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Risk Aversion or Myopia?
Choices in Repeated Gambles and Retirement Investments

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Abstract: We study how decision makers choose when faced with multiple plays of a gamble or investment. When evaluating multiple plays of a simple mixed gamble, a chance to win x or lose y , subjects show a sensitivity to the amount to lose on a single trial, holding the distribution of returns for the portfolio constant; that is, they display “myopic loss aversion.” Many subjects who decline multiple plays of such a gamble will accept it when shown the resulting distribution. This analysis is applied to the problem of retirement investing. We show that workers invest more of their retirement savings in stocks if they are shown long-term (rather than one-year) rates of return.

Introduction

Many choices under uncertainty are available repeatedly. Each week during the football season we choose whether or not to bet on our favorite team. Each night on the way home we can run that yellow light, or not. And our retirement funds are invested, in either safe or risky assets, every day until we retire or perhaps until we die. How do people make such repeated decisions, and how should they?

The subtle interplay between single and repeated gambles, both normatively and descriptively, is well illustrated by the literature that has followed an early paper by Paul Samuelson (1963). In this paper, "Risk and Uncertainty: A Fallacy of Large Numbers," Samuelson describes a lunchtime conversation in which he offered an attractive bet to one of his colleagues: flip a coin; heads you win \$200, tails you lose \$100. The colleague declined Samuelson's offer but announced his willingness to take a series of 100 such bets. This behavior, turning down one bet but accepting many, struck Samuelson as inconsistent and induced him to prove a theorem. The theorem states that if an individual is unwilling to take a single play of a bet at any wealth level that could obtain over a series of such bets (here current wealth minus \$10,000 to plus \$20,000) then she should not accept multiple plays of the same bet. He offers a simple induction argument to prove the theorem.¹

Samuelson's theorem is limited to the case he described (and he warns explicitly against undue extrapolation of the theorem).² However, the conditions in which the theorem applies are not as limiting as it might seem. Suppose, for example, that Samuelson's colleague has retirement savings of \$500,000 invested in stocks and that in the past week the value of the portfolio has gone up or down \$10,000 (2%). It seems unlikely that this change would alter his

¹ To see the intuition, consider an individual who has announced Samuelson's colleague's preferences and has played 99 bets. If asked whether he would like to stop at this point he will say yes, by assumption (since he dislikes one bet at any relevant wealth level). However, this means that if asked after 98 bets whether he would like to play number 99 he must also decline since he should realize (by backward induction) that he would reject bet 100, implying that bet 99 is a single play and thus unacceptable. The same reasoning applies to the first bet.

² For a recent effort to elaborate on Samuelson's theorem, see Ross (1997).

willingness to take one of Samuelson's bets. If not, then the theorem applies to him (as Samuelson clearly thought it did), and he has committed a violation of expected utility theory. Indeed, as Tversky and Bar-Hillel (1983) have shown, SC (as they call Samuelson's colleague, a convention we will follow) violates an even more basic rationality condition involving dominance.

The normative analysis seems quite clear for Samuelson's restrictive conditions; yet, SC was an MIT economics professor, presumably no fool, and psychologist Lola Lopes (1981, 1996) has called his choices "eminently sensible" (1996, p. 184). Of course, SC's choices are understandable. The one-shot gamble entails a 50% chance of going home and explaining a loss of a nontrivial sum of money (especially in 1963 dollars); on the other hand, the series of 100 bets offers an expected gain of \$5000 and a chance of losing money of less than half a percent. If we accept the logic of the Samuelson and Tversky and Bar-Hillel proofs then one of these choices must be "wrong," but which one? Samuelson makes it clear that he thinks the faulty choice is accepting the 100 bets. The "fallacy of large numbers" that he accuses his colleague of committing is the erroneous belief that the variance of outcomes decreases as the number of trials increases. Since we, like Lopes, find accepting the 100-bet sequence at least eminently sensible, but unlike Lopes also find the arguments favoring consistency compelling, we are forced to point our criticism at the only other alternative: the decision to reject just one bet. We think that SC fell victim to what we have elsewhere (1995) called "myopic loss aversion."

Loss aversion is the property of the prospect theory value function (Kahneman and Tversky, 1979) that reductions in wealth, relative to the current reference point, are weighted much more heavily than increases in wealth. Roughly speaking, losses are weighted about twice as much as gains. In fact, SC explained his rejection of a single play of the gamble by saying that he was loss averse: "I won't bet because I would feel the \$100 loss more than the \$200 gain" (Samuelson, 1963, p. 109). While such a choice might seem consistent with simple risk aversion, it is hard to justify rejecting a bet as good as this one with any reasonable wealth level. For example, suppose SC's utility function is $U(W) = \ln W$ and his wealth is a modest \$10,000.

In that case, an expected utility maximizing SC would be willing to risk a 50% chance of losing \$100 if he had a 50% chance to gain a mere \$101.01! If his wealth is \$100,000, then with the same log utility function SC will risk losing \$100 in order to gain \$100.10. Similar results obtain for other reasonable utility functions.³ So, to explain SC's unwillingness to play one of Samuelson's bets we need to rely on loss aversion, not risk aversion.

There are two senses in which the loss aversion SC displayed deserves the additional adjective "myopic." First, SC could be accused of looking at the gamble at too close a cognitive distance (what Kahneman and Lovallo (1993) have called "narrow framing"); had SC incorporated the gamble into his wealth he would likely have accepted it, as the calculations in the previous paragraph show. Samuelson could have helped him out by suggesting an alternative frame: "are you willing to accept a gamble in which there is a 50% chance of having your current wealth plus \$200 and a 50% chance of having your current wealth minus \$100?" SC is likely to have been willing to accept this gamble when viewed from an appropriate distance. The other sense in which turning down one bet is myopic is that if Samuelson offered a single play of the bet every day at lunch SC would never get his desired portfolio of 100 bets unless he was willing to take the first one. Presumably, SC would have been willing to commit to 100 daily bets, especially if he did not have to find out how each bet came out along the way. Indeed, he probably was playing a less attractive version of this bet every day (passively) simply by holding some of his retirement portfolio in stocks.

If we agree with Samuelson that refusing one bet but accepting many violates attractive normative principles, then how can we settle the question of which decision was the incorrect one? If Samuelson is right -- that SC was committing a "fallacy of large numbers" in misestimating the variance of the many bet portfolio -- then he would presumably change his mind if he were shown the correct distribution. (This follows because when the actual

³ In fact, Rabin (1997) uses the same assumptions as Samuelson to show that a rational individual who turns down one play of the \$200/\$100 bet must also turn down a 50-50 chance to lose \$200 or win \$20,000. His results depend only on concavity. Rabin's conclusion, like ours, is that turning down a single bet must be wrong.

distribution is presented it is not possible to make the mistake Samuelson claims drives the behavior.) In this spirit we conduct several experiments in which people are offered repeated gambles described either in words (N plays of the gamble X) or in terms of possible outcomes (probability p of obtaining x, probability q of obtaining y, etc.). We find that there are discrepancies between these two presentation formats, but not in a way that favors Samuelson's hypothesis. When subjects are shown the distributional facts about repeated plays of a positive expected value gamble they like them more, rather than less.

The story of Samuelson's colleague illustrates that even sophisticated people can make choices in repeated contexts that violate intuitively appealing normative analyses. Our goal here is to learn more about how people choose in these contexts. We show that SC is not alone in making inconsistent choices, but, perhaps of greater interest, we show that holding the distribution of final outcomes constant we can predict which repeated play gambles people will find attractive.

This line of research has more than just academic interest. There are interesting parallels between repeated plays of independent gambles (essentially addition problems) and investing over time where returns are compounded (essentially multiplication problems). Under certain assumptions (e.g., returns are a random walk and utility functions with constant relative risk aversion) then Merton (1969) and Samuelson (1969) have proved theorems much like Samuelson's theorem about his colleague: namely that asset allocation should be independent of the time horizon of the investor.⁴ These results have always been controversial and counterintuitive; in fact, most investment advisors explicitly recommend changing the asset mix (toward more conservative investments) as retirement becomes closer. Our goal, however, is not to contribute to the controversy about normative advice but rather to address a more practical

⁴ The idea is that if an investor is so risk averse that she wants to invest in a risk-free asset for the short run then she should also want to invest the same way for the long run. Just as risk increases when a bet is repeated, so does the variance of returns when an investment is held over time. In the case of stock returns if the log of stock price follows a random walk then the return variance increases in proportion to the return horizon. If returns are mean-reverting (as has been documented by [Poterba and Summers \(1988\)](#)) then the variance increases more slowly than the horizon.

question: How do investors think about investment decisions over long horizons, and how do their choices depend on the way in which risk and return data are presented?

Therefore, we conduct experiments about repeated investment decisions over time that are in parallel with our earlier experiments about repetitions of independent gambles. In the context of retirement savings decisions, employees are presented with a realistic decision: how to invest in a defined contribution, 401(k)-type pension plan. The subjects are either told about the characteristics of one-year return distributions (like one play of the gamble) or simulated distributions of many-year returns (like many plays). Once again, we find that subjects who are shown the explicit multi-year distributions are willing to accept more risks. We find that the manner in which past return data are displayed can have a significant effect on the asset allocation savers select.

The plan of the paper is as follows: Section 1 reviews some of the literature that has investigated similar topics. Section 2 reports a study that investigates gambles similar to Samuelson's gamble. Section 3 describes a more general experiment on single and repeated play gambles. Sections 4 and 5 turn to the study of retirement-saving decision making. Section 6 concludes.

1. Literature Review

Although most of the literature on decision making under uncertainty has concentrated on simple single-play gambles, there are a number of papers that have investigated whether the one-play results can easily be extended to repeated plays. On the normative side, Samuelson's (1963) paper stimulated a long series of papers regarding the conditions in which a decision maker should be consistent between single and repeated plays. Some recent contributions include [Pratt and Zeckhauser \(1987\)](#), [Kimball \(1993\)](#), [Gollier \(1996\)](#), and [Ross \(1997\)](#).

An excellent early contribution to the descriptive literature is [Coombs and Meyer \(1969\)](#). Subjects are offered both single- and repeated-play gambles and are asked to assess the riskiness of the gambles. In the case of the repeated plays, subjects are shown the actual distributions that

the gambles imply. Our study uses many of the same techniques, but our emphasis is on preferences rather than perceptions of risk. Since that early study little was done until the influential paper by Lola Lopes (1981). In this paper Lopes defends the choices of Samuelson's colleague, a position she has recently reiterated (1996). Tversky and Bar Hillel's paper, which makes both normative and descriptive contributions, was essentially a reply to Lopes. Their view (which we share) is that Samuelson's normative analysis is correct and to understand the behavior we observe we need explicitly descriptive theories such as prospect theory. Keren and Wagenaar (1987) and Keren (1991) take up additional descriptive questions. The former paper shows that many of the prospect theory findings cannot be extended to repeated plays in a straightforward manner. For example, although a majority of subjects prefer a certain (or nearly certain, i.e., $p=0.99$) prize of \$100 guilders to a 50% chance to win 250 guilders, when the gambles are repeated 10 times, a majority of the subjects switch to the risky option. In general, Keren and Wagenaar find that a positive expected value gamble becomes more attractive when it is repeated. However, their gambles involve only strictly positive or strictly negative outcomes (no mixed gambles), so their results may not generalize to mixed gambles. Keren (1991) does investigate the mixed gamble case: he conducts one experiment similar to our study 1, which we will discuss below.

Although there is a long tradition of investigating the role of providing information to consumers in other contexts, (e.g., [Russo, 1977](#)), less has been done in the context of gambles. [Montgomery and Adelbratt \(1982\)](#) investigate what happens if subjects are given information about the expected value of alternative prospects. They do not find strong effects except in the case of repeated gambles, where they find that the information about EV had more influence on subjects' choices.

An alternative to providing a calculation of the expected value is to show the subjects the distribution of outcomes that might occur from a given gamble. Lopes (1984) adopts this approach in a study of strictly positive gambles. More closely related to our analysis is the

article by Redelmeier and Tversky (1992), who offer subjects choices of single and multiple plays of gambles. Their results are similar to ours.

2. Samuelson's Bet (Study 1)

Samuelson's colleague turned down a single play of an attractive bet, but was willing to accept many such bets. Putting aside for now the question of whether such behavior is rational, there are two interesting empirical questions that this story provokes. First, is SC typical? Would many (most?) people react to Samuelson's bet the same way? Second, for those who are willing to take many such bets, do they change their mind when they see the actual distribution of outcomes produced by this parlay (as Samuelson's "fallacy of large numbers hypothesis would suggest)? Our first study addresses these questions.

Methods

To determine whether SC is typical, we gave three groups of subjects scaled-down versions of the choice SC faced. Specifically, we asked subjects whether they were (hypothetically) willing to accept a single play of the Samuelson bet. Then, we also asked them whether they were willing to accept a series of 100 such bets. The subjects in the experiment were (A) 36 University of Southern California (USC) undergraduate business students, (B) 62 visitors to a coffee shop in Westwood, Los Angeles, and (C) 65 MBA students at the University of Chicago. We used three subject pools to see whether our findings were robust to variations in economics and statistics training.

After each subject answered the first two questions (about one play and 100 plays) we asked a third question: Will you accept a gamble with the following distribution of possible outcomes? The distribution we constructed was approximately the distribution that would be expected from 100 plays of the gamble. However, it is difficult to display graphically the minuscule chances of losing a large amount of money. To solve this problem we constructed a distribution that is strictly worse than the true distribution. Whereas the chance of losing 100 times in a row is $7.88 * 10^{-31}$, we have made it look as if one in 100,000 people should expect

such a loss. The purpose of this third question was to see whether the subjects that elected to accept the multiple-play gamble would change their mind when they saw the distribution of outcomes they would face (as Samuelson's hypothesis would suggest.)

The stakes we used in the experiment were somewhat lower than those used in the original Samuelson bet, since most of our subjects are students. USC students and visitors to the coffee shop were presented with one tenth of the original stakes (i.e., win \$20 or lose \$10), and the MBAs at the University of Chicago were presented with one half of the original stakes (i.e., win \$100 or lose \$50). To motivate participation, we offered three lotteries, one for each group of subjects. The three winners, who were selected at random, received \$100 each.⁵

Results

There are eight possible ways to answer the three questions posed to our subjects. The bottom panel of Table 1 shows the number of participants in each of our samples who selected each of the possible patterns. Not all the patterns are consistent with rational choice. For a pattern to be considered rational, a respondent must answer questions 2 and 3 the same since they are formally the same question. This logic implies that patterns 2, 3, 6, and 7 are not rational. Of the remaining four patterns, 1 and 8 are unobjectionable since all questions are answered the same way. Pattern 4, accepting one bet but rejecting many, could be rational in some circumstances (such as when a large loss, however unlikely, cannot be tolerated), but it is rarely chosen. Pattern 5 (and 6), rejecting one bet but accepting many, is the one selected by SC, and we know from Samuelson's theorem that this is not rational. Samuelson's explanation of this choice would suggest that we would observe more of pattern 6 (since the graph would reveal their hypothesized fallacy of large numbers). However, only one of our 163 subjects chose this way. In contrast, 23 subjects making the SC choice of rejecting a single bet but accepting 100 changed their mind when they were shown the chart.⁶

⁵ The stimuli are available from the authors upon request.

⁶ Similarly, of the 41 subjects who accept one play of the bet but reject many, 35 (85%) change their mind when they see the graph.

The SC pattern was not dominant in our samples, however. For all three groups of subjects, a majority were willing to play a single play of the bet.⁷ For the multiple-play bets we observe a difference between the two relatively unsophisticated groups (the USC undergraduates and the coffee shop visitors) and the more sophisticated Chicago MBA students. In the unsophisticated groups, significantly fewer subjects were willing to accept 100 plays of the gamble than were willing to take one. This pattern is the opposite to that chosen by Samuelson's colleague. In contrast, more of the Chicago MBAs (75 percent) were willing to take 100 bets than one (although not significantly more-- $p=.10$).⁸ In every group, a very large majority (from 83 to 90 percent) were willing to take 100 plays of the bet when shown the explicit distribution, even though the distribution they were shown was strictly worse than the actual distribution associated with the portfolio of bets.

[Insert Table 1 About Here]

To summarize our first study, we find no support for Samuelson's "fallacy of large numbers." In fact, the evidence is rather consistent with a fallacy of small numbers ([Kahneman and Tversky, 1972](#)). Subjects appear to have overestimated the variance of the multiple-play gamble, rather than underestimating it. This error was particularly common among the less sophisticated subjects. When shown how unlikely it is to lose any money, virtually all of the subjects accept the repeated gamble.

⁷ In contrast, 79 percent of Keren's (1991) undergraduate students turn down one play of a bet at similar stakes. There are several possible explanations for this difference in the willingness to take the single bet. First, Keren used somewhat different methods: he asked other questions before the pair we are comparing, and he asked the repeat gamble question quite differently (see the next footnote). He also told subjects that a few would be selected to play out one of their bets whereas our questions were strictly hypothetical. Regarding the high rates of risk seeking in our business students (the USC undergraduates and the University of Chicago MBA students), this may reflect their chosen field of study. Thaler and Johnson (1990) report similar behavior for Cornell MBA students. As for the coffee shop visitors, the coffee shop is located in an affluent neighborhood and the participants may have found the stakes low enough to be attractive. In any case, the primary focus of this study is to compare the two versions of the multiple-play options so the underlying level of risk-seeking preferences should not be of great concern.

⁸ Keren (1991) also asks his subjects a question about multiple plays but phrases the question rather differently. "What is the minimum number of repetitions of the game described in the previous problem [that you would be willing to accept]? Five or less; 10 or less (but more than 5); more than 10; never." (The phrase in brackets does not appear but was implied.) Only 26 percent of the subjects answered never, implying a strong preference for even a small number of repetitions.

3. Preferences for Repeated Gambles (Study 2)

We now turn to a more general investigation of the preferences for repeated gambles. Consider a gamble that is described as N independent trials of a particular bet. On each trial there is a chance p of winning x and a chance $1-p$ of losing y . How will an individual evaluate this bet? Of course, a rational expected utility maximizer conversant with the binomial distribution will simply compute the expected utility of the distribution of possible outcomes and accept the gamble if it has positive expected utility. However, there are many ways for an actual human decision maker to diverge from this rational norm. First, the subject may not be capable of estimating the distribution of outcomes and may concentrate on the features of the individual bets, i.e., the probability of winning, p , and the amounts to win and lose, x and y .⁹ A loss-averse bettor might pay special attention to y . Second, if some intuitive attempt at guessing the distribution of possible outcomes is made, this estimated distribution might differ from the actual distribution. For example, Kahneman and Tversky (1972) found that intuitive estimates of frequency distributions often give little or no weight to sample size. Notice that this mistake is precisely the opposite one that Samuelson thinks his colleague made. These subjects do not think that the variance is falling as N increases; they believe that it grows faster than N ! This behavior is consistent with the choices we observed in study 1.

We examine how subjects view repeated gambles by giving them real choices between a certain amount and multiple plays of a gamble. To investigate the role of myopic loss aversion, we constructed three gambles that had the same distribution of payoffs but different component bets. Specifically:

- (1H) Gamble High Amount to Lose: 90% chance to win \$0.10; 10% chance to lose \$0.50; played 150 times.
- (1M) Gamble Medium Amount to Lose: 50% chance to win \$0.25; 50% chance to lose \$0.15; played 120 times.

⁹ Slovic and Lichtenstein (1968) and Payne and Braurstein (1971) stress how each component of a gamble can influence risk taking.

- (1L) Gamble Low Amount to Lose: 10% chance to win \$0.75; 90% chance to lose \$0.01; played 90 times.

We also gave subjects choices between certain amounts and explicit distributions of outcomes shown visually. Finally, we asked subjects to estimate the chance of losing money by electing Gamble High Amount to Lose and about a negative expected value version of this question. We designed the experiment to investigate the following hypotheses:

1. Holding the distribution of final outcomes constant, repeated plays of a positive expected value gamble will be more attractive the higher the ratio of the amount to win to amount to lose. Accordingly, Gamble Low Amount to Lose will be more attractive than Gamble High Amount to Lose. (Since the distributions of outcomes are all the same, the null hypothesis is that all three gambles will be equally attractive relative to the certain amount.)
2. Subjects will find repeated plays of a positive expected value gamble more attractive if they are presented with the distribution of final outcomes. (Again, the rational choice null hypothesis is no effect.)
3. Subjects overestimate the probability of losing (winning) money in repeated plays of a positive (negative) expected value gamble. (The null hypothesis is that estimates will be unbiased.)

Methods

We conducted the experiment in an advanced undergraduate economics class at Cornell University. Subjects were asked to complete a questionnaire, which contained eight choice problems and two estimation problems.¹⁰ Subjects were told that 10 of the students would be selected at random and would be given the chance to play out one of the choices they made. They could take advantage of this opportunity by signing their name to the form and agreeing to pay if they lost money.¹¹ Of the 48 subjects, 39 agreed to participate with a chance to have their

¹⁰ The questionnaire is available from the authors upon request.

¹¹ The experimenter was introduced to the class as someone who pays off when subjects win and collects when subjects lose. The students were told that in the event that someone lost more than \$5 they could elect to earn money to pay off their losses by xeroxing articles in the library (at a wage of \$5 per hour.) In fact, no subject lost any

choices played out. Of these, two had to be removed because they did not answer all the questions, leaving 37 subjects playing for real money. We permitted calculators, and several subjects elected to use them.

After the forms were collected, 10 students were selected at random, and one choice problem was selected at random for each student. If they selected the certain outcome they were paid immediately. If they selected the gamble they were given a time and place to come and play out their gambles later in the week. All subjects were paid in full.

Results

The problems given to the subjects and the results of the experiment are presented in Table 2. Looking first at problems 1H - 1L, we see that the proportion of subjects electing the gamble increases as the amount to lose decreases. Only 49 percent of the subjects elected the gamble in problem 1H, in which they faced a potential loss of \$0.50 on each trial, while 64 percent of the subjects chose to gamble on Problem 1M, where the potential loss on a given trial was \$0.15, and 75 percent gambled on Problem 1L where the potential loss per trial was just a penny. (The pair-wise comparisons of the proportions selecting to gamble are the following: 1H vs. 1M has a p-value of .06, 1H vs. 1L has a p-value of .01, and 1M vs. 1L has a p-value of .30).

The importance of a potential loss in the gamble is also illustrated by Problem 6, in which subjects were given a choice between two 100 trial gambles. Gamble A offered 100 plays in which there was a 90% chance to win \$0.10 and a 10% chance to lose \$0.30. Gamble B was 100 trials in which there was a 10% chance to win \$0.50 and a 90% chance to win or lose nothing. Gamble A has a higher mean and a lower variance than Gamble B, and offers a chance of losing money of less than .00001. Nevertheless, nearly half (49%) of the subjects chose B, presumably because its single trials do not have any chance of a loss. This behavior characterizes myopic loss aversion.

[Insert Table 2 About Here]

money.

Comparing the results of the repeated trial format (Problems 1H-1L) with those of the distributional format (Problem 2) reveals strong evidence in support of Hypothesis 2. Between 49 and 75 percent of the subjects elected the gamble in the first three cases, while 97 percent chose to gamble when presented with the distribution. (The pair-wise comparison of problem 2 with any of the first three problems is significant at the .01 level). However, there is a possible objection to this result. The distribution presented in Problem 2 is not exactly the distribution that would obtain from the gambles because very unlikely outcomes in both tails have been truncated. Perhaps subjects are concerned about the very small chance of losing more than a trivial amount of money. To control for this possibility, we also gave the subjects Problem 3, presented in distribution format. The distribution used in Problem 3 is the same as that used in Problem 2 except that the left tail is fatter, and the expected value is slightly lower. The distribution was altered such that it is strictly worse than the true distribution generated by Problem 1M. The results indicate that few of the subjects were sensitive to the small probabilities of losing money (.001 chance of losing \$3 and .00001 chance of losing \$18). Five subjects changed their choice, compared to Problem 2--four switched from the gamble to the certain amount, and one switched the other way. Still, 90 percent of the subjects elected the gamble. (The pair-wise comparison of Problem 2 vs. 3 has a p-value of .20.)

Problems 1-3 are, by most standards, small stakes gambles. A reasonable question to ask is whether the pattern we observe would change if the stakes were raised. To test for this possibility, Problems 4 and 5 were derived from Problems 1M and 2 by multiplying the stakes by 10. This change in stakes tended to make the subjects less willing to gamble in both formats, but the pattern of choices was virtually the same. Even at these high stakes, 95 percent of the subjects chose to gamble when given the distribution, while only 54 percent gamble in the repeated gamble format.

Estimation Problems

Since subjects in the choice problems gave different answers when presented with the distribution of outcomes, it is likely that their subjective distributions do not match the objective

distributions. We presented two estimation problems designed to investigate this issue. The first problem used the same gamble that had been used in Choice Problem 1H: a 90% chance to win \$0.10 and a 10% chance to lose \$0.50, repeated 150 times. Subjects were asked, "What do you think is the probability of losing money after all 150 trials? Please indicate a probability between 0 and 1." The subjects were also given the mirror image of this problem, namely a 90% chance to lose \$0.10 and a 10% chance to win \$0.50. Here they were asked to estimate the probability of being ahead after all 150 trials. The correct answer to both problems is .003, but our subjects thought both outcomes were much more likely. For Problem 1, the average estimate was .24 while for Problem 2 it was .29. Panel B of Table 2 reveals some other information about the estimates. For both problems, 81 percent of the subjects overestimated the probability. These results are fully consistent with Kahneman and Tversky's "Law of Small Numbers." Subjects do not appear to give nearly enough weight to the value of the repeated trials. Note that the similarity between the responses in the two versions of the problem rules out an explanation of the results based on pessimism.

Discussion

Why is the repeated play of an attractive gamble accepted more often when displayed in a distributional format rather than a repeated trial format? Two factors seem to be present. First, as the estimation problems reveal, subjects overestimate the chance of losing. While this estimation error alone could explain the result, we believe that another cause is "narrow framing" (Kahneman and Lovallo, 1993), i.e., the tendency for the subjects to treat each gamble as a separate event rather than integrate the series of gambles into a distribution of possible outcomes. Evidence in support of this hypothesis also comes from Thaler and Johnson (1990) and from Redelmeier and Tversky (1992). The latter authors have obtained some results similar to those presented here. For example, they first asked subjects whether they would accept a gamble that offers a 50% chance to win \$2,000 and a 50% chance to lose \$500. Only 43% of the subjects accepted this (hypothetical) gamble. Then they told subjects that they could play the gamble five times, not just once. Now, 63% of the subjects accepted the gamble. They presented another

group of subjects with the exact distribution of the five-fold gamble. Eighty three percent of the subjects preferred to play the gamble. Redelmeier and Tversky concluded that "people neither fully segregate nor properly aggregate multiple prospects; instead, they respond to only few salient features of the ensemble."

4. Preferences for Repeated Investments (Study 3)

In recent years, there has been a major change in the way U.S. firms provide pension benefits to their employees. The traditional "defined benefit" (DB) plans (in which firms promise to pay a specified retirement annuity based on salary and years of service) are rapidly losing favor to "defined contribution" (DC) plans (e.g., 401(k) plans).¹² In these plans, each employee has an individual retirement account, with contributions coming from the firm, the worker, or both. Along with the obvious change in the nature of the firms' liability (from a defined benefit to a defined contribution) there has been a change in the responsibility for investing the retirement funds. In the traditional DB plans, the retirement fund is managed by the firm (usually with professional help). In the newer DC plans, the employee makes his or her own asset allocation decisions. By most accounts the employees are not doing very well at this task. In most 401(k) plans, the most popular investment vehicle (besides stock in the company--a poor choice on diversification grounds) is some kind of fixed income account, typically a guaranteed investment contract (GIC).¹³ These investments provide meager returns and (we believe) are a poor choice for young workers. Many employers agree with this assessment, but are not sure what to do about it. Study 3 applies what we have learned from studies 1 and 2 to this problem.

The conclusions from the previous studies are that individuals find the repeated play of a positive expected value gamble more attractive if they are shown the explicit distribution of

¹² Greenwich Associates (1996) report that more than 60% of the cash inflows are directed to defined contribution plans.

¹³ The Institute of Management and Administration (1995) report the following asset allocation mix for defined contribution pension plans in August 1995: company stock: 38.1%; GICs: 27.9%; equities: 16.4%; balanced: 11.2%; bonds: 2.6%; cash: 3.2%; other: 0.8%.

possible outcomes. This result suggests that workers making retirement choices might invest more of their funds in higher risk/higher return securities such as equities if they were shown the equivalent long-term distributions. In this case the multiple plays are over time. Study 3 investigates this idea.

Methods

The subjects in this experiment are recently hired (nonfaculty) staff employees at the University of Southern California. USC, like many universities, has a defined contribution pension plan: the university contributes 10% of the worker's salary into the pension plan contingent on the worker contributing 5%. The workers can choose among three investment vendors (TIAA/CREF, Fidelity, and Prudential). Each vendor offers a range of investment options. Since all the workers we interviewed have this plan, they have all had to make a decision of which vendor to choose and then how to allocate their retirement funds.

The survey included some background questions about the respondents and their retirement planning process. Only 25% of the subjects answered these questions, so we will only briefly describe the answers of those who did. Most of our respondents did not devote much time to their asset allocation decision; 58% spent an hour or less. This fact is disturbing since their asset allocation is arguably the most important financial decision of their lives, and many will never change their initial choice (see [Samuelson and Zeckhauser, 1988](#)). Most respondents read only the material provided by the vendors and did not consult with anyone other than family members. Still, most expressed confidence that they had made the right choice.

The experiment consisted of one question about asset allocation. Respondents were told to assume that they could choose between only two funds, A and B. They were then given some information about the historical returns to these funds and were asked to decide, based on this information, how much of their retirement funds they would invest in each fund. The terms Fund A and Fund B were used to avoid any association the respondents might have with particular asset categories such as stocks or bonds. However, the returns for the funds were derived from CRSP value-weighted NYSE index for stocks and Ibbotson's annual returns on five-year bonds.

The manipulation in the experiment was the manner in which the fund returns were displayed. There were three versions. In the One-Year version, we showed subjects a distribution of one-year rates of return. This was the actual distribution of historic returns in 34 increments. Each bar on the histogram represented an event that would be expected to take place about 3% of the time. Since we had 68 years of data (1926-1993), we constructed the chart by taking the average return in the worst two years for the first entry, and so forth. The chart is displayed in Panel A of Figure 1.¹⁴

[Insert Figure 1 About Here]

In the 30-Year version, we showed subjects the distribution of 30-year returns, based on the following simulation. We pick years at random from the 1926-1993 period, 30 times, with replacement. This sample creates one possible 30-year experience. Then, we compute the average annual rate of return over this 30-year period. This process is then repeated 10,000 times, each time computing an annual rate of return. These simulated 30-year experiences are now ranked from worst to best, and then combined into 50 groups, each having 2% of the outcomes. This simulation was done for both the stock fund and the bond fund. The chart is shown in Figure 1, Panel B.¹⁵

The third version also used 30-year distributions, but instead of displaying rates of return, we made calculations of the replacement rates for the final year salary. Specifically, we assume that the employee is 40 years old and plans to retire at age 70. We also assume that the university will contribute 10% of the employee salary into the retirement plan and the employee will contribute an additional 5%. To determine the appreciation (or depreciation) in the value of the retirement account over time, we pick years at random from history as we did with the 30-Year Return chart. Finally, we assume that the employee's salary will grow at 1% a year above the rate of inflation. We compute retirement income using annuity rates and display it as a

¹⁴ Note that the chart has 35 increments rather than 34, because we have added the 1994-1996 period in study 4. To conserve space, we display the most recent chart only, although the different versions are virtually identical.

¹⁵ The stimuli are available from the authors upon request.

percentage of the employee's final salary before retirement.¹⁶ As we did in the 30-Year chart, we combine the results of 10,000 simulations into 50 groups, each representing 2% of the outcomes. This chart is shown in Figure 1, Panel C. It is interesting that investing exclusively in the bond fund offers no chance that the pension income will exceed the employee's final year salary. In contrast, the likelihood of the stock fund providing retirement income in excess of the final salary is above 50 percent.

Based on myopic loss aversion and the results so far, we predict that subjects viewing the One-Year chart will invest less in stocks than subjects viewing either of the 30-Year charts. The reason is that the One-Year chart accentuates the perceived risk of investing in stocks. Over a one-year period, for example, the likelihood of stocks underperforming bonds is about a third, whereas over a 30-year period the likelihood is about 5%. However, we do not make a prediction as to the difference between the two long-term charts. That difference depends on how subjects convert long-term returns into retirement income.

Results

The results of the experiment are shown in Table 3. There is a pronounced difference in allocation between the group that saw the annual returns and the other groups who saw one of the longer term charts. The mean allocation to stocks for those who saw the one-year returns is only 41%, whereas the mean allocation to stocks for the longer term displays varies between 75% and 82%. The difference between the short-term version and the two long-term versions is significant at the 0.001 level using an ANOVA test.

[Insert Table 3 About Here]

The difference in allocation between the one-year display and the long-term displays is even bigger if we focus on the medians rather than the means. The median allocation to stocks is 40% for those who viewed the one-year chart and 90% for those who viewed the long-term charts. Again, the difference is statistically significant at the 0.0001 level (Kruskal-Wallis test).

¹⁶ We did not include income from Social Security or any other savings the employee has, since we did not have that information available.

There is no significant difference between the two long-term versions ($p=0.80$, t-test). Those who saw the 30-year returns allocated 82% to stocks. Similarly, those who were presented with the retirement income chart allocated 75% to stocks. Thus, converting the 30-year returns into retirement income did not significantly alter asset allocations.

Discussion

The results indicate that the way in which information is provided to individuals may have a strong influence on their investment choices. We find that aggregating one-year returns into 30-year equivalents increases the attractiveness of stocks. We provide sensitivity analysis in the next section.

5. Retirement Investing Sensitivity Analysis (Study 4)

A possible objection to the results of study 3 is that very negative outcomes are actually not displayed. The worst outcome we show represents the bottom 2% of the distributions. Perhaps investors are worried about very small probabilities of very low equity returns. The first goal of this section is to examine whether the results are robust to this possibility.

Another question of interest is whether the effect of the different displays would diminish if the equity premium were lower. In the historic data we use, there is a very large difference (roughly 6% per year) between the returns on stocks and bonds; in fact, it is so large it has been dubbed the equity premium puzzle by [Mehra and Prescott \(1985\)](#). Many observers (e.g., [Blanchard, 1993](#); [Campbell and Shiller, 1998](#)) think that it is unrealistic to think that the equity premium will remain this large in the future. We therefore replicate the results in study 3 with additional stimuli in which the equity premium is assumed to be half the rate that has been observed in the past. These allow us to see whether the long-term returns will always make stocks look better or whether that depends on a large equity premium.

A final question is whether the results from study 3, which used nonfaculty staff members as subjects, would be different if we used a more sophisticated group of subjects. Therefore, this study uses faculty members as the subjects.

Methods

The subjects in this experiment are faculty at the eight campuses of the University of California. UC, like some other public universities, has both a defined benefit and a defined contribution plan. The defined benefit pension plan guarantees the worker a retirement income based on the number of years he or she worked for the university and preretirement income. There is also a mandatory defined contribution plan in which workers are required to contribute about 3% of their salaries into the plan. The workers are offered several investment vendors and a wide range of investment options. We survey workers about this portion of their retirement plan.

We employ the same between-subject procedures as in study 3. In this study, subjects saw one of seven different stimuli. The first three simply replicated the stimuli used in study 3 except that the data used were updated to include two additional years (in order to be current). The charts look virtually identical. We also added a fourth condition in which we have artificially inflated the left tail of the distribution of 30-year returns to ensure that the preference for stocks found when subjects look at the 30-year version is not due to the truncation of the left tail of the distribution. In this chart, the outcome labeled as the worst 2% actually reflects the worst scenario out of 10,000 repetitions. We will refer to this distribution as the “Thirty-Year Returns with a Fat Left Tail.” (See Panel D of Figure 1.)

The final three stimuli replace our original three charts with new ones in which the equity premium was reduced from 6% to 3%. Specifically, the annual rates of return on stocks were each reduced by three percentage points. This 3% equity premium is consistent with the expectations of pension fund managers surveyed by Greenwich Associates (1996). We use this “half equity premium” assumption for the One-Year Returns, 30-Year Returns, and Retirement Income. (See Figure 2.) In total, we have seven conditions: four using the historic equity premium and three using half the historic equity premium.

[Insert Figure 2 About Here]

Results

The results of the experiment are shown in Table 4. In Panel A, we used the historic equity premium to generate the return distributions. As in study 3 done at USC, there is a pronounced difference in allocation between the group that saw the annual returns and the other groups who saw one of the longer term charts. The mean allocation to stocks for the UC faculty who saw the one-year returns is only 63%, whereas the mean allocation to stocks for the longer term displays varies between 81% and 83%. The 20% difference between the short-term version and the three long-term versions is significant at the 0.001 level. The primary difference between these results and those of study 3 is that the USC staff were only willing to invest 41% of their money in stocks when shown the one-year chart, as opposed to the 63% here. This difference may be attributable to the greater level of education (and possibly financial sophistication) in the UC faculty sample.¹⁷

[Insert Table 4 About Here]

The reactions to the three different versions of the long-term charts were virtually identical ($p=0.97$, ANOVA test). The average allocation to stocks of those UC faculty who saw 30-year returns was 83%; 81% for those who saw the retirement income chart and also 81% for those who saw the 30-year chart with the fat left tail. Therefore, the shift toward stocks cannot be attributed to the truncation of the left tail in the original version.

The results using half the historic equity premium are presented in Panel B of Table 4. When the equity premium is reduced to 3% there are no longer significant differences among the allocations. The mean allocation to stocks for those who saw the one-year returns, 30-year returns, and retirement income are 63%, 62%, and 69%, respectively; the medians are all 70%. ANOVA and Kruskal-Wallis tests confirm that the differences across the three groups are insignificant at the 0.10 level. A careful look at the 30-year chart reveals why this might happen. Once the equity premium is reduced to 3%, stocks no longer appear to have a compelling

¹⁷ Demographic differences may also explain the results. We do not have demographic information to examine this possibility.

advantage. In particular, the percentage of outcomes in which stocks outperform bonds is roughly the same in the one-year and 30-year versions.

Discussion

The evidence in this section confirms our primary USC results: the way in which information is provided to individuals can have a strong influence on their investment choices. Using the historic equity premium, we find that aggregating one-year returns into 30-year equivalents increases the attractiveness of stocks, even when the risks of a very bad stock returns are greatly exaggerated. An interesting question, then, is how individuals actually allocate their retirement accounts. Do they behave as if they were presented with one-year returns or 30-year returns? Recall that UC faculty who saw the one-year returns allocated 63% to stocks, and those who saw the 30-year returns allocated 81% to stocks. Interestingly, these same respondents report that they allocate 66% of their actual retirement portfolio to stocks, which is quite similar to what they choose in the one-year version of the experiment. This finding is consistent with the fact that faculty are provided with short-term performance reports. In a newsletter called “Notice,” for example, the faculty are presented with the performance of the different investment options over the last month and the last year only.

The framing effect disappears, however, if the equity premium is cut in half. This result suggests that if the expected equity premium were in this neighborhood it would not matter which kind of information investors were given; they would allocate their retirement funds the same way. In some sense, the 3% equity premium represents a “framing equilibrium”; when the equity premium is in this range, myopia has less effect on asset allocation than when the differential is as large as it has been over the past 70 years.

6. Conclusions

This article is our second paper on myopic loss aversion. In the first one, we used the concept to try to “explain” the equity premium puzzle. We did so by estimating what time horizon loss-averse investors would have to have to make them indifferent between stocks and

bonds. The answer was one year. In that paper we did not actually "test" our explanation other than by asking whether this time horizon seemed plausible. In this paper, we have tried to put the concept to a more direct test. In study 2, we constructed three repeated gambles that are virtually identical from a normative perspective but that differ in terms of the magnitude of single trial losses. Consistent with myopic loss aversion, subjects found the gambles more attractive as the single trial loss was reduced. We also showed that this aversion to short-term losses can be overcome by providing the subjects with the explicit distribution of potential outcomes. In both studies 1 and 2, many more subjects were willing to accept a gamble when it was described in terms of its distribution of outcomes than in terms of N repetitions of gamble x. We used this finding in studies 3 and 4 to examine asset allocation. There we found that subjects were willing to invest up to 90% of their retirement funds in stocks when they were shown distributions of long-run returns. Again this finding is consistent with our theoretical predictions.

Our findings are consistent with many others (e.g., [Russo, 1977](#); Kahneman and Tversky, 1984) that the way information is provided can have a strong influence on choice. The findings are particularly important (and troubling) in the practical domain we have investigated, asset allocation in pension plans. In defined contribution pension plans, employers are required to give information about the investment alternatives to the participants but are forbidden from offering advice about which investments to choose. Our research shows that this combination of rules may be difficult to follow in practice since the manner in which the information is provided will influence the choices the employees make.

There is also a more general implication of this research. Myopic loss aversion is a particular example of what Kahneman and Lovallo (1993) have called "narrow framing" (i.e., thinking about gambles or investments one at a time rather than aggregating them into a portfolio). In discussing decision making within an organization, they argue, much as we do, that "overly cautious attitudes to risk result from a failure to appreciate the effects of statistical aggregation..." (p. 17). Our research suggests that decision makers can be helped to appreciate

the effects of statistical aggregation by doing the aggregation for them and then plotting the results.

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Table 1 (Study 1)**Willingness to Accept the "Samuelson Bet"**

Version	Subjects					
	USC Undergraduate Business Students (N=36)	Visitors to a Coffee Shop in Westwood (N=62)	Evening MBAs at the University of Chicago (N=65)			
<i>Panel A: Percent of Subjects Willing to Accept the "Samuelson Bet"</i>						
One bet	77	66	64			
Repeated plays of the bet (100 times)	50	43	75			
The explicit distribution of the repeated plays	83	90	86			
<i>Panel B: P-Values for Pair-wise Comparisons of the Willingness to Bet</i>						
One bet versus repeated plays	0.0162	0.0071	0.1088			
One bet versus the explicit dist.	0.0002	0.0003	0.0006			
Repeated plays versus the explicit distribution	0.5347	0.0001	0.0337			
<i>Panel C: Number of Subjects Electing the Following Combination of Choices</i>						
Pattern	One bet	Repeated plays	Explicit dist.			
(1)	Accept	Accept	Accept	14	19	35
(2)	Accept	Accept	Reject	0	1	1
(3)	Accept	Reject	Accept	10	20	5
(4)	Accept	Reject	Reject	4	1	1
(5)	Reject	Accept	Accept	4	7	12
(6)	Reject	Accept	Reject	0	0	1
(7)	Reject	Reject	Accept	2	10	4
(8)	Reject	Reject	Reject	2	4	6

Table 2 (Study 2)
Willingness to Accept Repeated Gambles

Panel A: Choice Problems (N=39)

<i>Choice problem</i>	<i>Probability</i>	<i>Amounts to win/lose</i>	<i>Certain amount</i>	<i>Percent choosing to gamble</i>
1. Repeated trial format, small stakes				
1H. High amount to lose (n=150 times)	.90 .10	+\$0.10 -\$0.50	\$3	49
1M. Medium amount to lose (n=120)	.50 .50	+\$0.25 -\$0.15	\$3	64
1L. Low amount to lose (n=90 times)	.10 .90	+0.75 -\$0.01	\$3	75
2. Explicit distribution format, small stakes	.01 .01 .04 .07 .12 .16 .18 .16 .12 .07 .04 .01 .01	Win \$12 Win \$11 Win \$10 Win \$9 Win \$8 Win \$7 Win \$6 Win \$5 Win \$4 Win \$3 Win \$2 Win \$1 0	\$3	97
3. Worse distribution, small stakes	.0000001 .000001 .01 .02 .06 .12 .18 .22 .18 .12 .06 .02 .01 .001 .00001	Win \$19 Win \$15 Win \$12 Win \$10.8 Win \$9.6 Win \$8.4 Win \$7.2 Win \$6 Win \$4.8 Win \$3.6 Win \$2.4 Win \$1.2 0 Lose \$3 Lose \$18	\$3	90

Table 2 (Cont.)

<i>Choice problem</i>	<i>Probability</i>	<i>Amounts to win/lose</i>	<i>Certain amount</i>	<i>Percent choosing to gamble</i>
4. Repeated trial format, large stakes	.50	+\$2.50	\$30	54
Medium amount to lose (n=120 times)	.50	-\$1.50		
5. Explicit distribution format, high stakes	.01	Win \$120	\$30	95
	.01	Win \$110		
	.04	Win \$100		
	.07	Win \$90		
	.12	Win \$80		
	.16	Win \$70		
	.18	Win \$60		
	.16	Win \$50		
	.12	Win \$40		
	.07	Win \$30		
	.04	Win \$20		
	.01	Win \$10		
	.01	0		
6. Choosing between:	.90	+\$0.10	N/A	51
Gamble A (n=100 times)	.10	-\$0.30		
AND	.10	+\$0.50	N/A	49
Gamble B (n=100 times)	.90	0		

We presented Cornell economic students with eight choice problems. In the first seven problems (1H through 5), we asked the students to choose between a certain amount and a gamble. We described the gamble as either a repeated game or an explicit distribution of possible outcomes. In the last problem (#6), we asked the students to choose between two repeated gambles. The table presents the choice problems and the percentage of subjects choosing to gamble.

Table 2 (cont.)

Panel B: Estimation Problems

1. Consider this gamble, repeated 150 times:

.9	+\$0.1
.1	-\$0.5

What is the probability of losing money after all 150 trials?

2. Consider this gamble, repeated 150 times:

.9	-\$0.1
.1	+\$0.5

What is the probability of winning money after all 150 trials?

Results (N=37)

Statistic	Question 1	Question 2
Average probability	0.237	0.286
Median probability	0.150	0.200
Percent of subjects whose predicted probability > 0.100	54%	54%
Percent of subjects whose predicted probability = 0.100	16%	19%
Percent of subjects whose predicted probability < 0.100	30%	27%
Percent of subjects whose predicted probability > 0.003	81%	81%
Percent of subjects whose predicted probability = 0.003	0	0
Percent of subjects whose predicted probability < 0.003	19%	19%

We asked Cornell economic students to estimate certain probabilities as indicated in questions 1 and 2 above. The correct answer to both questions is 0.003.

Table 3 (Study 3)

Percent Allocated to Stocks by USC Staff Employees

Information provided to the subjects	N	Median	Mean
One-year returns	25	40	41
Thirty-year returns	25	90	82
Retirement income	25	90	75
P-values comparing the mean (median) allocation to stocks using ANOVA (Kruskal-Wallis) tests.	75	0.001	0.001

We asked USC staff employees (nonfaculty) to allocate retirement contributions between Fund A (stocks) and Fund B (bonds), based on the performance of the two funds. We presented each employee with either historical one-year returns, simulated 30-year returns or simulated retirement income. We have assumed that the historical returns on stocks and bonds are representative of future returns. The table presents the mean and median allocation to stocks under each of the conditions.

Table 4 (Study 4)

Percent Allocated to Stocks by University of California Faculty

Information provided to the subjects	N	Median	Mean
<i>Panel A: Using the Historic Equity Premium</i>			
One-year returns	32	65	63
Thirty-year returns	26	92	83
Thirty-year returns with a fat left tail	30	87	81
Retirement income	15	100	81
P-values comparing the mean (median) allocation to stocks using ANOVA (Kruskal-Wallis) tests.	103	0.006	0.005
<i>Panel B: Using Half the Historic Premium</i>			
One-year returns	33	70	63
Thirty-year returns	32	70	69
Retirement income	19	70	62
P-values comparing the mean (median) allocation to stocks using ANOVA (Kruskal-Wallis) tests.	84	0.470	0.462

We asked University of California faculty to allocate retirement contributions between Fund A (stocks) and Fund B (bonds), based on the performance of the two funds. We presented each employee with either historical one-year returns, simulated 30-year returns, simulated 30-year returns with the left tail of the distribution being artificially inflated or simulated retirement income. The table presents the mean and median allocation to stocks for each of the conditions. In Panel A, we have used the historical returns on stocks and bonds. In Panel B, however, we have deducted three percentage points from the historical annual rates of return on stocks to accommodate the possibility that the past returns were unusually high.

Figure 1

Charts Presented to the Subjects in Studies 3 and 4: Historic Equity Premium

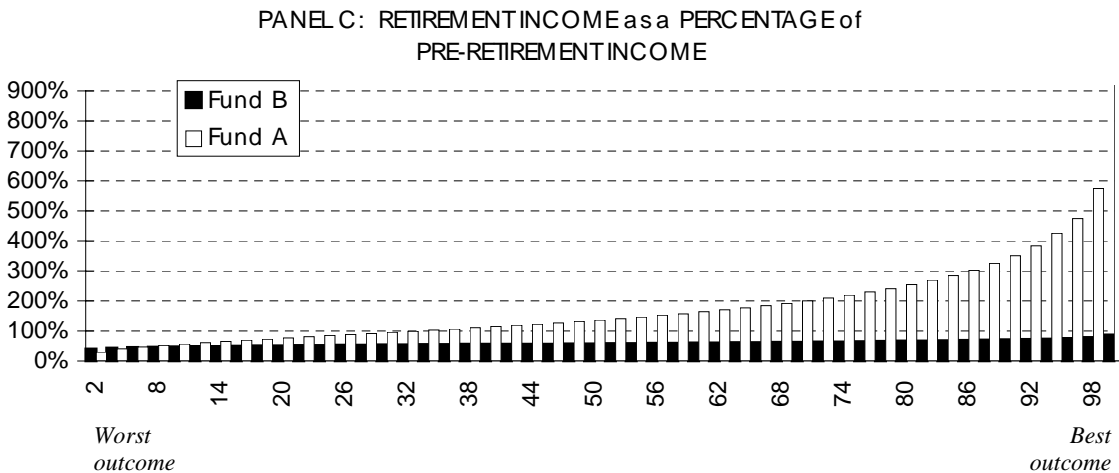
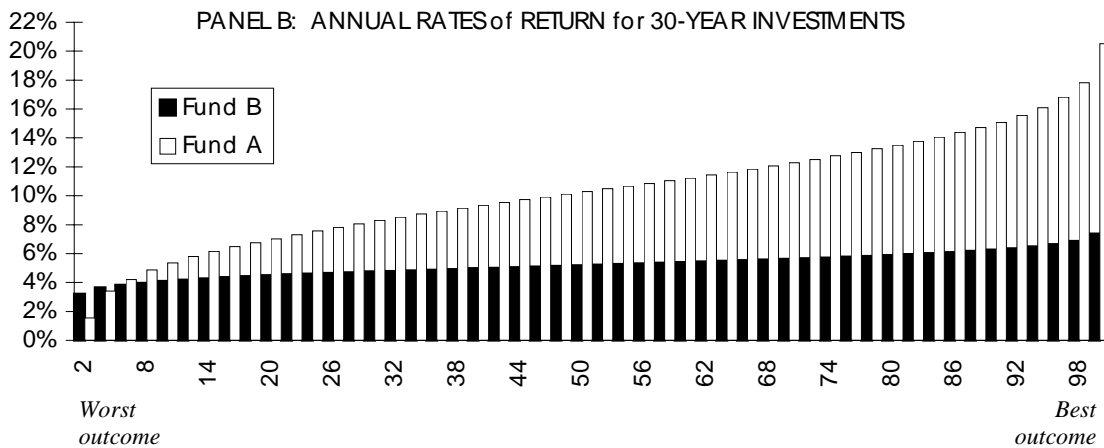
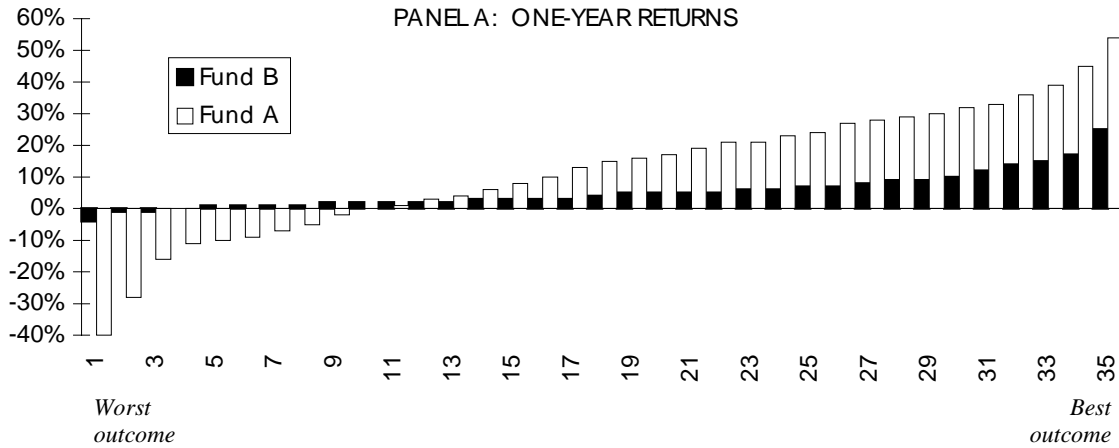


Figure 1 (Cont.)

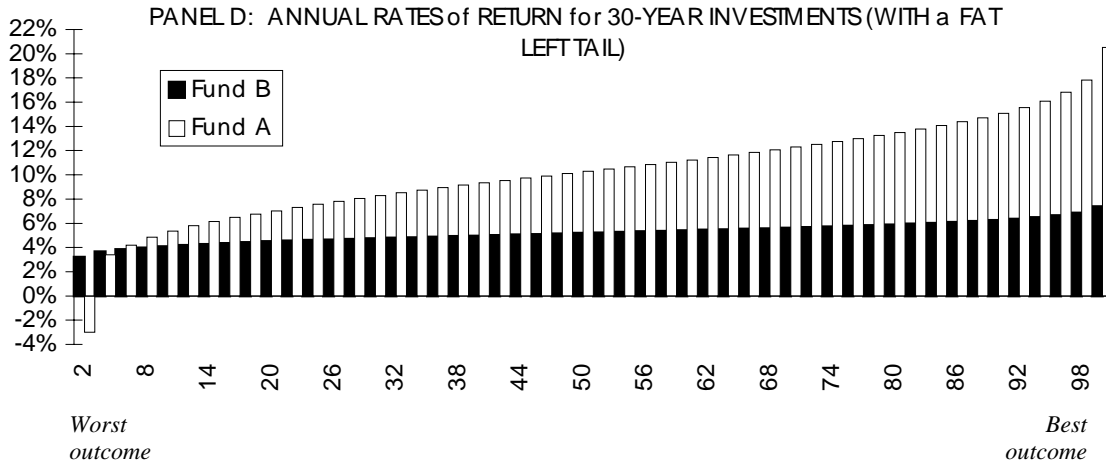


Figure 1 consists of the charts that were presented to individuals participating in the experiment. Fund A was constructed from the historical returns on the NYSE value-weighted index and Fund B was constructed from the historical returns on 5-year bonds. Thus, we have assumed that the historical returns on stocks and bonds are representative of future returns. Possible outcomes for the two funds are ranked from worst to best. In Panel A, for example, there are 35 possible outcomes; The worst outcomes (1, 2, 3...) are presented on the left, and the best outcomes are presented on the right (... 33, 34, 35).

Figure 2

Charts Presented to the Subjects in Study 4: Half the Historic Equity Premium

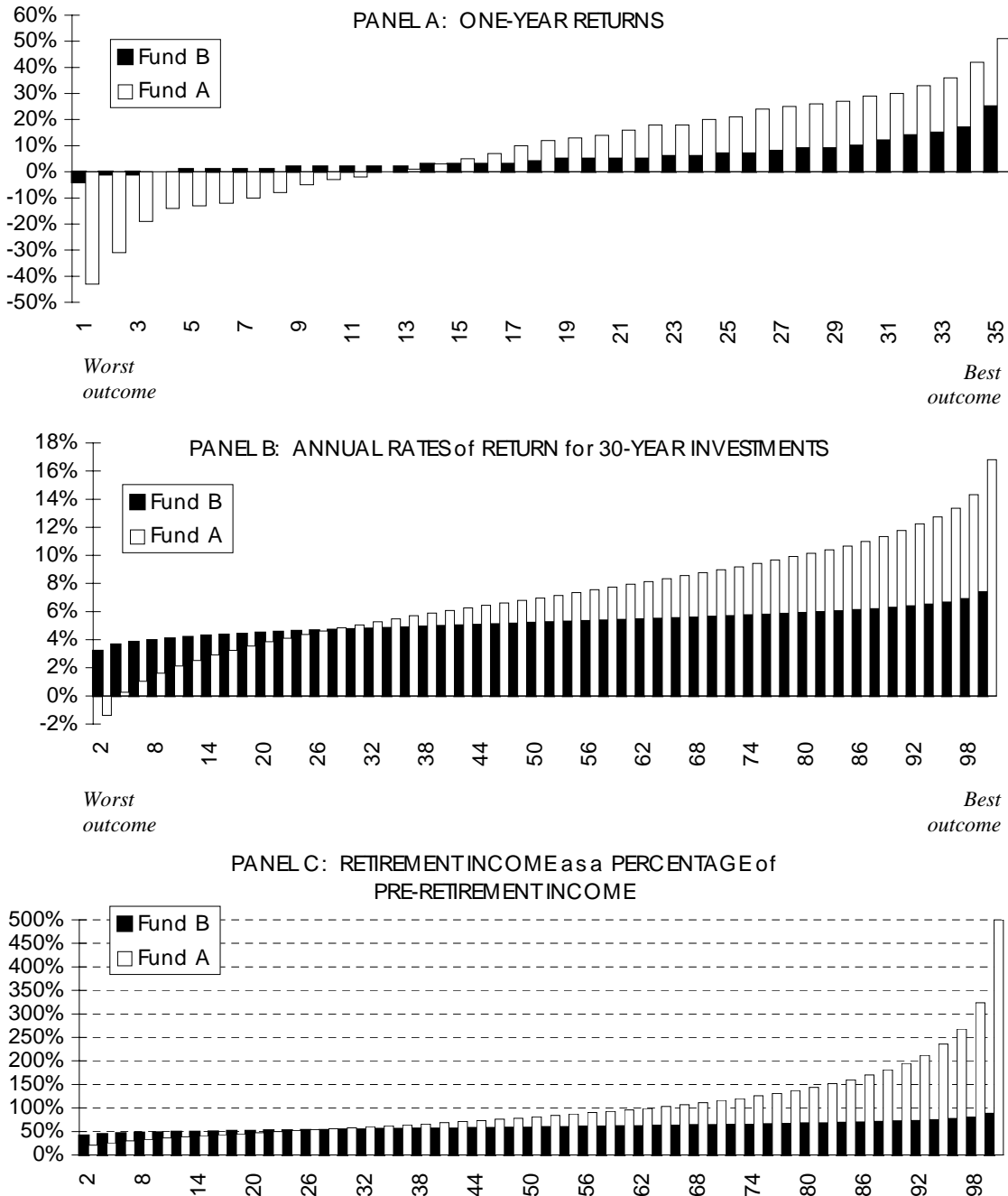


Figure 2 consists of the charts that were presented to individuals participating in the experiment. Fund A was constructed from the historical returns on the NYSE value-weighted index. To accommodate the possibility that future returns on stocks will be somewhat lower than the historical returns, we have deducted three percentage points from the historical annual rates of

return on stocks. Fund B was constructed from the historical returns on five-year bonds. Possible outcomes for the two funds are ranked from worst (on the left) to best (on the right).