

On the Evaluation of Options on Lotteries: An Experimental Study

Tal Shavit, Doron Sonsino and Uri Benzion

We present the results of a comparative experimental study of the evaluation of simple lotteries and call/put/insurance options on these lotteries. The main findings and conclusions are:

(a) The observed bidding patterns depend on the type of asset under evaluation. In particular, subject behavior when buying or selling a basic lottery seems much more cautious than their behavior when buying or selling options on that lottery.

(b) The observed bidding patterns also depend on subject positions with respect to the underlying asset. In particular, the bids for buying lotteries and options long are statistically uncorrelated with the bids for selling the same lotteries and options short.

(c) Subjects with extreme risk attitudes are more inclined to violate basic no-arbitrage conditions (like the call-put parity) when bidding for the different lotteries.

We demonstrate that it is difficult to reconcile the experimental evidence with mainstream theories on individual decision and choice (although we find strong support for prospect theory in some parts of the data). We conclude that the evaluation of options on lotteries is context-dependent and subtler than perceived by existing theories.

Mainstream finance research typically assumes that returns on financial assets are random variables with well-defined expectations and standard deviations. Theorists then assume that investors are risk-averse expected utility maximizers and derive the equilibria, limit behavior, or steady states of the corresponding models. Recent literature on behavioral finance, however, demonstrates the existence of psychological factors that are not taken into account by these theories. Such factors may play a significant role in financial decision-making and provide important insights for understanding prices and dynamics in financial markets (see, for example, Shleifer, 200; Shiller, 1998; Schwartz, 1998 and the references therein).

This paper deals with a comparative experimental investigation of the evaluation of simple lotteries and different (call/put/insurance) options on these lotteries. Our main goal is to examine the bidding patterns for such simple lotteries and options in a stylized controlled environment in order to analyze and characterize sub-

ject behavior in this context. In particular, we check whether subjects conform with the predictions of expected utility theory and whether alternative theories like prospect theory (Kahneman and Tversky, 1979) may shed light on subject behavior in this application.

We asked 118 introductory finance students at the Technion, Israel Institute of Technology, to bid prices for buying, selling, and short-selling some simple lotteries and different options on one of these lotteries (henceforth referred to as the basic lottery). For tighter control and to avoid possible labeling effects, we did not explicitly mention financial terms like stocks and options in the questionnaire.

For simplicity and enhanced control, we also suppressed the time dimension and used simple two-pay-off distributions to describe the current value of each lottery and option. Following a common practice in economic experimentation, we used second-price auctions to elicit meaningful price offers from the subjects (e.g., Coursey, Hovis, and Schulze, 1987 and Krahen, Rieck, and Theissen, 1997). More details on the experimental procedure are in the second section.

The main findings and conclusions (described in the third and fourth sections) are summarized as follows:

1. Subject bidding patterns and revealed risk preferences vary with the type of asset under evaluation. In particular, subjects act risk-aversively (by bidding less than the expected payoff) when buying, selling, or short-selling the basic lottery, and risk-seekingly (by

Tal Shavit is now a graduate student at Ben-Gurion University. This article is based on parts of his master thesis at the Technion.

Doron Sonsino is a professor in the Department of Industrial Engineering and Management at the Technion – Israel Institute of Technology.

Uri Benzion is a professor in the Department of Economics at Ben-Gurion University of Negev.

Requests for reprints should be sent to: Doron Sonsino, Technion – Israel Institute of Technology, Haifa 32000, Israel. Email: sonsino@ie.technion.ac.il

bidding more than the expected payoff) when buying, selling, or short-selling the different options on the basic lottery.

2. Subject bidding patterns depend strongly on their position with respect to the underlying asset. The bids for selling an option (call or put) short are significantly higher than the bids for buying the same option. Moreover, the bids for buying the assets (basic lottery, put option, or call option) are statistically uncorrelated with the bids for selling the same assets short.

3. The prices that subjects with a fixed endowment are willing to pay for the basic lottery are significantly higher than the prices at which they are willing to sell the lottery (long). In this sense, the endowment effect does not carry over when the basic income level of the subjects is fixed across treatments.¹

4. Subjects with extreme risk attitudes (strong risk aversions or strong risk preferences) are more likely to violate basic no-arbitrage conditions (e.g., the call-put parity) in their bidding patterns.

We demonstrate that it is difficult to reconcile our experimental evidence with mainstream theories on individual decision and choice. In particular, subject behavior is compatible with expected utility theory in certain applications, but contradicts it in others. The same is true for prospect theory. While some of the observed contradictions may be resolved by acknowledging the stronger impact of losses (than gains) on subject behavior, or by referring to a standard probability weighting function, other segments of our data seem to contradict the predictions of prospect theory.

Still, as outlined in Conclusions (1) to (4) above, we are able to identify and intuitively explain several statistically significant trends in the data. These suggest that, when evaluating lotteries and options, subject behavior is more complicated and subtle than perceived by existing theories. The observed behavior depends on the characteristics of the underlying lottery, the investor's position with respect to the underlying asset, and the initial endowment.

To the best of our knowledge, the experimental literature does not contain any preceding comparative studies on the evaluation of different options on lotteries. Kuon and Abbink [1996, 1998] conduct laboratory experiments in order to determine whether individuals recognize arbitrage opportunities. In these experiments, subjects were allowed to invest in three basic assets: stocks, options, and risk-free deposits. The prices were preselected to create arbitrage opportunities. The participants were asked to choose their investment strategy repeatedly for fifty rounds. The main conclusion was that subjects may learn to recognize arbitrage opportunities. The results of this paper, however, suggest that the fundamental bidding patterns of individual investors in financial markets may actually create such arbitrage opportunities [see conclusion (4)].

Even at the simple stylized level of our experiment, relatively sophisticated decision-makers systematically violated some of the basic premises of financial economics, which shows the importance and relevance of this research in behavioral finance. The implications (and limitations) of our analysis are further discussed in the conclusions of the final section.

The Experiment

The subjects were 118 students enrolled in the course "Introduction to Financial Management" at the Faculty of Industrial Engineering and Management at the Technion, Israel Institute of Technology. The course is taken by undergraduate engineering students from different departments at the Technion.² The experiment took place in class and lasted approximately one hour.

We first handed out written instructions and asked the students to read them independently (see <http://ie.technion.ac.il/sonsino.phtml> for the translated version). We then presented the instructions on the blackboard and answered questions individually. Finally, we handed out a twelve-problem questionnaire. Participants were given forty minutes to complete it.

The twelve problems appear in Appendix A. The contents of each problem are summarized in Table 1. The titles that identify the problems were not included in the original sets and are added here for the reader's convenience.

The problems were presented to the subjects in a random order (except for Problems 1 and 2, which were used to control for order effect as explained subsequently). In this sense, the numbering of the problems in the table is arbitrary.

To avoid a possible labeling effect, we did not explicitly mention financial terms like "stocks" and "options" in phrasing the problems.³ All assets were presented as lotteries, "rights" that depend on lotteries, and "obligations" that depend on lotteries. To simplify

Table 1. *Description of Problems*

Prob	Description
1	Control for Order (1)
2	Control for Order (2)
3	P Control for Risk Attitude
4	WTP (Willingness to Pay) for the Basic Lottery
5	WTA (Willingness to Accept) for the Basic Lottery
6	AS (Willingness to Accept) for Selling the Basic Lottery Short
7	LC (Long Call) on Basic Lottery
8	LP (Long Put) on Basic Lottery
9	SC (Short Call) on Basic Lottery
10	SP (Short Put) on Basic Lottery
11	DIO (Direct Insurance Option) on Basic Lottery
12	NIO (Naked Insurance Option) on Basic Lottery

the design, we suppressed the time dimension and implicitly assumed that the payoff from holding the asset is realized immediately after the purchase (or the sale) of the asset.⁴

Some of the problems in the questionnaire were designed to determine the subjects' willingness to pay (WTP) for lotteries and for the right to receive certain amounts of money contingent on the outcome of lotteries (representing call and insurance options on these lotteries). The term WTP is commonly used in the experimental literature to denote the maximum amount subjects are willing to pay for a given asset (for example, see Knetsch and Sinden, 1984).

Other problems were designed to determine the subjects' willingness to accept (WTA) for lotteries they own and for the obligation to pay certain amounts of money contingent on the outcome of lotteries (representing put options on these lotteries). The term WTA is commonly used in the literature to denote the minimum amount that subjects require for selling an asset they own (Knetsch and Sinden, 1984). In this paper, we extend the use of this term to cases where the subjects sell the asset "short," i.e., when subjects sell an asset they do not own.

As mentioned above, the problems (with two exceptions) were presented to the subjects in a random order, with each problem on a separate page. The subjects were requested to answer each problem separately, and to then place the answered page upside down on the corner of their table. Research assistants collected the finished forms as the experiment progressed, so that subjects could not reexamine their answers and use them to solve other problems.

Problems 1 and 2 were included to verify that the order in which the problems were presented did not affect the evaluation patterns. Approximately half the subjects (Group 1) received Problem 1 as the first problem, and Problem 2 as the last. The other half (Group 2) received Problem 2 first and Problem 1 last. The average bids obtained for the two problems, however, were not significantly different across the two groups.⁵ We thus conclude that the order did not affect the evaluations and ignore this issue henceforth.

Problem 3 was used to obtain an individual measure of risk aversion for each subject. We asked subjects to bid a price for a lottery that pays 100 NIS (new Israeli shekels) with a probability of 0.5 (and 0 otherwise). Using P_i to denote the bid of subject i for this lottery, we henceforth use $R_i = (100 - P_i)/100$ as an individual measure of risk aversion for subject i .

Problems 4-12 refer to a simple lottery (henceforth referred to as the basic lottery) that pays 100 with a probability of 0.7 and 40 with a probability of 0.3. In Problems 4, 5, and 6, we elicited the prices at which subjects were willing to buy, sell, and short-sell the basic lottery. In Problems 7-12, we checked the prices at which subjects were willing to buy, sell, and short-sell

different call, put, and insurance options on the basic lottery.

Subjects were told that the assets (and the obligations⁶) would be sold (or bought) using second-price (Vickrey) auctions. Bidding your true valuation is a dominant strategy in second-price auctions, and thus Vickrey auctions are frequently used to obtain truthful revelations of values in laboratory experiments (e.g., Coursey, Hovis, and Schulze, 1987 and Krahnen, Rieck, and Theissen, 1997).⁷

Subjects were also told that at the end of the experiment we would randomly divide them into groups of five. Each participant would then compete for buying (or selling) the assets (or the obligations) in the different problems through second-price auctions. For a problem that checks the WTP for a given asset, the asset would be sold to the highest bidder at the second-highest price. For a problem that checks the WTA for selling an asset or an obligation, we would buy the underlying asset (or obligation) from the lowest bidder at the second-lowest price.

In all problems, subjects were initially given 100 NIS.⁸ Each subject's final balance for each problem was determined by subtracting (or adding) the amounts paid (or received) in the auction (if any) from the initial balance, and then drawing the lotteries that the subject holds (or is committed to pay) at the end of the auction. The instructions outlined this mechanism without using the terms WTP or WTA. The instructions also illustrated the structure of each problem by using a simple example.

To provide concrete incentives, subjects were told that at the end of the experiment, we would randomly draw one of the twelve problems and pay each participant according to the formula $P_i = 20 + W_i(3,500 - 20N)/(\sum W_i)$, where P_i denotes participant i 's final check, 3,500 NIS is the total budget of the experiment, 20 NIS is a guaranteed minimum payment per subject, W_i is participant i 's final balance for the randomly chosen problem, and $N = 118$ is the number of participants. Note that under this scheme the actual payment increases with the final balance while guaranteeing a minimum payoff of 20 NIS per subject and meeting a total budget limit of 3,500 NIS.

Results

Lottery-Dependent Bidding Patterns

Recall that Lottery 3 pays 100 with a probability of 0.5 and 0 otherwise. Its expected payoff thus equals 50. Our results, however, indicate that 43% of the subjects offered prices higher than 50 for that lottery. We henceforth call these subjects risk-seeking. 19% of the subjects offered exactly 50 for Lottery 3; we henceforth call them risk neutral. The rest of the subjects (38%)

offered less than 50 for the lottery; we refer to them as risk averse.

Note, however, that when we use the basic lottery (see Problem 4) to characterize subject attitudes toward risk, the results are quite different. The expected payoff of the basic lottery is $0.7(100) + 0.3(40) = 82$. An examination of subject bids for that lottery shows that 14% offered prices higher than 82, 6% offered exactly 82, and 80% offered less than 82. These results are significantly different from those obtained in Problem 3 (see Table 2).

The average bid for Lottery 3 (47.1) was 6% lower than the lottery's expected payoff, while the average bid for Lottery 4 (64.76) was 21% lower. Forty of the 118 subjects (33.9%) acted risk-seekingly when bidding for Lottery 3 and risk-aversively when bidding for Lottery 4.

To reconcile these findings with existing theories, assume that some of the subjects are risk-seeking in the low-payoff domain and risk-averse when higher payoffs are involved. This type of behavior has indeed been observed in previous experimental studies (see Bosch-Domènech and Silvestre, 1999 for a recent example). If the utility function, for instance, takes the S-shaped form outlined in Figure 1, subjects may appear risk-seeking when evaluating the prospect of gaining 100 with a probability of 0.5, but risk-averse when bidding for a lottery that pays 100 with a probability of 0.7 and 40 with a probability of 0.3.⁹

Alternatively, the results may be explained by invoking Kahneman and Tversky's [1979] probability weighting idea. If the subjects overweight the 30% probability of obtaining the lower payoff in Lottery 4, and underweight the 70% probability of obtaining the higher payoff, they may be inclined to underestimate the value of Lottery 4 relative to the value of Lottery 3.¹⁰

Table 3 describes the average bids for Problems 3–12. The table also presents the ratio of the average bid to the expected payoff for each lottery.

Note that while the average bids for the basic lottery (examined in Problems 4–6) are all within the range of 0.73–0.8 from the expected payoff, the average bids for the different options (examined in Problems 7–12) are between 0.94 and 1.99 of the expected payoffs. In this sense, our subjects behave risk-aversively when bidding for the basic lottery and risk-seekingly when bidding for the different options. The case of Lottery 3 can be considered intermediate, with an average bid equal to 0.94 of the expected payoff.

Table 2. Risk Attitudes

	Problem 3	Problem 4
Risk Averse	38%	80%
Risk Neutral	19%	6%
Risk-Seeking	43%	14%
Average Bid	47.1	64.8

FIGURE 1
Utility Function

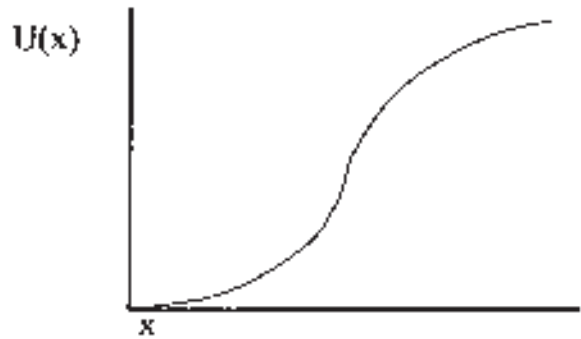


Table 3. Average Bids

Problem	Description	Average	Average/EP*
3	P	47.1	0.94
4	WTP	64.8	0.79
5	WTA	59.9	0.73
6	AS	65.3	0.80
7	LC	13.1	0.94
8	LP	17.4	1.45
9	SC	16.0	1.14
10	SP	23.9	1.99
11	DIO	31.3	1.73
12	NIO	19.1	1.06

Note: This column gives the ratio of the average bid to the expected payoff of the corresponding lottery.

An explanation for these findings may again be provided by Figure 1. The payoffs of the basic lottery are significantly higher than those of the corresponding options. The utility function of Figure 1 suggests that subjects may act risk-aversively in the first set of problems, and risk-seekingly in the latter. Lottery 3, with its 0.5 probability of winning 100, is indeed an intermediate case, where the average bid is close to the expected payoff of the lottery.

These findings are summarized in Conclusion 1.

Conclusion 1: The observed bidding patterns and (revealed) risk attitudes change according to the characteristics of the lottery under examination. In particular, subjects who act risk-aversively when bidding for one lottery may appear risk-seeking when bidding for a different lottery. On average, subjects are inclined to act risk-aversively when bidding for lotteries that involve relatively large payoffs, and risk-seekingly when bidding for options that involve small and zero payoffs.¹¹

Long/Short Bidding Modes

The coefficients of correlation between the bids for Lottery 3 (P) and the bids for all other lotteries are

shown in Table 4. The asterisks denote the statistically significant numbers at $p \leq 0.05$.

The table shows that the WTP for the basic lottery, the call option (LC), the put option (LP), and the naked insurance option (NIO) increase with the bids for the control lottery (P). In this sense, subjects who act risk-aversively when bidding for the control lottery are also inclined to act risk-aversively when bidding for the basic lottery, the call option, the put option, and the direct insurance option.

More surprisingly, the table suggests that the bids for selling the basic lottery (WTA) and short-selling the call option (SC) and the put option (SP) are not significantly correlated with P.

To further investigate the relationship between long and short bidding, we calculate the coefficients of correlation between the bids for buying three different assets (the basic lottery, the call option, and the put option) and the asks for selling the same three assets short. Table 5 shows that (in all three cases) we cannot reject the hypothesis that the coefficients of correlation are zero.

The data thus suggest that the price offers submitted by the subjects when buying an asset are statistically uncorrelated with their asks when selling the same asset short, so the bids cannot be used to predict the asks. In other words, subject behavior in the “long bidding” mode seems to be independent of their behavior in the “short-selling” mode.¹²

This surprising finding suggests we should check whether the bids in each mode are significantly corre-

lated. Our calculations revealed a highly significant ($t = 6.49$) positive correlation of 0.52 between LC and LP. We also found a highly significant ($t = 3.08$) positive correlation of 0.28 between SC and SP. The correlation between WTP and LC was 0.39 ($t = 4.56$), and the correlation between WTP and LP was 0.2 ($t = 2.19$). However, we could not reject the hypotheses that the coefficients of correlation between AS and SC and between AS and SP are equal to zero.

Conclusion 2: The observed bidding patterns strongly depend on subjects' positions with respect to the underlying assets. In particular, the bids for buying an asset (basic lottery, put, call) are not significantly correlated with the bids for selling the same asset short. The bids for buying the different assets, however, are all positively correlated. Similarly, the bids for selling the call and the put option short are also positively correlated. As an interpretation, we suggest two behavioral modes: a “long bidding” mode and a “short-selling” mode that are statistically independent.

Contradictions to the Endowment Effect

The average offer price for the basic lottery (the WTP measured in Problem 4) was 64.8, while the average selling price of the lottery (the WTA measured in Problem 5) was 59.9. A Wilcoxon signed-rank test suggests that the differences are significant at $p \leq 0.05$.

These numbers seem to contradict previous experimental evidence of the endowment effect for lotteries.¹³ According to the endowment effect, the price demanded by subjects when selling an asset they own (i.e., the WTA) is significantly higher than the price they are willing to pay for the asset when they do not own it (i.e., the WTP). Our results reverse the inequality. However, in the studies that documented the endowment effect, the subjects in the WTP treatment were given a monetary payoff equal to the expected value of the lottery. The subjects in the WTA treatment were only endowed with the lottery and did not receive money endowments.

In this study, subjects received the same 100 NIS endowment in both treatments. In addition, subjects received the lottery in the WTA problem. In this sense, the WTA subjects in our experiment were relatively more affluent than the corresponding subjects in previous studies. This may explain the contrary evidence in our data. It may be that relatively well-endowed subjects are more willing to give up the chance for an additional uncertain gain than subjects who begin with lower initial endowments.¹⁴ These findings are summarized in Conclusion 3.

Conclusion 3: The prices that subjects with a fixed income endowment are willing to pay for the ba-

Table 4. *Coefficients of Correlation*

	Coefficient	Significance Level
ρ (P, WTP)	0.45*	0.01 ($t = -5.53$)
ρ (P, WTA)	0.08	0.33 ($t = -0.97$)
ρ (P, AS)	-0.18*	0.04 ($t = 2.06$)
ρ (P, LC)	0.26*	0.01 ($t = -2.79$)
ρ (P, LP)	0.18*	0.04 ($t = -2.01$)
ρ (P, SC)	0.00	0.98 ($t = 0.014$)
ρ (R, SP)	-0.07	0.40 ($t = 0.83$)
ρ (R, DIO)	0.02	0.80 ($t = -0.25$)
ρ (R, NIO)	0.32*	0.01 ($t = -3.66$)

Table 5. *Coefficients of Correlation between Long and Short Bids*

	Correlation Coefficient	Significance Level
Basic Lottery	-0.07	0.39 ($t = -0.86$)
Call Option	-0.06	0.50 ($t = -0.66$)
Put Option	-0.05	0.62 ($t = -0.49$)

Note: The first row gives the coefficient of correlation between subject answers to Problems 4 and 6. The second gives the coefficient of correlation between the answers to Problems 7 and 9. The third row gives the coefficient of correlation between the answers to Problems 8 and 10.

sic lottery are higher on average than the prices they are willing to accept for selling the same lottery long. In this sense, the endowment effect does not carry over when the money endowment of the subjects is fixed across treatments.

Testing Expected Utility Predictions on Short-Selling Price

Recall that Problem 6 measures the minimum price demanded for selling the basic lottery short (AS). In this section, we compare this number to the two other bids submitted for the same lottery: the maximum price subjects are willing to pay for the basic lottery (the WTP measured in Problem 4), and the minimum price at which they are willing to sell the basic lottery when they own it (the WTA measured in Problem 5).

Claim 1 in Appendix B shows that, according to expected utility theory, $AS > WTP$ for risk-averse agents, $AS = WTP$ for risk-neutral agents, and $AS < WTP$ for risk-seeking agents. Table 6 demonstrates that subject behavior on average is compatible with these qualitative predictions. Risk-averse subjects (i.e., those who bid more than the expected value for the control lottery 3) demand a significantly higher price for selling the asset short, risk-neutral subjects demand/offer similar prices in both cases, and risk-seeking subjects offer significantly higher prices for buying the asset long.¹⁵

Expected utility theory also predicts that $AS > WTA$ for risk-averse agents, $AS = WTA$ for risk-neutral agents, and $AS < WTA$ for risk-seeking agents (see Claim 2 in Appendix B). Table 7 demonstrates that the predicted inequalities are met for risk-averse and risk-neutral subjects, but not for risk-seeking subjects. On average, AS is not significantly different from WTA for this group.

Conclusion 4: A comparative examination of the bids submitted for short-selling the basic lottery suggests that expected utility theory provides useful predictions of subject behavior in certain cases, but is violated in others. In particular, the data suggest that risk-averse subjects demand a special premium (relative to the WTP and the WTA) when short-selling a lottery. Risk-seeking subjects, on the other hand, are willing to short-sell the lottery at a discounted price (relative to the WTP), but on average demand similar prices when selling the lottery short and long.

Long and Short Options

Recall that Problem 7 measures the WTP for a call option with an exercise price of 80 on the basic lottery (LC). Problem 9 measures the WTA for selling the same call option short (SC).

Similarly, Problem 8 measures the WTP for a put option with an exercise price of 80 on the basic lottery (LP). Problem 10 measures the WTA for selling the same put option short (SP).

Claim 3 in Appendix B shows that $LC < SC$ and $LP < SP$ for risk-averse expected utility maximizers, $LC = SC$ and $LP = SP$ for risk-neutral agents, and $LC > SC$ and $LP > SP$ for risk-seeking agents. These predictions, however, were not confirmed in the experiment. In our sample, $LC < SC$ and $LP < SP$ for all three (risk) groups of subjects.¹⁶ In Table 8 we thus present the data for these problems without distinguishing between the different risk types.

While expected utility theory fails to explain subject behavior in this case, prospect theory seems to provide a clear explanation. When selling a given option short, the decision-maker is evaluating the prospect of losing a given amount, say, X , with some given probability, p .

Table 6. *WTP versus AS*

	WTP < AS	WTP = AS	WTP > AS	Avg. AS	Avg. WTP	Significance
Risk Averse	73%	9%	18%	70.9	54.9	0.01
Risk Neutral	22%	26%	52%	61	69.3	0.25
Risk Seekers	35%	8%	57%	62.3	71.2	0.03
All Subjects	47%	12%	41%	65.3	64.8	0.87

Note: The significance level is for testing the hypothesis $WTP < AS$ (one tail) for the risk-averse, $WTP > AS$ (one tail) for the risk-seeking, and $AS = WTP$ (two tails) for the risk-neutral and all subjects.

Table 7. *WTA versus AS*

	WTA < AS	WTA = AS	WTA > AS	Avg. AS	Avg. WTA	Significance
Risk Averse	57%	9%	34%	70.9	57.6	0.01
Risk Neutral	35%	35%	30%	61.0	60.8	0.96
Risk Seekers	33%	22%	45%	62.3	61.5	0.42
All Subjects	42%	19%	39%	65.3	59.9	0.06

Note: The significance level is for testing the hypothesis $WTA < AS$ (one tail) for the risk-averse, $WTA > AS$ (one tail) for the risk-seeking, and $AS = WTA$ (two tails) for the risk-neutral and all subjects.

Table 8. *Long and Short Options*

	L < S	L = S	L > S	Average S	Average L	Significance
Call Option	48%	20%	32%	16.0	13.1	0.01
Put Option	58%	14%	28%	23.9	17.4	0.01

Note: S denotes short positions, L denotes long positions. The significance level is for testing the hypothesis $S = L$ (two tails).

On the other hand, when buying the same option, the decision-maker is evaluating the prospect of gaining X with probability p . Loss aversion implies that a loss of X will loom larger than a gain of the same amount. It follows that the compensation demanded for taking the former obligation will be higher than the price offered for the latter prospect, as observed in the data above.¹⁷

Recall, however (see Table 6) that the “short higher than long” inequality does not hold for the basic lottery. The average price demanded for selling the basic lottery short (AS) was not significantly different from the average price offered for buying the lottery (WTP). This behavior pattern may still match the predictions of prospect theory, because the theory does not yield precise predictions for the relationship between AS and WTP. On one hand, loss aversion should push AS downward relative to WTP. But on the other hand, convexity of utility in the loss domain (compared to concavity in the gain domain) may push AS upward relative to WTP.¹⁸

Finally, note that the bids and asks for the put option were significantly higher than those for the call option (see Table 8). This seems questionable, because the expected payoff of the call (which pays 20 with a probability of 0.7) is higher than the expected payoff of the put (which pays 40 with a probability of 0.3). To explain these inequalities we once more use the two arguments outlined in the third section: 1) the probability weighting function, which underweights the 0.7 probability while overweighting the 0.3 probability, and 2) the convexity of utility in the low-payoff domain, which magnifies the difference between monetary payoffs of 40 and 20.

Conclusion 5: The prices that subjects (in all risk groups) demand for short-selling call and put options are significantly higher than the prices they are willing to pay for buying the corresponding options. On average, subjects offer (ask for) significantly higher prices when buying (short-selling) the put option, despite the fact that its expected payoff is lower than the expected payoff of the corresponding call. These observations contradict the predictions of expected utility theory, but can be resolved using the “loss aversion” and “probability weighting” ideas of prospect theory.

Direct and Naked Insurance Options

Problem 11 measures the WTP for a direct insurance option on the basic lottery (DIO). Problem 12

measures the WTP for the corresponding naked insurance option (NIO). According to Claim 4 in Appendix B, we expect $DIO > NIO$ for risk-averse agents, $DIO = NIO$ for risk-neutral agents, and $DIO < NIO$ for risk-seeking agents. In practice, we found that, on average, $DIO > NIO$ significantly for all three groups of subjects. Only 17% bid $DIO < NIO$, 18% bid $DIO = NIO$, and all others (65%) bid $DIO > NIO$. The average DIO (across all subjects) was 31.3, while the average NIO was 19.1.

Again, prospect theory provides an intuitive explanation for these results. The framing of Problem 11 suggests that by buying the (direct) insurance option, subjects may avoid a loss of 60. In Problem 12, on the other hand, subjects are asked to price an option that pays a gain of 60. Since losses loom larger than gains, the DIO is significantly higher than the NIO.

According to Claim 5 in Appendix B, we also expect $A = 100 - DIO$ for all subjects (independently of their risk attitude). In practice, we found that for 34% of the subjects, $A > 100 - DIO$, for 13% $A = 100 - DIO$, and for 53% $A < 100 - DIO$. On average (across all subjects), $A = 59.9$, while $100 - DIO = 68.7$, a highly significant difference.

When we decompose the data across the three risk groups, we find that on average, $A < 100 - DIO$ significantly ($p = 0.016$) only for the R-risk-averse agents. For the R-risk-neutral and the R-risk-seeking agents, we could not reject the hypothesis that $A = 100 - DIO$. The (straightforward) intuition is that the risk-averse subjects prefer to sell the endowed lottery rather than buying an insurance option that covers the corresponding risk. These results are summarized in Conclusion 6:

Conclusion 6: The data suggest that subjects are willing to pay a special premium on a given option when it directly covers an existing risk. This behavior violates the predictions of expected utility theory but is explainable by prospect theory. Moreover, the data suggest that the prices risk-averse subjects are willing to pay to insure against the risk of the basic lottery are low relative to the prices at which they are willing to sell the lottery.

Consistency of Price Offers

In this section we examine two basic inequalities (on prices) that should hold when the assets are

traded in financial markets. The call-put parity (CPP) stipulates that when a call and a put option on a given lottery (stock) have the same exercise price X , the price of a bundle consisting of (the lottery + the put option) should equal (the exercise price X + the price of the call option). Using the notation introduced earlier we write:

$$\text{The Call-Put Parity: } WTP + LP = LC + X$$

The well-known idea behind the condition is that the distribution of returns from holding the first bundle (lottery + put) equals the distribution of returns from holding the second (X + call). The two bundles should thus be traded at the same price.

In our specific application, $X = 80$, so the condition becomes:

$$WTP + LP = LC + 80$$

The second inequality concerns the case where an investor concurrently holds the call and the put option on the basic lottery. Recall that the basic lottery pays either 40 or 100. Since the exercise price of the two options is 80, it follows that an investor who holds both options concurrently has a guaranteed minimal payoff of 20 but cannot earn more than 40. We thus require:

$$\text{Call + Put Inequality: } 20 \leq LC + LP \leq 40$$

We now check whether these two consistency conditions are met in our data. Note that the experiment underlying this paper does not involve any actual trading in the different assets. The basic no-arbitrage ideas underlying the two (in)equalities are therefore irrelevant here. However, it is still interesting to examine whether the individual bidding patterns conform with these consistency conditions.

The Call-Put Parity

Let $CPP = LC + 80 - WTP - LP$ denote the difference between the left-hand side (LHS) and the right-hand side (RHS) of the call-put parity equation. Table 9 presents the experimental data on the difference.¹⁹

The data demonstrate that all groups of subjects significantly violate (on average) the call-put parity in their bidding behavior. In particular, the price subjects are willing to pay for the call option is high relative to the price they are willing to pay for a bundle consisting of the basic lottery and the put option. The CPP is especially large for the risk-averse agents. The average CPP for the twenty most risk-averse agents (i.e., the agents who bid the lowest for Lottery 3) is 26, while the average CPP for the twenty most risk-seeking subjects is -3 . The coefficient of correlation between the individual measure of risk aversion (R) and the CPP is 0.447, and is highly significant ($t = 5.2$). The inclination to violate the call-put parity thus increases with the degree of risk aversion, as captured in the control problem 3.

Call + Put Inequality

Table 10 presents the experimental results on this issue.

The table shows that about 32% of the subjects violated the call + put inequality requirement when bidding for the two options. The risk-averse subjects tend to violate the LHS of the inequality, while the risk-seeking subjects tend to violate the RHS of the inequality. In particular, five of the twelve subjects who bid prices lower or equal to 10 for Lottery 3 violated the LHS of the inequality; four of the seven who bid prices higher or equal to 90 for Lottery 3 violated the RHS of the inequality. The coefficient of correlation between the individual measure of risk aversion (R) and the sum $LP + LC$ equals -0.23 , and is highly sig-

Table 9. *CPP*

	$CPP < 0$	$CPP = 0$	$CPP > 0$	Average CPP	Significance level
Risk Averse	15	5	80	21.9	0.01
Risk Neutral	23	10	67	3.4	0.04
Risk Seekers	41	2	57	4.8	0.05
All Subjects	28	4	68	10.9	0.01

Note: The significance level is for the hypothesis *CPP* is equal to zero.

Table 10. *LP+LC*

	$LC + LP > 40$	$LC + LP < 20$	$20 < LC + LP < 40$	Average $LC + LP$
Risk Averse	9	30	61	25.6
Risk Neutral	24	10	66	33.9
Risk Seekers	28	8	74	33.2
All Subjects	15	17	68	30.5

nificant ($t = -2.5$). Again, this suggests that the inclination to violate the no-arbitrage condition increases with the revealed degree of risk aversion as measured in Problem 3.

These findings are summarized in Conclusion 7.

Conclusion 7: Subjects who exhibit strong risk aversion or strong risk attraction are more likely to violate basic no-arbitrage conditions in their bidding patterns than subjects who are less extreme in their risk attitudes.

Concluding Discussion

The results and conclusions outlined in this paper seem quite surprising. Basically, the results suggest that the behavior of decision-makers when evaluating simple lotteries and options on lotteries may be more complicated and “rich” than typically assumed in economic and financial models. In particular, the values assigned to different lotteries and options on lotteries may depend on the characteristics of the underlying lottery, on the position of the decision-maker with respect to the lottery,²⁰ on initial endowments, and on individual risk preferences. Moreover, the nature of these dependencies is quite subtle and cannot be easily resolved by applying mainstream theories like expected utility or prospect theory.

For example, while some of our observations seem compatible with the predictions of expected utility, others seem to sharply contradict it. Prospect theory, on the other hand, seems to provide some interesting insights into subject behavior when bidding/asking for call/put and insurance options. Still, some aspects of the observed behavior (e.g., the zero correlation between long and short bidding) cannot be directly explained by that theory or other theories of choice.

The major limitations of this study are: 1) the sterile presentation of the options as rights or obligations that depend on the results of a simple two-prize lottery, and 2) the specific pool of subjects, undergraduate students in an introductory finance class. The sterile stylized presentation of the lotteries and the options was obviously chosen for increased control. The literature on experimental economics and finance, however, suggests that in such stylized experiments there are no significant differences in behavior between student-subjects and professionals (for examples, see Siegel and Harnett, 1964; King et al., 1992; Banks, Camerer, and Porter, 1994 and Ball and Cech, 1996). Abbink and Kuon [1998] even show that professional traders exhibit a significantly lower ability to recognize arbitrage opportunities in a “sterile” application than a corresponding pool of students.

Clearly, one should also be very careful when generalizing from a simple experiment in options evaluation to behavior and prices in general financial markets. However, the results of this study seem to support recent attempts to formally investigate the implications of alternative theories (e.g., prospect theory) on financial models and markets (see the surveys on behavioral finance mentioned in the introduction). On the normative level, our results may prove important for individual non-professional investors: If loss aversion indeed plays a role in individual investor considerations when contemplating an ask for short-selling some securities, then being aware of this possible bias may improve individual performance in the market.

Specifically, our results suggest that risk attitudes should be measured locally, as they may change with the structure of the underlying risk, with the position of the decision-maker with respect to that risk, and with the initial endowments. Extending these findings to the financial market realm, we conjecture that individual risk attitudes when bidding for stocks or bonds may be quite different from the revealed risk preferences when bidding for options.

Our results also suggest that agents with extreme risk attitudes are more inclined to violate basic no-arbitrage conditions in their bidding patterns. Extending this result to the financial market domain, one may conjecture that investors with moderate risk preferences and institutional or professional traders may earn profits on the backs of agents with extreme risk attitudes (e.g., individual speculators).

Acknowledgments

We thank Wulf Albers, Gary Charness, Ido Erev, Werner Guth, Wilhelm Neufeind, Robin Pope, and Ariel Rubinstein for helpful comments on different aspects of this article. We thank the fund for the promotion of research at the Technion for financial support.

Notes

1. The endowment effect says that the amount a person is willing to pay for an object is significantly lower than the amount he is willing to accept for selling it (long); more details are in the third section.
2. For most participants, the course provides the first encounter with finance. Most students are third-year undergraduates. The average age is about 23.5.
3. The same approach is taken by Kuon and Abbink [1996, 1998].
4. Note, however, that the proofs outlined in Appendix B hold when the expected utilities are multiplied by some *fixed* discount factor. This implies that the theoretical predictions outlined in the appendix carry over when all payoffs are made at some future date t . The experimental literature suggests, however, that the intensity of discounting may depend on the characteristics of the underlying lottery (for examples, see Ben-

- zation, Rapoport, and Yagil, 1989; Albrecht and Weber, 1997, and the references therein).
5. The average bids for Problem 1 were 13.1 in the first group and 13.4 in the second group. The corresponding average bids for Problem 2 were 16.4 and 15. The t-statistic significance levels (for comparing the average bids across the two groups) were 0.86 and 0.37, respectively.
6. The cases where subjects were asked to bid the price at which they were willing to short-sell a lottery or an option were formulated as "selling an obligation" (see Problems 6, 9, and 10 in Appendix B).
7. Alternatively, we could have used the BDM (Becker-DeGroot-Marschak) mechanism to encourage truthful revelation. We chose the second-price auction mechanism instead because this "competitive" mechanism seemed more effective for approximating subject behavior in financial markets (see the discussion in Coursey, Hovis, and Schulze, 1987).
8. The conversion rate at the time of the experiment was approximately four shekels per dollar.
9. Figure 1 implicitly assumes that the lotteries are evaluated with respect to a zero reference point. The argument, however, can be easily modified to fit the case where the reference point is the initial balance (100 NIS), or the initial balance minus the bid (i.e., 100 WTP in Problem 4).
10. For recent empirical findings that support the hypothesis that the 30% probability is overweighted and the 70% probability is underweighted, see the parameter-free estimations of Bleichrodt and Pinto [2000] and Abdellaoui [2000].
11. Shavit, Sonsino, and Benzion [2001] also show that the bidding prices for different call options in a web experiment are significantly higher than the corresponding bids in a classroom experiment.
12. The distinction between *behavioral modesis* frequently drawn in the psychological literature to characterize subject behavior in different applications. We could not trace any previous uses of this term in the literature on decision theory. For an example of the use of this term in *Industrial Organization*, see Lofgren [1989] and the references therein.
13. See Knetsch and Sinden [1984] for the first documentation of the endowment effect for lotteries. See Coursey, Hovis, and Schulze [1987], Kahneman, Knetsch, and Thaler [1991], Loomes and Weber [1996], Tietz [1990], and Weber, Keppe, and Meyer-Delius [2000] for several interesting studies of the effect.
14. The idea may be formally demonstrated by using a utility function with an S-shape, similar to the one outlined in Figure 1. If subjects are risk-seeking at low wealth levels and risk-averse at higher wealth levels, an increase in the initial (monetary) wealth may indeed decrease the WTA for the endowed lottery. (Note, however, that this argument ignores the possible switch in reference points with the initial endowments.)
15. The qualitative results of this section hold when we use the bids for Lottery 4 (instead of the bids for Lottery 3) to subdivide the subjects into the three different risk groups.
16. This conclusion is still valid when subjects are divided into three risk groups according to their bids for Lottery 4.
17. For additional experimental evidence indicating that investors dislike short positions, see Weber, Keppe, and Meyer-Delius [2000].
18. When applying prospect theory to our two options, only the loss aversion factor is relevant, because the options pay a given prize with a fixed probability (and zero with the complementary probability).
19. We chose to check the no-arbitrage conditions using the WTPs for the different lotteries. Note, however, that the qualitative results (violations of no-arbitrage conditions, positive correlation with risk aversion) do not change when we use alternative formulations, e.g., when we check the call-put parity for the

case of buying the call option long and selling the stock and the put option short (so that $LC + X - AS - SP = 0$).

20. This seems to resemble previous experimental observations on the dependency of discounting on the magnitude and the framing of future payoffs (for examples, see Benzion, Rapoport, and Yagil, 1989 and Albrecht and Weber, 1997).

References

- Abdellaoui, M. "Parameter-Free Elicitation of Utility and Probability Weighting Functions." *Management Science*, 46, (2000), pp. 1497–1512.
- Albrecht, M., and M. Weber. "An Empirical Study on Intertemporal Decision Making Under Risk." *Management Science*, 43, (1997), pp. 813–826.
- Ball and Cech, P. "Subject Pool Choice and Treatment Effects in Economic Laboratory Research," *Research in Experimental Economics*, 6, (1996), pp. 239–292.
- Banks, J., C. Camerer, and D. Porter. "An Experimental Analysis of Nash Refinements in Signaling Games." *Games and Economic Behaviour*, 6, (1994), pp. 1–31.
- Benzion, U., U. Rapoport, and J. Yagil. "Discounted Rates Inferred from Decisions: An Experimental Study." *Management Science*, 35, (1989), pp. 270–284.
- Bleichrodt, H., and J.L. Pinto. "A Parameter-Free Elicitation of the Probability Weighting Function in Medical Decision Making." *Management Science*, 48, (2000), pp. 1485–1496.
- Bosch-Domènech, A., and J. Silvestre. "Does Risk Aversion or Attraction Depend on Income? An Experiment." *Economic Letters*, 65, (1999), pp. 265–273.
- Camerer, C. "Individual Decision Making." In J. Kagel and A. Roth, eds., *The Handbook of Experimental Economics*. Princeton: Princeton University Press, 1995.
- Coursey, D.L., J.L. Hovis, and D.W. Schulze. "The Disparity between Willingness to Accept and Willingness to Pay of Value." *Quarterly Journal of Economic*, 102, (1987), pp. 679–690.
- Dejong, D.V., R. Forsythe, and W.C. Uecker. "A Note on the Use of Businessmen as Subjects in Sealed Offer Markets." *Journal of Economic Behavior and Organization*, 9, (1988), pp. 87–100.
- Kahneman, D., J.L. Knetsch, and R.H. Thaler. "Anomalies: The Endowment Effect, Loss Aversion and Status Quo Bias." *Journal of Economic Perspectives*, 5, (1991), pp. 193–206.
- Kahneman, D., and A. Tversky. "Prospect Theory: An Analysis of Decision Under Risk." *Econometrica*, 47, (1979), pp. 263–291.
- King, R.R., V.L. Smith, A.W. Williams, and M. van Boening. "The Robustness of Bubbles and Crashes in Experimental Stock Markets." In I. Prigogine, R.H. Day, and R. Chen, eds, *Evolutionary Dynamics and Nonlinear Economics—A Transdisciplinary Dialogue*. Oxford: Oxford Press, 1992.
- Knetsch, J.L., and J.A. Sinden. "Willingness to Pay and Compensation Demanded: Experimental Evidence of an Unexpected Disparity in Measures of Value." *Quarterly Journal of Economics*, 99, (1984), pp. 507–521.
- Krahnén, J.P., C. Rieck, and E. Theissen. "Inferring Risk Attitudes from Certainty Equivalents: Some Lessons from an Experimental Study." *Journal of Economic Psychology* 18, (1997), pp. 469–486.
- Kuon, B., and K. Abbink. "An Experimental Investigation of the Option Pricing Approach." Discussion Paper b-376, University of Bonn, 1996.
- Kuon, B., and K. Abbink. "An Option Pricing Experiment with Professional Traders." Discussion Paper b-426, University of Bonn, 1998.
- Lofgren, K. "Buying and Selling Behavior in Stochastic Environments with Backstop Markets." *Journal of Economics*, 50, (1989), pp. 87–112.

- Loomes, G., and M. Weber. "Endowment Effect for Risky Assets." In W. Albers, W. Güth, P. Hammerstein, B. Moldovanu, and E. van Damme, eds., *Understanding Strategic Interaction—Essays in Honor of Reinhard Selten*. New York: Springer-Verlag, 1996.
- Schwartz, H. *Rationality Gone Awry? Decision Making Inconsistent with Economic and Financial Theory*. Westport, CT and London: Greenwood, Praeger, 1998.
- Shavit, T., D. Sonsino, and U. Benzion. "A Comparative Study of Lotteries —Evaluation in Class and on the Web." *Journal of Economic Psychology*, 22, 4, August, (2001), pp. 483–491.
- Shiller, R.J. "Human Behavior and the Efficiency of the Financial System." National Bureau of Economic Research Working Paper 6375, 1998.
- Shleifer, A. "Inefficient Markets: An Introduction to Behavioral Finance." *Calderon Lectures in Economics*. Oxford and New York: Oxford University Press, 2000.
- Siegel, S., and D.L. Harnett. "Bargaining Behavior: A Comparison between Mature Industrial Personnel and College Students." *Operation Research*, 12, (1964), pp. 334–343.
- Tietz, R. "An Endowment Effect in Market Experiments." Frankfurt University, 1990.
- Weber, M., H.J. Keppe, and G. Meyer-Delius. "The Impact of Endowment Framing on Market Prices—An Experimental Study." *Journal of Economic Behavior and Organization*, 41, (2000), pp. 159–176.

APPENDIX A The Problems

Control Problem 1

Your initial balance is 100 NIS.

Assume we conduct the following lottery for a third party (you don't own the lottery):

Probability	NIS Value
0.7	80
0.3	30

What is the maximum price you are willing to bid for the right to get 20 NIS if the lottery's outcome is 80 and nothing if the lottery's outcome is 30?

Control Problem 2

Your initial balance is 100 NIS.

Assume we conduct the following lottery for a third party (you don't own the lottery):

Probability	NIS Value
0.7	80
0.3	30

What is the maximum price you are willing to bid for the right to get 30 NIS if the lottery's outcome is 30 and nothing if the lottery's outcome is 80?

Measuring Risk Attitude

Your initial balance is 100 NIS.

What is the maximum price you are willing to bid for the following lottery?

Probability	NIS Value
0.5	100
0.5	0

WTP for the Basic Lottery

Your initial balance is 100 NIS.

What is the maximum price you are willing to bid for the following lottery?

Probability	NIS Value
0.7	100
0.3	40

WTA for the Basic Lottery

Your initial balance is 100 NIS.

In addition, you have the following lottery:

Probability	NIS Value
0.7	100
0.3	40

What is the minimum price at which you are willing to sell the lottery? (If you won't sell the lottery, you will get the lottery's outcome.)

Selling the Basic Lottery Short

Your initial balance is 100 NIS.

What is the minimum price for which you are willing to pay the outcome of the following lottery?

Probability	NIS Value
0.7	100
0.3	40

Call Option C on the Basic Lottery

Your initial balance is 100 NIS.

Assume we conduct the following lottery for a third party (you don't own the lottery):

Probability	NIS Value
0.7	100
0.3	40

What is the maximum price you are willing to bid for the right to get 20 NIS if the lottery's outcome is 100 and nothing if the lottery's outcome is 40?

Put Option P on the Basic Lottery

Your initial balance is 100 NIS.

Assume we conduct the following lottery for a third party (you don't own the lottery):

Probability	NIS Value
0.7	100
0.3	40

What is the maximum price you are willing to bid for the right to get 40 NIS if the lottery's outcome is 40 and nothing if the lottery's outcome is 100?

Short on Call Option C

Your initial balance is 100 NIS.

Assume we conduct the following lottery for a third party (you don't own the lottery):

Probability	NIS Value
0.7	100
0.3	40

What is the minimum price for which you are willing to accept the obligation to pay 20 NIS if the lottery's outcome is 100 and nothing if the lottery's outcome is 40?

Short on Put Option C

Your initial balance is 100 NIS.

Assume we conduct the following lottery for a third party (you don't own the lottery):

Probability	NIS Value
0.7	100
0.3	40

What is the minimum price for which you are willing to accept the obligation to pay 40 NIS if the lottery's outcome is 40 and nothing if the lottery's outcome is 100?

Direct Insurance Option on the Basic Lottery

Your initial balance is 100 NIS.

In addition, you have the following lottery:

Probability	NIS Value
0.7	100
0.3	40

What is the maximum price you are willing to bid for the right to get 60 NIS if the lottery's outcome is 40 and nothing if the lottery's outcome is 100, so that you get 100 NIS either way?

Naked Insurance Option on the Basic Lottery

Your initial balance is 100 NIS.

What is the maximum price you are willing to bid for the following lottery?

Probability	NIS Value
0.7	0
0.3	60

APPENDIX B Definitions and Claims

To formally present the basic concepts examined in the experiment, we adopt the expected utility model as a benchmark. We focus on a simple Lottery L that pays $W1 > 0$ with probability a , and $W2 > W1 > 0$ with the complementary probability $(1 - a)$. We use $E(L) = aW1 + (1 - a)W2$ to denote the expected payoff from L. We use $U(\cdot)$ to present the monotonically increasing utility function of a (representative) decision-maker (DM); the expected utility from Lottery L is thus equal to $aU(W1) + (1 - a)U(W2)$. We say that DM is risk averse when $U(aW1 + (1 - a)W2) > aU(W1) + (1 - a)U(W2)$ for every Lottery L as described above. We say that DM is risk-seeking when $U(aW1 + (1 - a)W2) < aU(W1) + (1 - a)U(W2)$ for every such lottery.

In the next three definitions we draw a distinction between three different prices for Lottery L: The maximum price DM is willing to pay for the lottery; the minimum price at which DM is willing to sell the lottery when he owns it; and the minimum price at which DM is willing to sell the lottery when he does not own it, i.e., the minimum price at which DM will sell the lottery "short."

Definition 1: The willingness to pay for Lottery L at income level I, $WTP(I)$, denotes the maximum amount

DM is willing to pay for Lottery L at the basic income level I. Formally, WTP(I) is defined by:

$$U(I) = aU(I - WTP(I) + W1) + (1 - a)U(I - WTP(I) + W2)$$

Definition 2: The willingness to accept for Lottery L at income level I, WTA(I), denotes the minimum amount at which DM is willing to sell Lottery L at the basic income level I. Formally, WTA(I) is defined by:

$$U(I + WTA(I)) = aU(I + W1) + (1 - a)U(I + W2)$$

Definition 3: The willingness to accept for selling Lottery L short at income level I, AS(I), is the minimum amount at which DM is willing to sell Lottery L short. Formally, AS(I) is defined by:

$$U(I) = aU(I + AS(I) - W1) + (1 - a)U(I + AS(I) - W2)$$

Our first claim says that the minimum price demanded for selling the lottery “short” is higher than the maximum price offered for buying the lottery when the agent is risk averse. The inequality is reversed when the agent is risk-seeking.

Claim 1:

If U is concave, then $AS(I) > WTP(I)$.

If U is convex, then $AS(I) < WTP(I)$.

Proof:

For convenience, we use WTP to denote WTP(I) and AS to denote AS(I).

By definition of WTP, if U is concave, then

$$U(I) = aU(I - WTP + W1) + (1 - a)U(I - WTP + W2) \leq U(I - WTP + E(L)) \quad (1)$$

so that $I \leq I - WTP + E(L)$, and

$$WTP \leq E(L) \quad (2)$$

By definition of AS, if U is concave, then

$$U(I) = aU(I - W1 + AS) + (1 - a)U(I - W2 + AS) \leq U(I - E(L) + AS) \quad (3)$$

so that $I \leq I - E(L) + AS$, and

$$E(L) \leq AS \quad (4)$$

From (2) and (4), it follows that $WTP \leq AS$.

The proof that $WTP \leq AS$ when U is convex is similar.

The next claim shows that a similar relationship exists between the minimum price demanded for selling

the lottery “short,” and the minimum price asked for selling the lottery “long.”

We now set $A(I) = WTA(I)$ to abbreviate the notation for the WTA.

Claim 2:

If U is concave, then $AS(I) \geq A(I)$.

If U is convex, then $AS(I) \leq A(I)$.

Proof:

For convenience, we use A to denote A(I).

By definition of A, if U is concave, then

$$U(I + A) = aU(I + W1) + (1 - a)U(I + W2) \leq U(I + E(L)) \quad (5)$$

so that $A \leq E(L)$.

From Equations (4) and (5), it follows that $A \leq AS$.

The proof that $A \geq AS$ when U is convex is similar.

The following definitions and results refer to options on Lottery L as defined above. In particular, we refer to a call option with an exercise price X satisfying $W1 < X < W2$, and a put option with the same exercise price X.

Definition 4: The willingness to pay for a call option with an exercise price X on Lottery L at income level I, LC(I), is the maximum amount DM is willing to pay for the option. Formally, LC(I) is defined by:

$$U(I) = aU(I - LC(I)) + (1 - a)U(I - LC(I) + W2 - X)$$

Definition 5: The willingness to pay for a put option with an exercise price X on Lottery L at income level I, LP(I), is the maximum amount DM is willing to pay for the option. Formally, LP(I) is defined by:

$$U(I) = aU(I - LP(I) + X - W1) + (1 - a)U(I - LP(I))$$

Definition 6: The willingness to accept for selling short a call option with an exercise price X on Lottery L at income level I, SC(I), is the minimum amount at which DM is willing to sell the option short. Formally, SC(I) is defined by:

$$U(I) = aU(I + SC(I)) + (1 - a)U(I + SC(I) - W2 + X)$$

Definition 7: The willingness to accept for selling short a put option with an exercise price X on Lottery L at income level I, SP(I), is the minimum amount at

which DM is willing to sell the option short. Formally, $SP(I)$ is defined by:

$$U(I) = aU(I + SP(I) - X + W1) + (1 - a)U(I + SP(I))$$

Claim 3 shows that the relationship between the price offered for an option and the price demanded for selling the same option “short” depends on the risk preferences of the decision-maker.

Claim 3:

If U is concave, then $LC(I) \leq SC(I)$ and $LP(I) \leq SP(I)$.
If U is convex, then $LC(I) \geq SC(I)$ and $LP(I) \geq SP(I)$.

Proof:

The claim may be considered a special case of Claim 1. We thus omit the details.

The next two definitions deal with insurance options on Lottery L . These options pay the difference $W2 - W1$ when the realized payoff from the lottery is $W1$. We distinguish between the case when the insurance option is “direct,” i.e., sold to the owner of Lottery L , and the case when the insurance is “naked,” i.e., sold to an investor who does not own the corresponding Lottery L .

Definition 8: The willingness to pay for a direct insurance option on Lottery L at income level I , $DIO(I)$, is the maximum amount that DM is willing to pay to ensure he will receive the higher payoff $W2$ even when the lottery’s outcome is $W1$. Formally, $DIO(I)$ is defined by:

$$U(I - DIO(I) + W2) = aU(I + W1) + (1 - a)U(I + W2)$$

Definition 9: The willingness to pay for a naked insurance option on Lottery L at income level I , $NIO(I)$, is the maximum amount DM is willing to pay for a lottery that pays $W2 - W1$ with probability a and 0 otherwise. Formally, $NIO(I)$ is defined by:

$$U(I) = aU(I - NIO(I) + W2 - W1) + (1 - a)U(I - NIO(I))$$

Claim 4 shows that the relationship between NIO and DIO also depends on the risk preferences of the decision-maker.

Claim 4:

If U is concave, then $DIO(I) \geq NIO(I)$.
If U is convex, then $DIO(I) \leq NIO(I)$.

Proof:

For convenience, we use DIO to denote $DIO(I)$ and NIO to denote $NIO(I)$.

By definition, $E(L) + a(W2 - W1) = W2$.

By definition of $DIO(I)$, if U is concave, then

$$U(I - DIO + W2) = aU(I + W1) + (1 - a)U(I + W2) \leq U(I + E(L)) \quad (6)$$

so that

$$I - DIO + W2 \leq I + E(L)$$

and

$$DIO \geq W2 - E(L) = a(W2 - W1) \quad (7)$$

By definition of NIO , if U is concave, then

$$U(I) = aU(I + W2 - W1 - NIO) + (1 - a)U(I - NIO) \leq U(I + a(W2 - W1) - NIO)$$

so that

$$I \leq I + a(W2 - W1) - NIO$$

and

$$NIO \leq a(W2 - W1) \quad (8)$$

From (7) and (8), it follows that $NIO \leq DIO$.

The proof that $NIO \geq DIO$ when U is convex is similar.

Claim 5 finally shows that the willingness to pay for direct insurance on Lottery L plus the willingness to accept for the lottery must always sum to $W2$ (independently of the risk preferences).

Claim 5:

$$A(I) = W2 - DIO(I)$$

Proof:

By definition of $DIO(I)$,

$$U(I - DIO + W2) = aU(I + W1) + (1 - a)U(I + W2) \quad (9)$$

By definition of $A(I)$,

$$U(I + A) = aU(I + W1) + (1 - a)U(I + W2) \quad (10)$$

From (9) and (10), it follows that $U(I - DIO + W2) = U(I + A)$, so that $I - DIO + W2 = I + A$, and

$$A(I) = W2 - DIO(I) \quad (11)$$

Copyright of Journal of Psychology & Financial Markets is the property of Lawrence Erlbaum Associates and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.