monitor contestants and their behavior.

Appendix: Endogenous reference point

The endogenous reference point of Kőszegi and Rabin (KR; 2006) is equal to the optimal solution to the decision problem. Since the optimal solution may be a risky alternative, the reference point in their model may be a random variable. Using this endogenously determined, stochastic reference point differs from the original interpretation of the reference point as an exogenously fixed constant. A given choice alternative is a possible solution for the decision problem (or "personal equilibrium") if it is preferred to all other alternatives when the outcomes are measured relative to this choice alternative. If multiple solutions exist, the endogenous reference point equals the optimal solution (or "preferred personal equilibrium"), that is, the solution that optimizes the objective function. The purpose of this appendix is to apply the KR model to our "Deal or No Deal" framework and to show that the current bank offer arises as the relevant reference point for identifying the optimal decision. We stress in advance that we consider a special case of the KR model. While the general model mixes a classical utility function with a value function, our analysis focuses on the value function exclusively, as in the original formulation of prospect theory. In addition, "Deal or No Deal" involves only two choice alternatives, a riskless one ("Deal") and a risky one ("No Deal"), which simplifies the analysis.

Since the contestant has to choose between "Deal" and "No Deal", the KR model forwards two relevant specifications for the reference point: (1) the current bank offer, or $B(x_r)$, and (2) the uncertain bank offer in the next round, or $B(z)$, where every $z \in X(x_r)$ occurs with probability p_r. The first specification is required to test if a "Deal" solution (DS) exists, that is, if "Deal" is preferred to "No Deal" given $RP_r = B(x_r)$. Using this specification, the value of a "Deal" is:

(A1) $$V_D^{(D)} = v(B(y) \mid B(x_r))$$

and the value of a "No Deal" is:

(A2) $$V_{ND}^{(D)} = \sum_{y \in X(x_r)} p_r v(B(y) \mid B(x_r))$$

A DS exists if $V_D^{(D)} \geq V_{ND}^{(D)}$. If this condition is violated, it follows directly that "No Deal" is the optimal solution. If a DS does exist, the KR model requires that we also test if a "No

Deal" solution (NDS) exists, that is, if "No Deal" is preferred to "Deal" if we use the second, stochastic specification. The value of a "Deal" given this specification is:

(A3) $$V_D^{(ND)} = \sum_{z \in \mathrm{X}(x_r)} p_r v(B(x_r) \mid B(z))$$

and the value of a "No Deal" is:

(A4) $$V_{ND}^{(ND)} = \sum_{y \in \mathrm{X}(x_r)} \sum_{z \in \mathrm{X}(x_r)} p_r^2 v(B(y) \mid B(z))$$

A NDS exists if $V_{ND}^{(ND)} \geq V_D^{(ND)}$. If this condition is violated, it follows directly that "Deal" is the optimal solution. If both a DS and a NDS exist, "Deal" is the optimal solution if $V_D^{(D)} > V_{ND}^{(ND)}$ and "No Deal" is optimal if $V_D^{(D)} < V_{ND}^{(ND)}$.

To summarize, the KR model requires testing if a DS exists, testing if a NDS exists and choosing from the existing solutions. However, in our special case, only testing if a DS exists is required. Specifically, it follows directly that a DS feels neutral, or $V_D^{(D)} = 0$, because the contestant does not experience gain or loss if she accepts an offer that is equal to her reference point. By contrast, a NDS always feels unpleasant due to loss aversion. Using $v(B(y) \mid B(y)) = 0$ and $v(B(y) \mid B(z)) + v(B(z) \mid B(y)) = (1 - \lambda)\left|B(y) - B(z)\right|^{\alpha}$, the value of the NDS can be rewritten as:

(A5) $$V_{ND}^{(ND)} = \sum_{z \in \mathrm{X}(x_r)} \sum_{\substack{y \in \mathrm{X}(x_r): \\ B(y) > B(z)}} p_r^2 (1 - \lambda)\left|B(y) - B(z)\right|^{\alpha}$$

In case of loss aversion, or $\lambda > 1$, we find $V_{ND}^{(ND)} < 0$. A NDS feels unpleasant, because of loss experienced every time a possible future offer is smaller than another possible future offer. Thus, a NDS is always inferior to a DS, that is, $V_{ND}^{(ND)} < V_D^{(D)} = 0$, and we only have to test if a DS exists. The contestant will select "No Deal" if and only if "No Deal" feels pleasant given $RP_r = B(x_r)$, because we already know that "Deal" feels neutral given $RP_r = B(x_r)$ and that "No Deal" feels unpleasant given the stochastic reference point. In brief, the test for existence of a DS, which uses $RP_r = B(x_r)$, is a necessary and sufficient condition for establishing the optimal solution.

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Table 1

Summary statistics

The table shows descriptive statistics for our sample of 151 contestants from the Netherlands (51; Panel A), Germany (47; Panel B) and the United States (53; Panel C). The contestants' characteristics age and education are revealed in an introduction talk or in other conversations between the host and the contestant. Age is measured in years. Gender is a dummy variable with a value of 1 assigned to females. Education is a dummy variable that takes a value of 1 for contestants with a bachelor-degree level or higher (including students) or equivalent work experience. Stop Round is the round number in which the bank offer is accepted. The round numbers from the first series of German episodes are adjusted by +1 to correct for the lower initial number of briefcases and game rounds; for contestants that played the game to the end, the stop round is set equal to 10. Best Offer Rejected is the highest percentage bank offer the contestant chose to reject ("No Deal"). Offer Accepted is the percentage bank offer accepted by the contestant ("Deal"), or 100 percent for contestants who rejected all offers. Prize Won equals the accepted bank offer in monetary terms, or the prize in the contestant's own briefcase for contestants who rejected all offers.

	Mean	Stdev	Min	Median	Max
A. Netherlands (*N* = 51)					
Age (years)	45.31	11.51	21.00	43.00	70.00
Gender (female = 1)	0.27	0.45	0.00	0.00	1.00
Education (high = 1)	0.55	0.50	0.00	1.00	1.00
Stop Round	5.22	1.75	3.00	5.00	10.00
Best Offer Rejected (%)	55.89	32.73	10.17	55.32	119.88
Offer Accepted (%)	76.27	30.99	20.77	79.29	165.50
Prize Won (€)	227,264.90	270,443.20	10.00	148,000.00	1,495,000.00
B. Germany (*N* = 47)					
Age (years)	36.47	8.17	20.00	35.00	55.00
Gender (female = 1)	0.34	0.48	0.00	0.00	1.00
Education (high = 1)	0.47	0.50	0.00	0.00	1.00
Stop Round	8.21	1.53	5.00	8.00	10.00
Best Offer Rejected (%)	89.07	33.90	37.31	88.22	190.40
Offer Accepted (%)	91.79	19.15	52.78	95.99	149.97
Prize Won (€)	20,602.56	25,946.69	0.01	14,700.00	150,000.00
C. United States (*N* = 53)					
Age (years)	34.98	10.03	22.00	33.00	76.00
Gender (female = 1)	0.57	0.50	0.00	1.00	1.00
Education (high = 1)	0.49	0.50	0.00	0.00	1.00
Stop Round	7.70	1.29	5.00	8.00	10.00
Best Offer Rejected (%)	80.98	17.57	44.04	83.52	112.00
Offer Accepted (%)	91.43	15.31	49.16	97.83	112.50
Prize Won ($)	122,544.58	119,446.18	5.00	94,000.00	464,000.00

Table 2

Bank offers and contestants' decisions

The table shows summary statistics for the percentage bank offers and contestants' decisions in our sample of 151 contestants from the Netherlands (51; Panel A), Germany (47; Panel B) and the United States (53; Panel C). The average bank offer as a percentage of the average remaining prize (%BO), the average remaining prize in Euros (Stakes) and the number of contestants (No.) are reported for each game round ($r = 1,\cdots,9$). The statistics are also shown separately for contestants accepting the bank offer ("Deal") and for contestants rejecting the bank offer ("No Deal"). The round numbers from the first series of German episodes are adjusted by +1 to correct for the lower initial number of briefcases and game rounds.

	Unconditional			"Deal"			"No Deal"		
Round	%BO	Stakes	No.	%BO	Stakes	No.	%BO	Stakes	No.
A. Netherlands (*N* = 51)									
1	6%	387,867	51	-	-	0	6%	387,867	51
2	14%	376,664	51	-	-	0	14%	376,664	51
3	34%	369,070	51	36%	409,802	10	33%	359,135	41
4	61%	348,820	41	69%	394,860	11	58%	331,939	30
5	77%	317,618	30	82%	557,680	7	76%	244,555	23
6	88%	234,877	23	90%	237,416	12	87%	232,107	11
7	98%	243,868	11	104%	414,106	6	91%	39,582	5
8	96%	50,376	5	100%	78,401	3	90%	8,338	2
9	106%	11,253	2	91%	17,500	1	120%	5,005	1
B. Germany (*N* = 47)									
1	8%	24,277	27	-	-	0	8%	24,277	27
2	15%	24,915	47	-	-	0	15%	24,915	47
3	34%	23,642	47	-	-	0	34%	23,642	47
4	46%	21,218	47	-	-	0	46%	21,218	47
5	59%	22,304	47	59%	29,976	2	59%	21,963	45
6	72%	20,557	45	67%	48,038	7	73%	15,494	38
7	88%	15,231	38	85%	21,216	5	88%	14,324	33
8	98%	15,545	33	91%	28,813	10	101%	9,776	23
9	103%	14,017	23	109%	13,925	11	99%	14,101	12
C. United States (*N* = 53)									
1	11%	152,551	53	-	-	0	11%	152,551	53
2	21%	151,885	53	-	-	0	21%	151,885	53
3	36%	147,103	53	-	-	0	36%	147,103	53
4	50%	148,299	53	-	-	0	50%	148,299	53
5	62%	148,832	53	79%	118,517	1	61%	150,434	52
6	73%	150,549	52	74%	139,421	9	73%	152,879	43
7	88%	154,875	43	91%	204,263	15	86%	128,416	28
8	92%	114,281	28	96%	183,917	14	88%	44,644	14
9	98%	39,922	14	99%	53,825	8	97%	21,384	6

Table 3

Example "Frank"

The table shows the gambles presented to a Dutch contestant named Frank and the "Deal or No Deal" decisions made by him in game round one to nine. This particular episode was broadcasted on January 1, 2005. For each game round, the table shows the remaining prizes, the average remaining prize, the bank offer, the percentage bank offer and the "Deal or No Deal" decision. Frank ended up with a prize of €10.

	Game Round (*r*)								
Prize (€)	1	2	3	4	5	6	7	8	9
0.01	x	x							
0.20	x	x							
0.50	x	x	x	x	x	x	x		
1	x	x	x	x	x				
5									
10	x	x	x	x	x	x	x	x	x
20	x	x	x	x	x	x	x	x	
50									
100									
500									
1,000	x								
2,500	x	x	x						
5,000	x	x							
7,500									
10,000	x	x	x	x	x	x	x	x	x
25,000	x	x							
50,000	x	x	x	x					
75,000	x	x	x						
100,000	x	x	x						
200,000	x	x	x	x					
300,000	x								
400,000	x								
500,000	x	x	x	x	x	x			
1,000,000	x								
2,500,000									
5,000,000	x								
Average (€)	383,427	64,502	85,230	95,004	85,005	102,006	2,508	3,343	5,005
Offer (€)	17,000	8,000	23,000	44,000	52,000	75,000	2,400	3,500	6,000
Offer (%)	4%	12%	27%	46%	61%	74%	96%	105%	120%
Decision	No Deal	No Deal	No Deal	No Deal	No Deal	No Deal	No Deal	No Deal	No Deal

Table 4

Example “Susanne”

The table shows the gambles presented to a German contestant named Susanne and the “Deal or No Deal” decisions made by her in game round one to nine. This particular episode was broadcasted on August 23, 2006. For each game round, the table shows the remaining prizes, the average remaining prize, the bank offer, the percentage bank offer, and the “Deal or No Deal” decision. Susanne ended up with a prize of €150,000.

	Game Round (*r*)								
Prize (€)	1	2	3	4	5	6	7	8	9
0.01	X	X	X	X					
0.20	X	X	X						
0.50	X	X	X	X	X	X	X		
1									
5									
10									
20	X	X							
50	X	X							
100	X	X	X	X					
200									
300	X	X	X						
400	X								
500									
1,000	X	X	X	X	X	X	X	X	
2,500	X	X	X	X	X	X			
5,000	X								
7,500									
10,000	X	X							
12,500	X	X	X						
15,000	X								
20,000	X	X							
25,000	X	X	X	X	X				
50,000	X								
100,000	X	X	X	X	X	X	X	X	X
150,000	X	X	X	X	X	X	X	X	X
250,000	X								
Average (€)	32,094	21,431	26,491	34,825	46,417	50,700	62,750	83,667	125,000
Offer (€)	3,400	4,350	10,000	15,600	25,000	31,400	46,000	75,300	125,000
Offer (%)	11%	20%	38%	45%	54%	62%	73%	90%	100%
Decision	No Deal	No Deal	No Deal	No Deal	No Deal	No Deal	No Deal	No Deal	No Deal

Table 5

"Deal or No Deal" decisions after bad and good fortune

The table summarizes the "Deal or No Deal" decisions for our sample of 151 contestants from the Netherlands (51; Panel A), Germany (47; Panel B) and the United States (53; Panel C). The samples are split based on the fortune experienced during the game. A contestant is classified as a "loser" if her average remaining prize after eliminating the lowest remaining prize is among the worst one-third for all contestants in the same game round; she is a "winner" if the average after eliminating the largest remaining prize is among the best one-third. For each category and game round, the table displays the percentage bank offer (%BO), the number of contestants (No.) and the percentage of contestants choosing "Deal" (%D). The round numbers from the first series of German episodes are adjusted by +1 to correct for the lower initial number of briefcases and game rounds.

	Loser			Neutral			Winner		
Round	%BO	No.	%D	%BO	No.	%D	%BO	No.	%D
A. Netherlands (N = 51)									
1	6%	17	0%	6%	17	0%	6%	17	0%
2	15%	17	0%	12%	17	0%	15%	17	0%
3	40%	17	12%	29%	17	41%	31%	17	6%
4	69%	14	14%	58%	13	46%	54%	14	21%
5	82%	10	10%	71%	10	20%	78%	10	40%
6	94%	8	50%	85%	7	43%	86%	8	63%
7	99%	4	25%	97%	3	67%	99%	4	75%
8	105%	1	0%	91%	3	67%	100%	1	100%
9	120%	1	0%	-	0	-	91%	1	100%
2 - 9		72	14%		70	31%		72	25%
B. Germany (N = 47)									
1	7%	9	0%	7%	9	0%	8%	9	0%
2	16%	16	0%	13%	15	0%	14%	16	0%
3	35%	16	0%	33%	15	0%	33%	16	0%
4	46%	16	0%	44%	15	0%	47%	16	0%
5	65%	16	0%	54%	15	13%	57%	16	0%
6	83%	15	0%	67%	15	20%	66%	15	27%
7	107%	13	0%	80%	12	25%	76%	13	15%
8	117%	11	0%	89%	11	55%	86%	11	36%
9	107%	8	38%	106%	7	57%	98%	8	50%
2 - 9		111	3%		105	17%		111	13%
C. United States (N = 53)									
1	9%	18	0%	10%	17	0%	13%	18	0%
2	19%	18	0%	19%	17	0%	25%	18	0%
3	41%	18	0%	29%	17	0%	39%	18	0%
4	57%	18	0%	42%	17	0%	51%	18	0%
5	69%	18	0%	55%	17	6%	62%	18	0%
6	78%	18	11%	68%	16	31%	73%	18	11%
7	92%	15	27%	87%	13	23%	84%	15	53%
8	94%	9	22%	95%	10	70%	87%	9	56%
9	92%	4	50%	101%	6	67%	99%	4	50%
2 - 9		118	8%		113	18%		118	14%

Table 6

Expected utility theory results

The table displays the estimation results of expected utility theory for our sample of 151 contestants from The Netherlands (51), Germany (47) and the United States (53). Shown are maximum likelihood estimators for the α and β parameters and the wealth level (W, in Euros) of the utility function (3), and the noise parameter σ. The table also shows the overall mean log-likelihood (MLL), the likelihood ratio (LR) relative to the naïve model of risk neutrality, the percentage of correctly predicted "Deal or No Deal" decisions (Hits), and the total number of "Deal or No Deal" decisions in the sample (No.). Finally, the implied certainty coefficient (CC; certainty equivalent as a fraction of the expected value) is shown for 50/50 gambles of €0 or €10^z, z = 3, 4, 5, 6. *P*-values are shown in brackets.

	Netherlands		Germany		United States	
α	0.424	(0.000)	1.58e-05	(0.049)	4.18e-05	(0.000)
β	0.791	(0.000)	0.000	(1.000)	0.171	(0.000)
W	75,203	(0.034)	544	(0.481)	101,898	(0.782)
σ	0.428	(0.000)	0.467	(0.000)	0.277	(0.000)
MLL	-0.365		-0.340		-0.260	
LR	24.29	(0.000)	3.95	(0.267)	15.10	(0.002)
Hits	76%		85%		89%	
No.	214		327		349	
CC (0/10^3)	0.994		0.996		0.998	
CC (0/10^4)	0.946		0.960		0.984	
CC (0/10^5)	0.637		0.640		0.859	
CC (0/10^6)	0.141		0.088		0.302	

Table 7

Path dependence

The table shows the estimation results of expected utility theory for our sample of 151 contestants from the Netherlands (51; Panel A), Germany (47; Panel B) and the United States (53; Panel C). The samples are split based on the fortune experienced during the game. A contestant is classified as a "loser" if her average remaining prize after eliminating the lowest remaining prize is among the worst one-third for all contestants in the same game round; she is a "winner" if the average after eliminating the largest remaining prize is among the best one-third. Shown are maximum likelihood estimators for the α and β parameters and the wealth level (W, in Euros) of the utility function (3), and the noise parameter σ. The table also shows the overall mean log-likelihood (MLL), the percentage of correctly predicted "Deal or No Deal" decisions (Hits), and the total number of "Deal or No Deal" decisions in the sample (No.). Finally, the implied certainty coefficient (CC; certainty equivalent as a fraction of the expected value) is shown for 50/50 gambles of €0 or €10^z, z = 3, 4, 5, 6. P-values are shown in brackets.

	Loser		Neutral		Winner	
A. Netherlands						
α	-244.904	(0.022)	0.044	(0.204)	0.125	(0.831)
β	0.993	(0.000)	0.687	(0.000)	0.736	(0.011)
W	0	(1.000)	304	(0.671)	3061	(0.824)
σ	0.627	(0.000)	0.323	(0.000)	0.309	(0.000)
MLL	-0.300		-0.383		-0.325	
Hits	89%		81%		83%	
No.	72		70		72	
CC (0/10^3)	1.347		0.723		0.928	
CC (0/10^4)	1.355		0.392		0.630	
CC (0/10^5)	1.363		0.150		0.216	
CC (0/10^6)	1.371		0.032		0.035	
B. Germany						
α	-7.914	(0.117)	0.364	(0.000)	0.087	(0.000)
β	0.814	(0.000)	0.759	(0.000)	0.651	(0.000)
W	930	(0.825)	50926	(0.481)	113582	(0.180)
σ	0.659	(0.000)	0.241	(0.000)	0.454	(0.000)
MLL	-0.276		-0.257		-0.278	
Hits	90%		87%		88%	
No.	111		105		111	
CC (0/10^3)	1.584		0.990		0.995	
CC (0/10^4)	1.823		0.911		0.949	
CC (0/10^5)	1.891		0.485		0.614	
CC (0/10^6)	1.929		0.072		0.101	
C. United States						
α	-203.512	(0.006)	1.96e-05	(0.000)	0.938	(0.000)
β	0.995	(0.000)	0.086	(0.000)	0.998	(0.000)
W	54	(0.691)	934904	(0.331)	29468	(0.107)
σ	0.193	(0.000)	0.308	(0.000)	0.326	(0.000)
MLL	-0.194		-0.275		-0.253	
Hits	92%		86%		91%	
No.	118		113		118	
CC (0/10^3)	1.054		0.999		0.992	
CC (0/10^4)	1.071		0.986		0.927	
CC (0/10^5)	1.081		0.863		0.646	
CC (0/10^6)	1.089		0.252		0.289	

Table 8

Prospect theory results

The table shows the estimation results of prospect theory for our sample of 151 contestants from The Netherlands (51), Germany (47) and the United States (53). Shown are maximum likelihood estimators for the loss aversion (λ) and curvature (α) of the value function, the three parameters of the reference point model θ_1, θ_2 and θ_3, and the noise parameter σ. The table also shows the overall mean log-likelihood (MLL), the likelihood ratio (LR) relative to the naïve model of risk neutrality, the percentage of correctly predicted "Deal or No Deal" decisions (Hits), and the total number of "Deal or No Deal" decisions in the sample (No.). *P*-values are shown in brackets.

	Netherlands		Germany		United States	
λ	2.375	(0.013)	4.501	(0.008)	4.528	(0.001)
α	0.516	(0.000)	0.486	(0.000)	0.836	(0.000)
θ_1	0.474	(0.000)	1.096	(0.000)	1.163	(0.000)
θ_2	-0.285	(0.000)	-0.026	(0.000)	0.031	(0.329)
θ_3	-0.028	(0.000)	-0.052	(0.000)	-0.093	(0.023)
σ	0.345	(0.000)	0.533	(0.000)	0.193	(0.000)
MLL	-0.309		-0.303		-0.228	
LR	48.41	(0.000)	27.44	(0.000)	37.28	(0.000)
Hits	85%		89%		91%	
No.	214		327		349	

Table 9

Experimental results

The table shows the estimation results for our three experiments. The first column (Base case) displays the results for the classroom experiment with the original monetary amounts in the Dutch TV format of "Deal or No Deal" divided by 10,000, the second column (Large stakes) displays the results for the classroom experiment with prizes scaled down by a factor of 1,000, and the third column (Lab) displays the results for the laboratory experiment with prizes scaled down by a factor of 1,000. Panel A shows the results for expected utility theory. Shown are maximum likelihood estimators for the α and β parameters and the wealth level (W, in Euros) of the utility function (3), and the noise parameter σ. Panel B shows the results for prospect theory. Shown are maximum likelihood estimators for the loss aversion (λ) and curvature (α) of the value function (12), the three parameters of the reference point model θ_1, θ_2 and θ_3, and the noise parameter σ. Both panels also include the overall mean log-likelihood (MLL), the likelihood ratio (LR) relative to the naïve model of risk neutrality, the percentage of correctly predicted "Deal or No Deal" decisions (Hits), and the total number of "Deal or No Deal" decisions in the sample (No.). For expected utility theory, the implied certainty coefficient (CC; certainty equivalent as a fraction of the expected value) is shown for 50/50 gambles of €0 or €10^z, z = 0, 1, 2, 3. P-values are shown in brackets.

	Base case		Large stakes		Lab	
A. Expected utility theory						
α	0.019	(0.000)	1.87e-03	(0.001)	1.67e-07	(0.000)
β	0.000	(1.000)	0.000	(1.000)	0.000	(1.000)
W	11	(0.920)	50	(0.930)	5	(0.920)
σ	0.306	(0.000)	0.294	(0.000)	0.342	(0.000)
MLL	-0.342		-0.337		-0.365	
LR	10.17	(0.017)	10.14	(0.017)	0.06	(0.996)
Hits	81%		83%		80%	
No.	231		234		268	
CC ($0/10^0$)	0.995		1.000		1.000	
CC ($0/10^1$)	0.953		0.995		1.000	
CC ($0/10^2$)	0.583		0.953		1.000	
CC ($0/10^3$)	0.072		0.588		1.000	
B. Prospect theory						
λ	2.307	(0.000)	2.678	(0.000)	1.597	(0.003)
α	0.732	(0.000)	0.695	(0.000)	0.569	(0.000)
θ_1	1.045	(0.000)	1.024	(0.000)	1.018	(0.000)
θ_2	-0.119	(0.000)	0.019	(0.000)	0.010	(0.119)
θ_3	-0.086	(0.000)	-0.046	(0.000)	-0.050	(0.000)
σ	0.267	(0.000)	0.196	(0.000)	0.299	(0.000)
MLL	-0.275		-0.265		-0.244	
LR	40.94	(0.000)	44.04	(0.000)	64.77	(0.000)
Hits	87%		88%		90%	
No.	231		234		268	

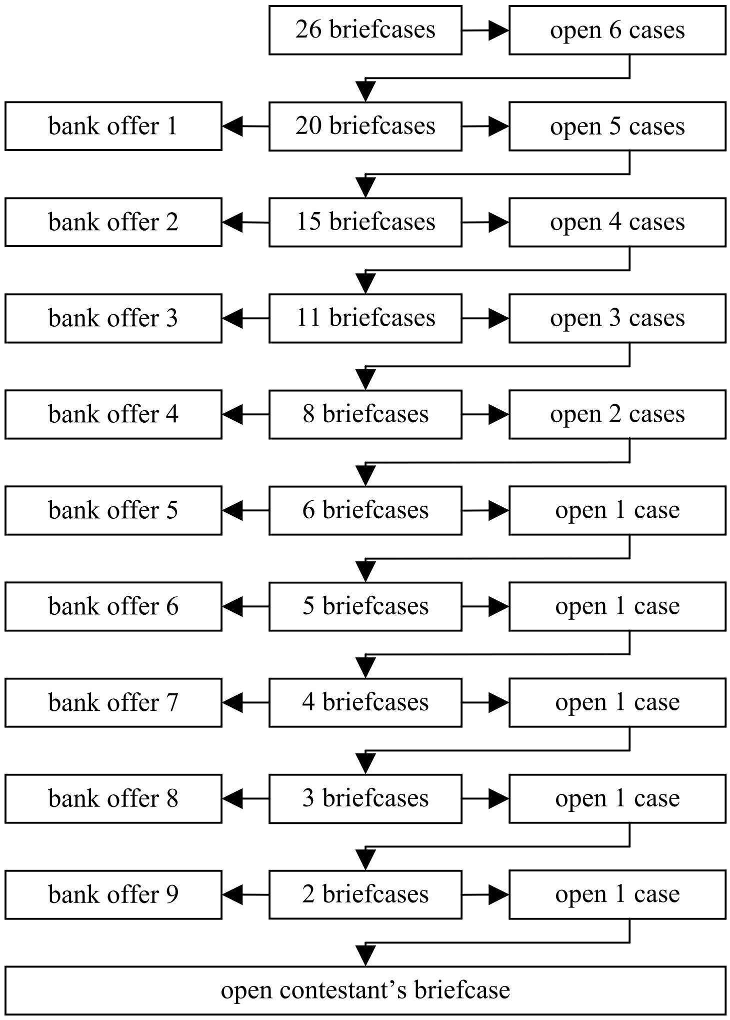

Figure 1: Flow chart of the main game. In each round, the finalist chooses a number of briefcases to be opened, each opened briefcase giving new information about the unknown prize in the contestant's own briefcase. After the prizes in the chosen briefcases are revealed, a "bank offer" is presented to the finalist. If the contestant accepts the offer ("Deal"), she walks away with the amount offered and the game ends; if the contestant rejects the offer ("No Deal"), play continues and she enters the next round. If the contestant decides "No Deal" in the ninth round, she receives the prize in her own briefcase. The flow chart applies to the Dutch and US edition, and the second German series. The first German series involves eight game rounds and starts with 20 briefcases.

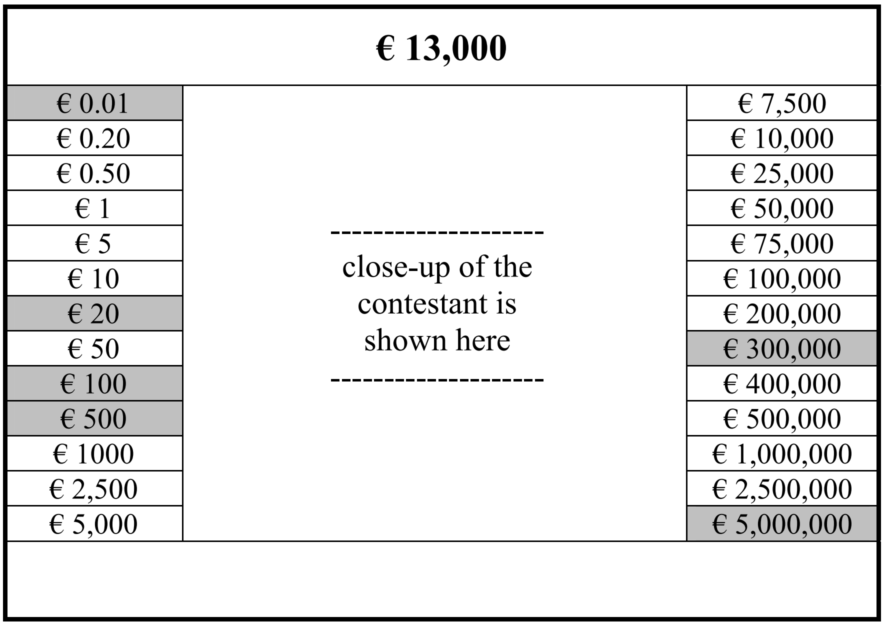

Figure 2: Example of the main game as displayed on the TV screen. A close-up of the contestant is shown in the center of the screen. The possible prizes are listed in the columns to the left and right of the contestant. Prizes eliminated in earlier rounds are shown in a dark color and remaining prizes are in a bright color. The top bar above the contestant shows the bank offer. This example demonstrates the two options open to the contestant after opening six briefcases in the first round: accept a bank offer of €13,000 or continue to play with the remaining 20 briefcases, one of which is the contestant's own. This example reflects the prizes in the Dutch episodes.

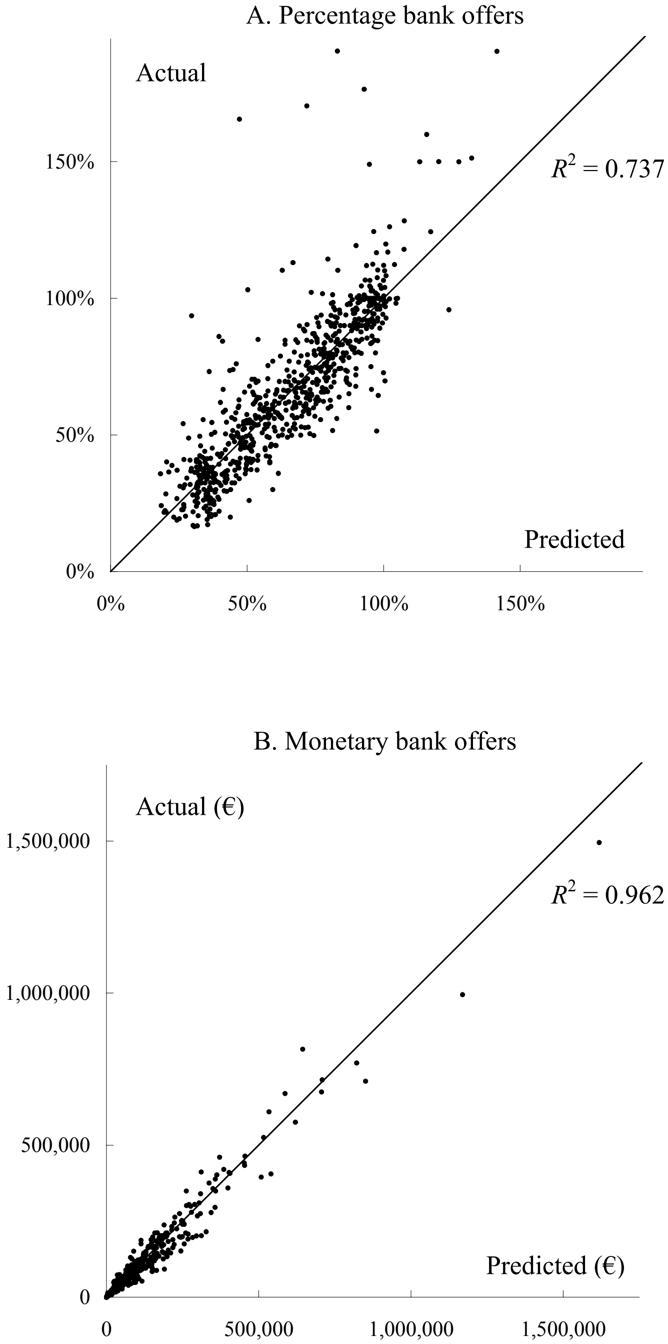

Figure 3: Predicted bank offers versus actual bank offers. The figure displays the goodness of our bank offer model by plotting the predicted bank offers versus the actual bank offers for all relevant game rounds in our pooled sample of 151 contestants from the Netherlands, Germany and the US. Panel A shows the fit for the percentage bank offers and Panel B shows the fit for the monetary bank offers (in Euros). A 45-degree line (perfect fit) is added for the ease of interpretation.

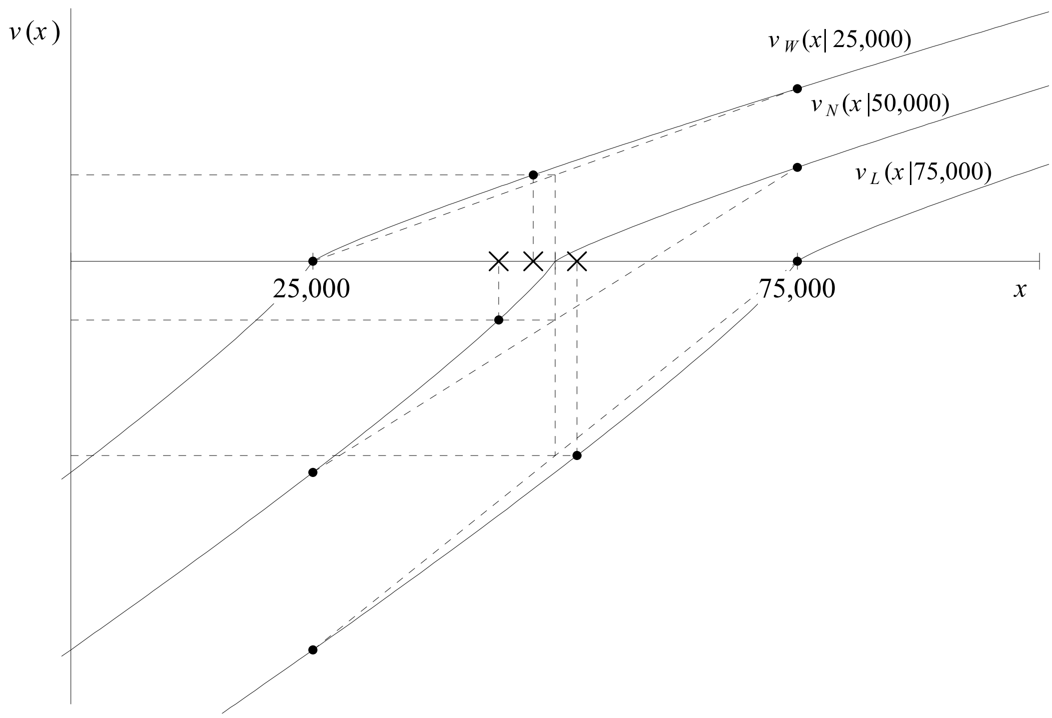

Figure 4: Break-even and house-money effects in prospect theory. The figure displays the prospect value function (12) for three different levels of the reference point (*RP*) and the associated certainty equivalents (*CE*) for a 50/50 gamble of €25,000 or €75,000. Value function $v_N(x|50{,}000)$ refers to a neutral situation with RP_N = €50,000 and CE_N = €44,169, $v_W(x|25{,}000)$ to a winner with RP_W = €25,000 and CE_W = €47,745, and $v_L(x|75{,}000)$ to a loser with RP_L = €75,000 and CE_L = €52,255. All three value functions are based on the parameter estimates of Tversky and Kahneman (1992), or $\alpha = 0.88$ and $\lambda = 2.25$. The crosses indicate the certainty equivalents for the 50/50 gamble.

Notes

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[2] In the U.S. version and in the second German series, three or four friends and/or relatives sit on stage nearby the contestant. In the Dutch version and in the first German series, only one person accompanies the contestant.

[3] An earlier edition called "*Der MillionenDeal*" started on May 1, 2004. The initial average prize was €237,565 and the largest prize was €2,000,000. This edition however lasted for only 6 episodes and is therefore not included here.

[4] A spokesman from Endemol, the production company, confirmed that the guidelines for bank offers are the same for all three editions included in our sample.

[5] To account for the variation in the initial set of prizes within each edition (see Section II), BC_r and BW_r are scaled by the initial average prize.