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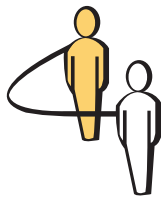
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# Deal or No Deal: A Spreadsheet Game to Introduce Decision Making Under Uncertainty

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In this paper, I introduce a spreadsheet-based implementation of the game show Deal or No Deal. I describe how this game can be used in class to illuminate topics in decision making under uncertainty to students in both engineering and business. I show that specific scenarios encountered in the game can lead to rich discussions on topics like risk, utility, and probability. The game is easy to learn and play in class and usually receives a strong positive response from students.

*Key words:* teaching decision analysis, spreadsheet modeling, classroom games, risk, utility, probability

*History:* Received: August 2012; accepted: December 2012.

## 1. Introduction

Decision making under uncertainty is a core operations research concept that is often introduced through simple models like decision trees. Although decision trees and the expected value decision criterion may be fairly intuitive to the beginner student, concepts like risk and utility, because they speak to an individual's preferences, may be better introduced through a game where students need to make decisions as the game unfolds.

This paper describes the development and use of a spreadsheet-based version of the game show Deal or No Deal, which illustrates decision analysis concepts like risk and utility in a stimulating manner. I developed this spreadsheet in 2006. At the time, I was a teaching assistant in an MBA course at the Massachusetts Institute of Technology (MIT) that covered topics including decision analysis, statistics, and optimization. In developing this spreadsheet, my goal was to introduce decision analysis in a fun and interactive way and create a stronger link between class material and real-life decision problems. Note that Deal or No Deal was one of the most watched TV shows back in 2006 (Brooks and Marsh 2007).

One of the primary goals of this paper is to encourage more widespread use of games such as this one to teach operations research concepts. In my experience, using a game to motivate and demonstrate mathematical concepts leads to more active student engagement, which is widely believed to improve student learning and development (Astin 1984). Furthermore, by thoughtfully implementing a game in

a classroom, instructors are engaging in many of the well-documented principles believed to reflect good practice in teaching, such as encouraging student-faculty contact, developing cooperation among students, and participating in active learning (Chickering and Gamson 1987). A benefit of embedding the game within a spreadsheet environment is the possibility of customization by users who wish to modify the game and conduct what-if and other numerical analyses. Giving students the ability to replay and manipulate the game off-line provides an opportunity to further reinforce the concepts discussed in class.

The Deal or No Deal game show has generated a lot of data for academic research. For example, Andersen et al. (2008) reviews the use of TV game show data to study risk attitudes, focusing on Deal or No Deal as a case study along with other game shows. De Roos and Sarafidis (2010) reported significant heterogeneity in risk preferences among contestants in the Australian version, and Deck et al. (2008) noted that contestants in the Mexican version generally exhibited higher risk aversion, possibly due to economic and cultural factors. Post et al. (2008) suggest that prospect theory better explains behavior observed by contestants than expected utility theory. In particular, they note that outcomes from previous rounds of the game influence behavior in future rounds—a phenomenon that I have also witnessed in class.

The rest of the paper is organized as follows. Section 2 provides background on the U.S. version of the TV game show. Section 3 describes the corresponding spreadsheet implementation. Section 4 provides

context on how the game is played in class, and §5 provides multiple examples of topics that can be discussed with the aid of the spreadsheet. I provide some thoughts on the assessment of this game to date in §6 and offer conclusions in §7. In the appendix, I provide example problems that instructors could pair with the spreadsheet to be examined in class or as homework assignments.

## 2. Deal or No Deal Background

Deal or No Deal is a popular TV game show that originated in the Netherlands in 2000. A U.S. version hosted by Howie Mandel premiered in 2005 on NBC. The spreadsheet-based game described in this paper is based on the U.S. version. The game involves a set of 26 briefcases, each containing a different dollar amount from \$0.01 to \$1,000,000 (see Table 1). At the start of the game, the contestant chooses one briefcase and then starts opening the other briefcases one at a time. Each briefcase that is opened provides information, by elimination, on what is in the contestant's briefcase. In the first round, the contestant opens six briefcases in a row, and then the "banker" will make the contestant an offer to buy his/her briefcase. If the contestant accepts ("Deal"), then the game ends and the contestant wins the amount offered by the banker. If the contestant rejects ("No Deal"), the second round begins. In the second round, the contestant must open five briefcases in a row before the next banker offer, and so on. In the sixth round and beyond, the contestant only opens one new briefcase before the banker makes an offer. The game ends either when the contestant accepts an offer or when all briefcases have been opened. If the contestant accepts an offer by the banker, the host usually keeps the game going by asking the contestant what briefcases s/he would have chosen next, in order to find out whether s/he made a good deal (i.e., if subsequent offers would have been lower had s/he not taken the deal and kept playing). If the game reaches the situation where

only two briefcases remain—the one the contestant initially chose and one other—the contestant is given an opportunity to switch briefcases.

On the game show, the banker's offers in the early rounds tend to be substantially less than the expected value of the remaining dollar amounts in play. The exact formula by which the offers are calculated is unknown. I believe offers are calculated as a fraction of the expected value of the remaining dollar amounts (Post et al. 2008 make a similar observation, supported by a conversation they had with a spokesperson from the show's production company). Furthermore, this fraction tends to increase as the game progresses. On rare occasions, offers have been observed to exceed the expected value. This only seems to occur near the end of the game when the contestant eliminates the final large dollar amount, typically \$100,000 or more, leaving only small amounts. I suspect this is done to soften the blow of losing out on a big payoff. In these situations, it seems that contestants rarely take the deal and typically play all the way to the end with a risk-seeking attitude (Post et al. 2008). Interestingly, the banker in the Italian version of the game makes offers strategically with knowledge of the contents of the contestant's briefcase (Bombardini and Trebbi 2012; e.g., higher offers when the contestant holds a more valuable briefcase). The U.S. version and other versions do not seem to have such an omniscient banker.

## 3. Spreadsheet Implementation

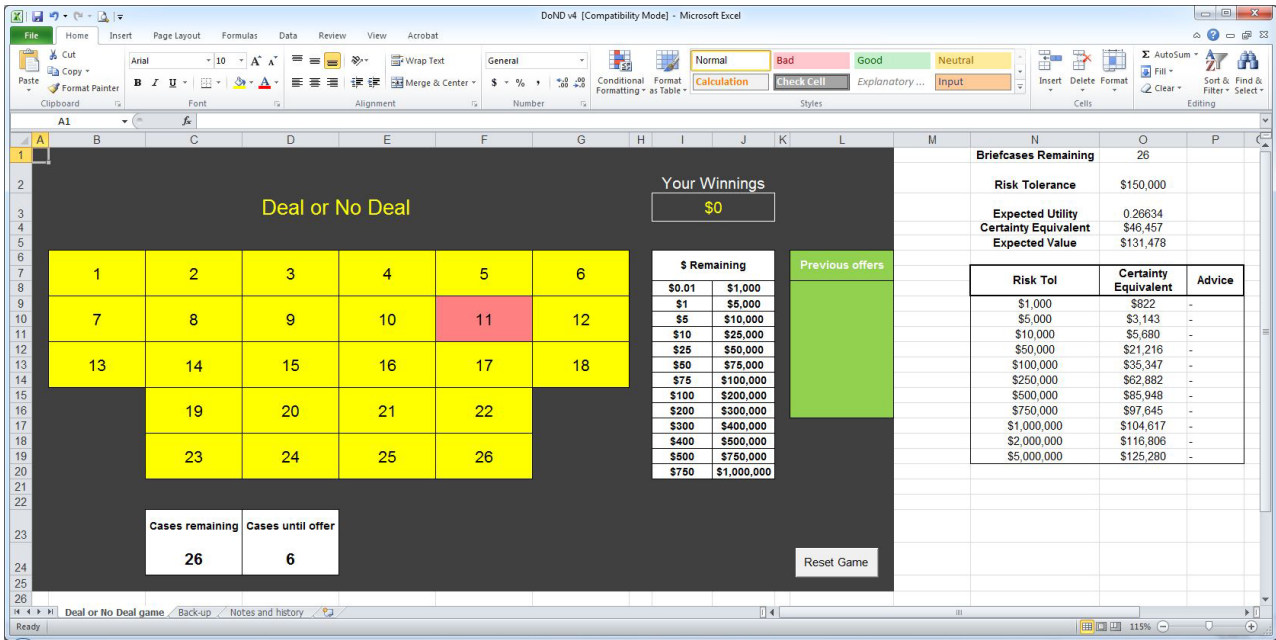
The spreadsheet version of the game<sup>1</sup> follows the structure of the U.S. game show faithfully, with the exception that the option to switch briefcases at the very end is omitted. When the spreadsheet application is first opened, the active tab is the "Deal or No Deal game" tab and a pop-up window describes the basic rules of the game. Once the "Start" button is clicked, the application will prompt the contestant to choose a briefcase by clicking on the game board. Clicking the first briefcase turns it pink (see Figure 1). Subsequent clicks on another briefcase will reveal the dollar amount contained within it. To keep the game board clean and tidy, this dollar amount is shown for only a few seconds before disappearing. The banker's offer is made via a pop-up window at the appropriate time and the contestant will be asked to choose between "Deal" or "No Deal." If the player chooses to accept the banker's offer, the game gives the contestant the option to keep opening briefcases to see

**Table 1** The Dollar Amounts in the Briefcases

0.01	1,000
1	5,000
5	10,000
10	25,000
25	50,000
50	75,000
75	100,000
100	200,000
200	300,000
300	400,000
400	500,000
500	750,000
750	1,000,000

<sup>1</sup> The spreadsheet DoND\_v4.xls is available at <http://dx.doi.org/10.1287/ited.2013.0104>. It was developed in Windows and has not been thoroughly tested in other operating systems. You will need to enable macros to be able to run the game.

Figure 1 A Screenshot of the Game Board at the Start of the Game



what future offers would have been and what is in the original briefcase.

A “Reset Game” button allows the contestant to start the game over at any time, randomizing the dollar amounts in the briefcases. Information on the number of briefcases remaining, the number of briefcases that must be opened until the next banker offer, the remaining dollar amounts in play, and the previous offers made are shown on the game board. To the right of the game board, the expected value of the remaining dollar amounts is shown. Based solely on the remaining dollar amounts in play, the game will calculate the contestant’s expected utility and certainty equivalent using an exponential utility function and a user-chosen value that represents the contestant’s risk tolerance (see appendix). Furthermore, there is a table that performs certainty equivalent calculations for a menu of risk tolerances and provides advice on whether to choose “Deal” or “No Deal” depending on the amount of the banker’s offer. Note that proper analysis of the decisions prior to the last stage requires an assumption on how future offers are calculated. For example, even if an offer exceeds the certainty equivalent in some round, it may be optimal to reject the deal because future offers could be calculated as a higher fraction of the expected value of the remaining amounts.

The “Back-up” tab contains the discount schedule used to calculate the banker’s offer. Each offer is discounted from the expected value of the remaining dollar amounts according to the numbers shown in Table 2. For example, the first offer is half of the expected value of the remaining dollar amounts

Table 2 The Discount Schedule Used to Calculate Banker Offers

Offer no.	Discount
1	0.5
2	0.5
3	0.6
4	0.6
5	0.7
6	0.7
7	0.8
8	0.9
9	0.99
10	0.99

in the game. This schedule can be altered by the instructor/user. Other supporting functionality is also included in this tab but is not meant to be altered.

#### 4. Playing the Game in Class

In class, I have the students all play together on one team. I ask for a student volunteer to choose the initial briefcase and then for other students to start suggesting briefcases to open. When the banker makes an offer, the decision whether to accept or reject is based on a class-wide vote. Early on, the class is invariably in favor of “No Deal.” Toward the end, when the class is divided, students debate before voting. I ask a student in favor of “Deal” to offer his/her reason and then a student in favor of “No Deal” to offer his/hers. After hearing the arguments, the students vote. This exercise challenges students to justify their decisions



to their peers and requires a thoughtful analysis of the consequences of their choice. I find this process to be a very good learning experience for the students. I can help them refine their reasoning by playing devil's advocate or asking about tacit assumptions they are making. For example, to students who want to reject the current deal because there are many small value briefcases remaining, I might ask them "how much will the offer decrease if you eliminate a large amount in the next round?" and "what is the likelihood of eliminating a large amount in the next round?" This leads to a discussion about probabilities versus expected values (see §5.3.1).

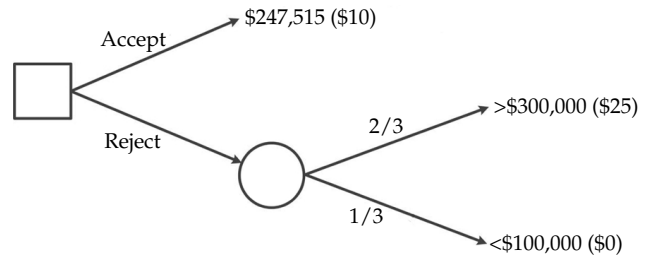
Although I cannot offer the students real money in the same dollar amounts as the TV show, I believe it is critical for them to have something tangible to play for in order to encourage them to play honestly (and not just reject every offer until the end). To this end, I offer bookstore gift cards with values linked to the final dollar amount they win from the game. Specifically, I offer \$25 gift cards to two randomly chosen students if they win at least \$300,000 from the game, \$10 gift cards to two randomly chosen students if they win at least \$100,000, and nothing if they win less than \$100,000. I think that offering multiple gift cards encourages more students to be active in the game. It is important to stress that the class does not split the prize. If the splitting mechanism is nontrivial, it could lead to more complicated dynamics in both the decision making process and the discussion.

#### 4.1. Classroom Context

At the University of Toronto, I currently use the Deal or No Deal game in an undergraduate industrial engineering course that covers basic topics in decision analysis, Markov chains, random processes, and queuing. I use the game in the first lecture of the course to review topics like probability and expected value (a course in probability is a prerequisite to this course) and to motivate concepts they will learn in the upcoming decision analysis module.

This game is also relevant in a business school. It has been used at MIT's Sloan School of Management in a core MBA course (six sections of approximately 60 students) that covers decision analysis, statistics, and optimization. The game is delivered during recitation sessions run by the teaching assistants in order to engage students in topics like decision trees (e.g., Figure 2), risk, and probability distributions. The game has also been used in an MBA course at the Fuqua School of Business at Duke University. Because students clearly understand the dilemmas that arise in the game, it can be used to illustrate calculations like certainty equivalence, which can then be further explored by the students using a copy of the spreadsheet off-line.

**Figure 2** The Decision Faced by Students with The \$50, \$75,000, and \$750,000 Briefcases Remaining



Note. In-game dollar amounts shown on the branches with gift card amounts in parentheses.

## 5. Teaching Situations

In this section, I describe concepts that can be illustrated using the spreadsheet game and some examples of classroom situations that I have encountered. Because I play this game with students during the first lecture, before they have had formal instruction in decision analysis topics, my primary goal is to pique the students' curiosity.

### 5.1. Risk and Utility

It is easy to illustrate risk, utility, and other related concepts using the Deal or No Deal game and some well-planned discussion. Consider the following scenario, which is summarized in Figure 2. There are three briefcases remaining with the dollar amounts \$50, \$75,000, and \$750,000. The current offer from the banker is \$247,515 (i.e., 90% of the expected value of the remaining dollar amounts, according to the discount schedule in Table 2). If the class accepts the offer, each student will have a chance to win one of two \$10 gift cards. If the students reject the offer and open one more briefcase, they have a 2/3 chance of eliminating one of the small value briefcases, most likely increasing their next offer above \$300,000, which is worth two \$25 gift cards. Students tend to correctly assume that at this stage of the game the offers are roughly equal to the expected value of the remaining dollar amounts. If they eliminate the large dollar amount remaining, their next offer will definitely be less than \$100,000 and they will win no gift cards. I have encountered this exact situation and other similar ones in the past. A rich discussion typically ensues.

Students who argue to accept the current deal commonly express a preference toward winning a "sure thing" (\$10) as opposed to taking a chance to win more (\$25). By pointing out that these students are proposing to accept a deal worth less than the expected value of rejecting the deal, the concept of risk aversion is naturally illustrated. This could also transition into a discussion on the shape of one's utility function and its relationship with risk attitude. Without formally defining a utility function,

but assuming students understand expected value, an instructor could write the equation  $u(10) > 2/3u(25) + 1/3u(0)$  to express the student's preference of "Deal" over "No Deal." After arguing that  $u(0) = 0$  and  $u(25) = 1$  and drawing a straight line between  $(0, 0)$  and  $(25, 1)$ , it is easy to show that  $(10, u(10))$  lies above the line. The connection between the shape of a utility function (e.g., concave) and the decision maker's risk attitude (e.g., risk averse) can be made in a later lecture, referencing this situation.

## 5.2. Advanced Topics in Risk and Utility

Depending on the flavor of the course and the interests of the instructor, Deal or No Deal can provide a platform to discuss a variety of advanced topics in decision analysis. For example, although decision analysis is a normative theory of decision making (i.e., a theory about determining optimal decisions built from a set of axioms), there exists a substantial amount of literature on descriptive or behavioral decision theory (i.e., how people have been observed to make decisions). To avoid confusion, an instructor may wish to stick with topics from the normative theory when playing and dissecting the game. This is also my focus. However, I believe it is educational to also point out paradoxes or examples of behavior that appear inconsistent with the basic theory of expected utility maximization. For example, I discuss framing (Kahneman and Tversky 1979) and the Allais paradox (Allais 1953) later in the course. For the instructor so inclined, I provide two examples of behavioral topics that could be discussed in the context of Deal or No Deal. I emphasize the importance of clearly differentiating between the normative and descriptive decision theories, especially to students in an introductory class who could be easily confused and incorrectly interpret the descriptive theory as how one *should* make decisions.

First, the instructor could discuss the topic of changing risk attitudes following big gains or losses or how risk aversion in general may be influenced by the sequence of events leading to the current situation (Post et al. 2008). Note that with only three prize levels (\$0, \$10, \$25), decreased risk aversion following a loss is hard to observe—if the current offer is \$10 and a loss drops the offer to \$0, the offers cannot get any worse, so there is no reason to stop; if the current offer is \$25, the students would accept the offer and a loss would not be observed. With more prize levels or with the gift card value tied to a fixed percentage of the final dollar amount won (e.g., 0.01%), I suspect decreased risk aversion following a loss will be more readily observable.

Second, the "break-even" effect described by Thaler and Johnson (1990) may also be observable in the game and, if so, would be another way to generate

discussion on the topic of changing risk preferences as the game progresses. For example, consider the situation where the current offer is in the high \$200,000s, it is rejected, and the next offer drops to the low \$100,000s. Although the gift card value remains the same, the students are much closer to losing everything. At this point, students may exhibit a risk-seeking preference and reject the offer with the hopes of getting a future offer above \$300,000. I hypothesize that having been so close to the \$25 gift card level previously sets the class's reference point there, and therefore they would express a desire to get back to that level. This effect may be exacerbated because the students do not have to pay to play the game.

Another topic for discussion could center on the limitations of the exponential utility function. Although this utility function is relatively easy to describe and analyze (see the appendix), it does lack realism in certain circumstances. For example, consider a large stakes gamble where a decision maker has a 50–50 chance at \$500,000 and \$1,000,000. Furthermore, suppose the decision maker's certainty equivalent is \$725,000, which implies the following equation must hold

$$\frac{1}{2}(1 - e^{-500,000/R}) + \frac{1}{2}(1 - e^{-1,000,000/R}) = 1 - e^{-725,000/R}. \quad (1)$$

Via simple algebraic manipulation of equation (1), the following equation must also hold

$$\frac{1}{2}(1 - e^{-0/R}) + \frac{1}{2}(1 - e^{-500,000/R}) = 1 - e^{-225,000/R}. \quad (2)$$

Equation (2) implies that the same decision maker is indifferent between a guaranteed \$225,000 and a 50–50 gamble for \$0 and \$500,000. In most cases, assuming the implied risk tolerance is correctly calibrated for the \$500,000/\$1,000,000 gamble, \$225,000 is probably too high to be the true certainty equivalent for the second gamble. Risk aversion is generally decreasing in wealth, which is not possible to model using the exponential utility function. This observation may lead to discussions about other types of utility functions or ways to estimate one's utility function. An instructor could introduce the logarithmic utility function ( $u(x) = \log(x)$ ) as one where risk aversion decreases with increasing wealth and ask students to code it into the spreadsheet to contrast with the exponential utility function.

## 5.3. Decision Making Criteria

As the class debates whether to accept or reject banker offers, the instructor can also lead the class through a discussion about different decision criteria that can be used in decision making problems under uncertainty. Maximizing expected value seems intuitive to most students. However, one may be able to elicit other

criteria from students who exhibit risk-averse or risk-seeking behavior. For example, in the \$50, \$75,000, \$750,000 example above, the (risk-averse) students who choose “Deal” are following something close to the maximin criterion, whereas the (risk-seeking) students who choose “No Deal” are approaching the maximax criterion.

Another popular line of reasoning offered by students goes like this: “There are more briefcases with values below the current offer than there are briefcases with values above, so there is a greater than 50% chance of increasing the next offer if we reject the current offer and open one more briefcase.” This “increasing offer value” decision criteria is compelling to many students. However, although students understand that the probability of the offer going up is more than 50%, they often neglect to observe that the offer would increase by a smaller amount than it would decrease should they eliminate a high dollar amount. This issue is quite common on the TV show as well, as described next.

**5.3.1. Expectation vs. Probability.** On the TV show, when the banker makes an offer near the end of the game, a graphic is often shown with a message of the form “if Arnie rejects the offer, he has a  $x\%$  chance of increasing his next offer.” For audience members not conversant in probability and expectation, this information can be misleading. Students can also fall into this trap. Consider the situation where the remaining amounts are \$0.01, \$1, and \$300,000. Assume banker offers are exactly the expected value of the remaining dollar amounts rounded to the nearest dollar. In this case, the current offer would be \$100,000 and some students may argue (rightly so) that the probability of increasing the next offer is  $2/3$  if they reject the deal. In fact, this very argument is commonly used on the TV show to justify rejecting deals near the end of the game. However, other students or the instructor may point out that even though it is more likely the offer will increase, the amount of increase (\$50,000) will be smaller than the amount of decrease (–\$100,000) should the largest value briefcase be eliminated. An astute student may even notice that the expected change in the offer would be exactly \$0! This scenario provides a good opportunity to engage students on the topic of probability. Even if the chances of improving the offer are better than 0.5, one must also consider the amount of gain relative to the potential for loss when making a decision under uncertainty.

#### 5.4. Monty vs. Howie

One can make an interesting connection between the Monty Hall problem and Deal or No Deal. In the Monty Hall problem, based on the game show *Let’s Make a Deal*, there are three doors. One has a prize

behind it and the other two have nothing. Two goats are often used to represent the two non-prizes. The contestant chooses one door, then the host opens one of the remaining two doors. The door the host opens cannot contain the prize. At this point, the contestant is given a choice whether to switch to the remaining door or stay with the originally chosen door. It is well known that switching doors is the optimal strategy, with probability  $2/3$  of winning the prize. The problem was first posed in 1975 (Selvin 1975) and is often used in introductory probability courses to stress the importance of careful reasoning using conditional probability (see, for example, Bertsekas and Tsitsiklis 2002).

Now, suppose there are two briefcases remaining in Deal or No Deal, one with \$1,000,000 and one with \$0.01. If the students have the option to switch briefcases, then whether they switch or not, they have a 50–50 chance of winning the \$1,000,000. This is due to the random nature in which the original briefcase is chosen and how the briefcases are opened throughout the game. However, in the Monty Hall problem, the host cannot make a completely random choice about which door to open—if the contestant chooses one of the non-prize doors initially, then the host must open the other non-prize door. The feature that distinguishes these two games from each other is the information that is available to the person deciding which briefcase or door to open. The host in the Monty Hall problem has extra information that the contestant in Deal or No Deal does not have. As previously described, an omniscient banker, through his final offer, could signal to the player the value of the player’s briefcase. My observations of this situation in the game show suggest that the banker offer is very close to the expected value and does not offer any signal to the contestant.

Contrasting these two problems may help students solidify their probabilistic intuition and reassure those students who struggled with the Monty Hall problem. Student intuition on uniform distributions and independence is generally quite accurate when it comes to Deal or No Deal, and these concepts are the probabilistic tools needed to justify the 50–50 chance of winning \$1,000,000 in the example above.

## 6. Assessing the Use of the Spreadsheet Game

My assessment of the game is based primarily on personal observations at this stage. Having played this game in different types of courses with different audiences (undergraduate engineering students versus MBA students), I consistently find student response to be very positive. Students are actively engaged during the game, which I believe sets a



positive tone for the remainder of the course. Students recognize that I value discussion during class and require them to think deeply and justify their responses. The game also requires students to clearly communicate their arguments and practice consensus building because they are working together in one large team to achieve a common goal.

In playing this game with different audiences, I have found that MBA students are typically more eager to speak up than are engineering students and more willing to challenge the assumptions and reasoning of others. This may have to do with MBA students being accustomed to a classroom setting where interaction and discussion are expected (e.g., case study discussions). The engineering instructor may need to lead the class a bit more, asking “what if” questions to get students to consider alternative points of view or avenues of reasoning and help them get over the fear of being wrong. For example, in the “expectation versus probability” discussion (§5.3.1), if a student convincingly argues for “No Deal” based on the “probability” argument and there are no objections, an instructor could ask, “What if you eliminate the big dollar amount? What do you think the next offer would be? How would that compare with eliminating one of the small dollar amounts?” Overall, in both the MBA and engineering classrooms, I think the game can be played the same way, with the primary goal of motivating the students being unchanged.

By providing a concrete real-life application, I believe this game helps elucidate difficult decision analysis concepts and is a valuable supplement to traditional lectures. Although I have not attempted a formal measurement of the pedagogical impact of this game, I have received feedback in a course evaluation that my “games really help explain concepts” (in addition to Deal or No Deal, I use other games in my course). Going forward, I plan to directly solicit student feedback on the game to help improve the spreadsheet model as well as the overall learning experience. I also plan to explore the integration of this spreadsheet with homework assignments on decision analysis.

## 7. Conclusions

This paper describes a spreadsheet-based implementation of the game Deal or No Deal, which is easy to learn and play. This game is a highly interactive way to motivate and demonstrate core OR/MS concepts. Students relate easily to the game and the game can be used in many educational settings. This game can help elucidate complex decision analysis topics including risk, utility, and probability and can provide a memorable connection between the classroom and real-life decision making problems. Students are

highly engaged while playing this game and, if it is used in one of the first lectures, the game gets students excited about the course and topics to come.

## Supplementary Material

Files that accompany this paper can be found and downloaded from <http://dx.doi.org/10.1287/ited.2013.0104>.

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## Appendix

### A. Exponential Utility Function and Certainty Equivalent Calculation

The exponential utility is concave with a single parameter that measures the risk attitude of the decision maker. The utility of a value  $x$  is defined as

$$u(x) = 1 - e^{-x/R}, \quad x \geq 0 \quad (A1)$$

where  $R > 0$  is known as the “risk tolerance.”

Given a lottery  $L$  with outcome values  $x_1, \dots, x_n$  and corresponding probabilities  $p_1, \dots, p_n$ , the expected utility of the lottery ( $EU(L)$ ) is

$$EU(L) = \sum_{i=1}^n p_i u(x_i). \quad (A2)$$

The certainty equivalent of a lottery ( $CE(L)$ ) is the amount such that a decision maker is indifferent between playing the lottery and taking the certain payoff  $CE(L)$ . In other words, the certainty equivalent of a lottery satisfies  $u(CE(L)) = EU(L)$ .

In the spreadsheet game, when there are  $n$  briefcases remaining with values  $x_1, \dots, x_n$ , the expected utility is

$$EU = \frac{1}{n} \sum_{i=1}^n u(x_i) \quad (A3)$$

and the certainty equivalent is

$$CE = -R \ln(1 - EU). \quad (A4)$$

### B. Potential Students Exercises

Below, I offer some example exercises that could be conducted in class with the students or assigned as homework problems. Note that these problems may require refinement depending on the class.



**1. A decision tree representation.** Have students play the game and draw the decision tree representing the decision problem they face when they arrive at the stage where there are only three briefcases remaining (see Figure 2). Have them specify the appropriate probabilities on the branches and leaf values. You may give them a specific discount factor to use for the final offer. Compare their decision with expected value maximization. Draw the connection with expected utility maximization.

**2. A decision tree representation revisited.** Draw the decision tree when there are four briefcases remaining. Provide a few different discount schedules for the remaining offers (e.g., one schedule with small discount values, another with values close to 1, etc.). Students will learn that beliefs about the future discount schedule can have a substantial influence on the optimal decision at each stage.

**3. The effect of the discount schedule.** Change the discount schedule to make all values 1 (or even greater than 1). Have students play the game multiple times and record the round in which when they accept the deal. Measure how much earlier deals are made.

**4. Monty or No Monty.** If students are allowed to swap briefcases in the final round when there are two left, should they do it? This is really a probability exercise. The students could be asked to develop a simple simulation in the spreadsheet to verify their answer.

**5. Exploring the logarithmic utility function.** Code up the logarithmic utility function next to the exponential utility function in the spreadsheet. Add a parameter to indicate the contestant's initial wealth. Have students play the game using different values of the contestant's initial wealth and note the differences between the certainty equivalent value given by the exponential versus log utility functions. With larger initial wealth, they should see risk aversion decrease.

**6. Determining one's risk tolerance.** Students can estimate their risk tolerance using the exponential utility function. One option is to augment the risk tolerance table on the main worksheet to include many more intermediate risk tolerance values. Assuming a deal is accepted at some point, the students can identify the closest risk tolerance in the table that indicates "Deal." Alternatively, the students could be asked to analytically calculate their break-even risk tolerance based on the final deal amount.

**7. Comparing decision policies.** Make students or teams of students commit to a certain decision policy. Example policies: always "No Deal," "Deal" when offer exceeds \$ $x$ , "Deal" when difference between expected value of remaining amounts and offer is less than \$ $x$ , etc. Then play the game and see which students/teams do the best. The game will need to be played multiple times in order to generate some variability. Alternatively, students could be asked to code up a simulation that generates the 26 dollar amounts in a random sequence and test out different decision policies.

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