



Effects of Outcome and Probabilistic Ambiguity on Managerial Choices

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Abstract

Information ambiguity is prevalent in organizations and likely influences management decisions. This study examines, given imprecise probabilities and outcomes, how managers make choices when they are provided with single-figure benchmarks. Seventy-nine MBA students completed two experiments. We found that, in a decision framed as a decision under certainty involving an ambiguous outcome, the majority of the subjects were ambiguity prone in the loss condition and switched to ambiguity aversion in the gain condition. However, in the presence of probabilistic ambiguity in a decision under risk, this expected switching pattern was shown only when the difference in riskiness between the two choice options (in the loss condition) was perceived to be relatively small. In a companion study, we used a written protocol approach to identify factors that affect decision makers' investment choices when faced with ambiguous outcomes. Protocols frequently mentioned that the ambiguous outcome option was risky, even in the case which was framed as a decision under certainty in the problem statement. In a decision under risk with ambiguous outcomes, the combination of probabilistic risk and outcome ambiguity was seen as even more risky.

Keywords: ambiguity aversion, decision frame, outcome ambiguity, probability ambiguity

JEL Classification: D81, M41

While managerial decisions involving allocation of resources are primarily based on possible outcomes and their relative likelihoods, these decisions may also be affected by any ambiguity¹ concerning these payoffs and probabilities (Curley and Yates, 1985; Kahn and Sarin, 1988). We examine in this experimental study two distinct decision frames involving ambiguity which managers may face. First, we consider a *decision under risk frame* involving ambiguous probabilities. Second, we consider a *decision under certainty² frame* with ambiguous outcomes.

For example, assessing the success probability of a new product at 40% is unambiguous, but ambiguity exists when a manager can only conclude that the success probability

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lies between 20% and 60%. In the first case, the process is precisely known, even though there is probabilistic uncertainty about which outcome will occur: there is exactly a 40% chance of success and 60% chance of failure. This is a decision under risk since "the decision maker does not know for certain what the ultimate outcomes of his choices will be" (Yates and Zukowski, 1976, p. 16), because the outcome will be the result of the probabilistic process. In the latter case, there is ambiguity about what the correct probability is, on top of the probabilistic uncertainty. So this second case is a decision under risk and ambiguity.

The study of ambiguity in decision-making has focused primarily on probabilistic ambiguity. One way to think about such probabilistic ambiguity is that we are unsure which probability distribution will be used to determine the outcome (Curley and Yates, 1985, p. 274). In a seminal study, Ellsberg (1961) demonstrated that people choosing between options with chances of positive monetary outcomes tend to choose the option with the lower probabilistic ambiguity over an identical one except with an ambiguous probability. Expected utility theory would prescribe that the two options should have equal utility. Subsequent studies, including Einhorn and Hogarth (1986) and Viscusi and Magat (1992), found ambiguity aversion. Further research has shown that people are willing to pay to avoid ambiguity (Becker and Brownson, 1964). And ambiguity avoidance was not eliminated even after subjects were presented with counterarguments and explanations of their "error" (Curley, Yates, and Abrams, 1986; Slovic and Tversky, 1974). Fox and Tversky (1995) did observe that ambiguity aversion is a contingent behavior which is produced when a comparison with less ambiguous events is involved or upon confrontation with more knowledgeable individuals. Camerer and Weber (1992) contains a comprehensive review of recent literature on ambiguity in decision making.

Managers are normally provided with a target or a benchmark to measure their performance. For instance, Gumpert (1984) pointed out that companies use benchmark targets (e.g., budgeted revenues and costs) to gauge their success. Prospect theory (Kahneman and Tversky, 1979, 1984) suggests that individuals evaluate options relative to some reference point, which might be a performance benchmark. Assuming that higher outcomes are better, outcomes below the reference point are framed in prospect theory as losses, while outcomes above the reference point are framed as gains. According to the notion of loss aversion, losses are more aversive than equivalent gains are attractive.

Most prior studies involving either gain or loss conditions have shown that people tend to avoid ambiguity. In this study, we demonstrate that ambiguity aversion is a contingent behavior and that there are instances in which people are ambiguity prone. Viscusi and Cheson (1999) examined the reversal in attitudes toward ambiguity as the mean risk rises and used "fear" and "hope" effects to account for ambiguity-averse and ambiguity-seeking behaviors contingent on risk level. More specifically, when ambiguity generates a 'fear' effect (i.e., offering a small chance of a significant loss), people are inclined to be ambiguity averse. However, when ambiguity generates a "hope" effect (i.e., offering a chance of avoiding a very likely adverse event), people tend to be ambiguity seeking.

Outcome ambiguity is also prevalent in managerial settings and may influence management decisions. For example, when making decisions, managers may receive an imprecise outcome (e.g., the estimated return on investment of a project lies between 14% and

20%). Managers routinely predict and evaluate figures for cost and revenue outcomes on a regular basis and their performance reviews are normally based on budgeted outcome figures and are not concerned with probabilities. It is important to examine ambiguity framed in terms of outcomes, since managers generally do not use precise probability estimates very much and may tend to avoid probabilities whenever possible (March and Shapira, 1987, p. 1411).

This study extends prior experimental research by examining differences in decision makers' choices when facing either imprecise outcomes or imprecise probabilities in managerial decision contexts involving either gains or losses with respect to a target level. Our results show that managers exhibit somewhat different choice behaviors in the presence of probabilistic and outcome ambiguities. Since there has been little work on characterizing outcome ambiguity decision processes, we conducted an additional study using a written protocol approach to identify factors being considered when faced with outcome ambiguity in decisions framed as being under certainty or risk.

1. Theoretical issues and hypothesis development

1.1. Ambiguity and judgment processes

Most theoretical work in decision theory on ambiguity has focused on modeling the effect of ambiguous probabilities on choice or judgment.³ Ambiguity is sometimes conceived as adding a "second order" probability distribution on top of the probabilistic uncertainty in a decision under risk. In such a case, people may reason in a way analogous to how they face an unambiguous decision under risk involving possible gains, by mentally paying an ambiguity aversion premium to avoid ambiguity, like they might pay a risk premium to avoid risk. In contrast, when outcomes are ambiguous, people may or may not think of such ambiguity as consisting of a probability distribution over possible outcomes. We aim to explore how people think about probabilistic and outcome ambiguity when making managerial choices. We first present a prototypical model by Einhorn and Hogarth which incorporates ambiguity. Then we divide our discussion, first addressing probabilistic ambiguity then outcome ambiguity.

Einhorn and Hogarth (1985) proposed a model of belief revision that includes an effect of probabilistic ambiguity. An anchoring and adjustment process is proposed in which an initial probability estimate, provided by others or available from memory, is adjusted to reflect existing probabilistic ambiguity via a mental simulation process. When there is little ambiguity about the probability of the event, the initial estimate is weighted heavily, serving as a strong anchor. When there is much ambiguity about the probability of the event, there is less weight on the a priori estimate and more weight on the mental simulation process. This process could include imagining other values the probability could take, both below and above the anchor. In the model, the amount of ambiguity perceived in the situation determines the weight on the a priori probability versus the mental simulation. The individual's attitude toward ambiguity affects the degree of adjustment in probability attained from the mental simulation. Furthermore, Hogarth (1989) pointed

out that for outcomes in the gains domain, more weight is given to possible values of the probability below the anchor as payoffs increase. For outcomes in the loss domain, the larger the stakes, the greater the weight given to values above the anchor. Thus, the model suggests that decision makers' judgments under ambiguity may be "domain-contingent," since judgments and subsequent choices may depend on whether the outcomes are in the gain or loss domain.

1.2. Probabilistic ambiguity and gains versus losses

In making decisions, managers usually compare expected performance (e.g., return on a contemplated investment) with a target aspiration level. When the expected performance is below the benchmark, the situation can be viewed as a loss, whereas the situation can be viewed as a gain when the expected performance exceeds the benchmark. Kahneman and Tversky (1979) and follow-up research by others have shown that the prospect theory model can describe people's decision making in a gain or loss situation better than expected utility theory can. Prospect theory incorporates a value function over outcomes: an S-shaped function with concavity in a gain situation and convexity in a loss situation. This, in conjunction with prospect theory's probability weighting function, implies that people tend to be risk averse when they might have something to gain and to be risk prone when they might have something to lose. Findings from field studies also reveal that managers take fewer risks when things are going well and more risks when they are not (e.g., MacCrimmon and Wehrung, 1986). Although the probability weighting function of the prospect theory model deals with unambiguous probabilities, Kahneman and Tversky point out that such probabilistic decision weights may be affected by ambiguity (p. 289).

Differences in choices of ambiguous options resulting in gains or losses have been investigated empirically through the use of gambles (Cohen, Jeffrey, and Said, 1985; Einhorn and Hogarth, 1986; Hogarth and Einhorn, 1990). In these studies, each subject responded to both a gain and a loss condition. The results indicate the subjects were generally ambiguity averse under both types of gambles. However, in a consumer choice context, Kahn and Sarin (1988) found that their subjects generally avoided ambiguity (were ambiguity averse) in the gains domain and were ambiguity prone in the loss domain. They presented a model that can predict such patterns in the face of probabilistic ambiguity. This is consistent with the "fear" effect suggested by Viscusi and Chesson (1999) and the notion of loss aversion that losses appear psychologically bigger and, thus, more aversive and painful than equivalent gains. Prior studies using both field and laboratory approaches indicate that the primary focus of managers who generally perform above a given target is on avoiding actions that might place the manager below the target (Ho and Vera-Munoz, 2001; MacCrimmon and Wehrung, 1986; March and Shapira, 1987). In other words, the dangers of falling below the target are more salient to managers in a gain condition and, therefore, potential losses dominate their attention when they make decisions on behalf of their organizations.

Analogously, when faced with a possible loss condition and with an imprecise probability, a manager may try to reach the target despite the risks inherent in this ambiguous

situation. Suppose a manager is given two relatively unfavorable options which differ only in whether the probability of meeting the target is a precise probability p or is a range of probabilities constructed as $p \pm \Delta$, with p as the midpoint. In such a case, people will likely consider the ambiguous option with the range of probabilities to be their best opportunity to meet the target. This is similar to the "hope" effect suggested by Viscusi and Chesson (1999). Conversely, when performance is above the target, decision makers may focus primarily on avoiding choices that might jeopardize meeting their target (Bell, 1982; Frisch and Baron, 1988). That is, the "fear" effect is more evident in the gain condition, which may lead managers to exhibit ambiguity-averse behavior.⁴ Therefore, the following hypothesis is proposed:

Domain-contingent *probabilistic* ambiguity preference hypothesis: More decision makers will prefer the ambiguous option with *an imprecise probability*, $p \pm \Delta$, of meeting the target over its corresponding unambiguous option (with probability p of meeting the target equal to the midpoint of the imprecise probability) in an expected loss condition than in an expected gain situation. (We assume $p > .30$, i.e., p is not a small probability.)

Figure 1 characterizes the types of questions in the first two experiments conducted in this study. Looking at the probabilistic ambiguity experiment, we examined individual ambiguity behaviors in a decision under risk condition in which options involved either an ambiguous probability or a unambiguous probability of falling below (or above) the target outcome.

1.3. Outcome ambiguity and gains versus losses

We have considered the case of ambiguous information expressed as a range of probability estimates, and now consider the case of ambiguity expressed as a range of outcome values, such as imprecise monetary profits or costs. An ambiguous outcome has a range of projected or actual results. We will examine outcome ambiguity framed within a decision under certainty in the second experiment and under certainty and risk in the written protocol experiment.

There are two main ways of thinking about outcome ambiguity. In this section we primarily focus on the first way, which considers the range of outcomes without explicitly invoking probabilistic reasoning. The second way is to portray outcome ambiguity as an unknown probability distribution over the potential range of outcomes $m \pm \Delta$. Camerer and Weber (1992, p. 331–332) take this position, and thus argue that outcome ambiguity is not really a separate concept from a) ambiguity about probabilities (if there is more than one possible probability distribution over the range $m \pm \Delta$ of the outcomes) or just b) decision making under risk (if there is a single probability distribution over the outcome range). Following their reasoning, in the case of ambiguity about probabilities, our domain-contingent probabilistic ambiguity preference hypothesis pattern should hold for outcome ambiguity. Next consider the case of decision making under risk, with a single probability distribution over the outcome range. Then, the predominant choice pattern

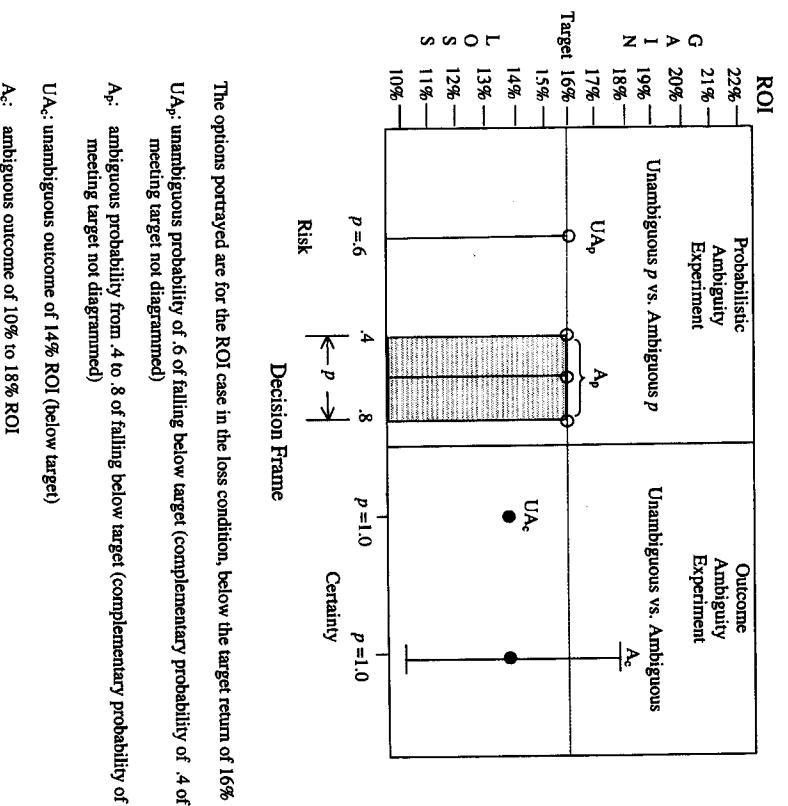


Figure 1. Characterization of probabilistic and outcome ambiguity.

predicted by prospect theory would apply, due to the S-shaped value function and the probability weighting function, assuming the probability distribution over the outcome range is uniform or bell shaped, for example, with the expected value of the "ambiguous" option equal to the unambiguous outcome m . This pattern is also domain-contingent: risk aversion (choice of the "unambiguous outcome" option yielding outcome m) in the gains domain and a switch to risk proneness (choice of the "ambiguous outcome" option yielding an outcome in the range $m \pm \Delta$) in the loss domain.

However, since it is possible that managers will treat a decision framed as under certainty with a vague outcome differently from an unknown probability distribution over outcomes, we now examine outcome ambiguity separately from probabilistic ambiguity. Consider a situation in which the company-required target return for all projects is 16%. Managers have to choose between an option with a precise outcome of an 18% return, just above the target, and the other option with an ambiguous outcome ranging from a 12% to 24% (18% \pm 6%) return. Suppose the manager mentally simulates the experience of having chosen one option or the other. This process involves imagining what the

experience would feel like, but does not require probabilistic thinking. Prospect theory's S-shaped value function portrays outcomes in the loss domain as having a steeper slope for the value function than do outcomes in the gains domain. It is especially steep near the target reference level. (This feature of the model thus portrays "loss aversion.") In this case, the extra 6% at the upper end of the range is in the gains domain (above the target) and it will be more than offset in a mental simulation by the lower end of the range that goes down 6% and enters into the loss domain (below the target of 16%). Thus, when comparing an unambiguous gain with a corresponding ambiguous option, ambiguity generates a "fear" effect (i.e., focusing on the feared outcome of failing to make the target return) and managers are inclined to be ambiguity averse.

In contrast, suppose managers are asked to choose between an option with the outcome of a precise 14% return, below the target, and the other option with an ambiguous outcome ranging from 8 to 20% (14% \pm 6%) return. Since the value function is steepest just below the target reference level, there is a large increase in value as we move from below the target to above the target. In this case, in a mental simulation, the extra 6% at the upper end of the range that reaches into the gains domain will offset the part of the range that goes down 6% in the loss domain. Thus, in this case, when comparing an unambiguous loss with a corresponding ambiguous option, ambiguity generates a "hope" effect (i.e., offering a chance of meeting the target) and managers tend to be ambiguity seeking. The notion of a mental simulation (which considers loss aversion) and imagines different outcomes does not rely on explicit consideration of probabilities of outcomes, although it can also occur in decisions under risk. Prior research shows that loss aversion affects decision making in riskless and risky contexts (Lopes, 1987; March and Shapira, 1987; Payne, Laughunn, and Crum, 1980; Taylor, 1991; Zeckhauser, Patel, and Hendricks, 1991).

Thus, both ways of thinking about ambiguous outcomes (as an unspecified probability distribution over outcomes or a mental simulation over riskless outcomes) lead to the following hypothesis:

Domain-contingent *outcome* ambiguity preference hypothesis: More decision makers will prefer the ambiguous option with an *imprecise numerical outcome*, $m \pm \Delta$, over an unambiguous option (with outcome m equal to the midpoint of the imprecise numerical outcome) in a loss condition than in a gain situation.

Some prior studies of outcome ambiguity examined outcomes which were gains or losses. In the gain condition, Gonzalez-Vallejo, Bonazzi, and Shapiro (1996) examined the effects of imprecise probabilities and imprecise numerical outcomes on choices. Undergraduates were presented with a set of positively valued gambles and then were asked to choose among all possible pairs of gambles. They found that subjects tended to avoid ambiguity in both probability and outcome conditions. That is, in a gain condition such as when expected performance of the unambiguous option is above the target, decision makers may consider the unambiguous option favorably and avoid ambiguous options that might make them fear they could jeopardize achieving the target.

A few studies have examined the effect of outcome ambiguity in the domain of losses. Oliver (1972) examined the effect of outcome ambiguity on bankers' loan deci-

sions. Half of the subjects were provided with conventional financial statements in which only point estimates were provided, and the other half were given financial statements that incorporated a range of numerical outcomes (e.g., cost of goods sold was \$1,308,100–\$1,231,900). Oliver observed that bankers were ambiguity averse. Specifically, those bankers provided with the interval condition were more reluctant to extend loans than were their counterparts who were given a single figure. Furthermore, Kunreuther and his associates have investigated the effect of ambiguity on decisions made by both actuaries and underwriters in different loss conditions (e.g., Hogarth and Kunreuther, 1989, 1992; Kunreuther, 1989; Kunreuther, Meszaros, Hogarth, and Spranca, 1995). Their results also robustly demonstrate ambiguity aversion by the price of the insurance policy being adjusted upward when ambiguity and uncertainty are present. Using environmental and health hazards cases, Kuhn and Budescu (1996) also observed consistent ambiguity avoidance behaviors across the probability and outcome conditions.

The studies discussed above suggest an ambiguity avoidance effect in both gain and loss conditions. However, the ambiguity avoidance effect observed in these loss conditions (which is opposite of our domain-contingent prediction of ambiguity proneness in the loss condition) may be because of the different contexts used and may not necessarily generalize to all loss conditions. In particular, we examine the condition when a performance target is given and managers face a choice of either having a known loss and not meeting the target (i.e., this option would result in a point estimate which was below the target) or having an imprecise option with vague information on meeting the target (i.e., the option would result in a range of values in which the minimum point is lower than the goal and the maximum point attains the goal). In this case, the decision maker's focal comparison option (Fox and Tversky, 1995) may be the unambiguous "known loss" option, and he/she may be more willing to tolerate ambiguity since the ambiguity option is the only opportunity to reach the target.

Referring to Figure 1 again, the outcome ambiguity experiment, we studied individual ambiguity behaviors in both the gain and loss conditions. In this experiment, no probability is specified with either the ambiguous or unambiguous option, but since the decision is framed as a decision under certainty, the probability is implicitly 1.0. In a third experiment, we used a written protocol approach to better understand the process by which outcome ambiguity is considered when there are no probabilities specified in a decision frame or under probabilistic risk. The questions for that experiment will be described later and portrayed in Figure 2.

2. Outcome ambiguity experiment

Thirty-nine MBA students from a large state university participated in this experiment. All were enrolled in a managerial accounting class and had completed at least one statistics course. They had an average of 3.4 years business-related work experience.⁵ When capital budgeting decisions are made within an organization, all levels of managers are included in the process. Even managers with one year of experience are expected to evaluate all proposals and recommend what they deem is best for the department. Therefore,

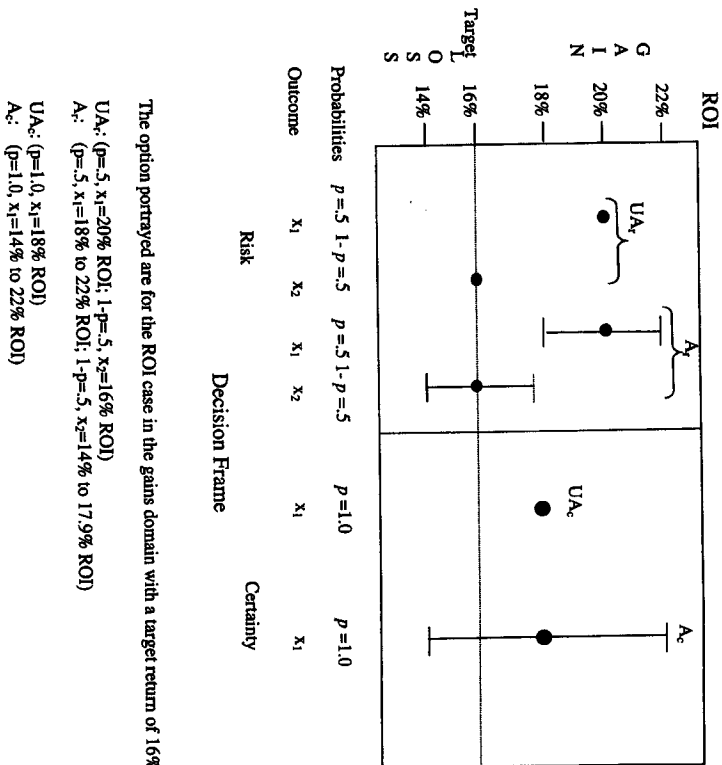


Figure 2. Characterization of written protocol experiment questions on outcome ambiguity.

MBA students with business experience are appropriate for this study. Participants were given 20 bonus points (2% of the final grade) for participating in the experiment.

2.1. Experimental design

To test for consistency of responses, the subjects were provided with two cases, the Internal Rate of Return (IRR) and Return on Investment (ROI) cases (see Appendix 1 for the loss and gain conditions of the ROI case).⁶ Each case involves a gain and a loss condition to investigate individuals' choices in decisions under certainty involving ambiguous outcomes resulting in each subject providing four responses. For example, in the ROI case, the subjects were told that, based on actual returns, the ROI for his/her division's projects is 16%. A project with an expected ROI of an unambiguous 14% provided a loss condition, and a second project with an expected ROI of an unambiguous 18% provided a gain condition. In the loss condition, the subjects were provided with two options, ambiguous and unambiguous. For example, in the ROI case, as shown in Figure 1, the *ambiguous option* is described as "With option B the staff has different

opinions and has provided a range of 10% to 18% for the ROI." The *unambiguous option* is described as "The staff agrees that undertaking option A would result in a ROI of 14%." Note that the ambiguous outcome ranges from below the benchmark to above the benchmark of 16% ROI for the division. The subjects were then asked to choose between these two options, one with an ambiguous outcome of $14\% \pm 4\%$ and the other with an unambiguous outcome of 14% (the midpoint of the range of the ambiguous outcome). The gain condition involves a structure similar to the loss condition except the precise outcome, which is also the midpoint of the imprecise outcome, was better than the benchmark.⁷ For example, in the ROI case, the *ambiguous option* is described as "With option D the staff has different opinions and has provided a range of 9% to 27% for the ROI." The *unambiguous option* is described as "The staff agrees that undertaking option C would result in a ROI of 18%."

The internal rate of return case had a similar structure, with the target IRR set at 15%, the loss condition compared option A with an IRR of 13% versus option B with an IRR of 9% to 17%. The gain condition compared option C with an IRR of 17% versus option D with an IRR of 8% to 26%.

After making choices between the two options in each condition, the subjects were asked to directly rate their perceived risk and perceived ambiguity of each of the two options on a seven-point Likert-type scale anchored at 1 ("extremely low") and 7 ("extremely high").

2.2. Procedures

The subjects completed the case materials during the last week of classes. To ascertain that the subjects understood the definitions of ambiguity and risk, a brief review was provided prior to distributing the cases, and definitions were available in the materials.⁸ After the subjects completed the cases, they were asked to indicate whether they had enjoyed participating and how much difficulty they had in responding. Responses were indicated on a seven-point scale with a maximum of "very much" or "extremely difficult" (coded 7) and a minimum of "not at all" (coded 1). The mean (standard deviation) of the "participation enjoyment" responses was 4.06 (1.48), and the "difficulty" mean (standard deviation) was 3.40 (1.41). The subjects indicated that the materials were not difficult and that they had enjoyed participating in the experiment.

2.3. Results

2.3.1. Manipulation check. Recall that subjects were asked to rate the perceived risk and ambiguity of each of the two options on a seven-point Likert-type scale. Paired comparison *t*-tests were conducted to determine if manipulating ambiguity was successful. The results of the *t*-tests show that subjects considered the "ambiguous" options more ambiguous than the "unambiguous" ones.⁹ Also, interestingly, the "ambiguous" options were perceived to be more risky than the "unambiguous" ones, even though no proba-

bilitistic uncertainty was included in either option.¹⁰ This provides a hint that subjects may be thinking of outcome ambiguity as a sort of probability distribution. This is explored more later in the written protocol experiment section.

2.3.2. Gain/loss domain-contingent effect. Recall that both the IRR and ROI cases were designed to examine how the gain/loss domain affects subjects' choices of ambiguous options. To examine whether scenario and outcome domain (gain vs. loss) influenced individuals' choices under ambiguity, logistic regression (maximum-likelihood method) was conducted with option choice (i.e., ambiguous or unambiguous option) as the dependent variable and outcome domain (gain vs. loss) and case (IRR vs. ROI) as the independent variables. Also, we included in the logistic regression as independent variables differences in each subject's perceived risk and differences in each subject's perceived ambiguity of the two options.¹¹

The results of the logistic regression reveal that the outcome domain affected their choices ($\chi^2(1) = 61.775, p < 0.000$). That is, being in either a gain or loss condition affected their choice option. No significant difference between the IRR and ROI cases existed. The overall results across the subjects are shown in Panel A of Table 1 for the Outcome Ambiguity Experiment. For both the IRR and ROI scenarios combined, 69% of the subjects selected the ambiguous option in the loss condition, and, as hypothesized, fewer (just 10%) of the subjects chose the ambiguous option in the gain condition. So, we have found our *Domain-Contingent Outcome Ambiguity Preference Hypothesis* to hold at the aggregate (between-subjects) level, which could be used in predicting patterns of managers' investment behavior or consumer choices.

Since all the subjects were asked to respond to both gain and loss conditions in the IRR and ROI cases (a within-subject design), we examined individual choice behavior across these two conditions for both cases. The four possible individual choice patterns are: "always choosing an ambiguous option (A/A)," "always choosing an unambiguous option (U/A/U)," "choosing an unambiguous option in a loss and an ambiguous option in a gain condition (U/A/A)," and "choosing an ambiguous option in a loss and an unambiguous option in a gain condition (A/U/A)." For our two scenarios, it turned out that a large number of individuals exhibited the last pattern (A/U/A)—switching their choices from the ambiguous option in the loss domain to the unambiguous option in the gains domain. Such domain-contingent switching behavior would be expected to occur frequently when options are relatively close in preference, so that just changing outcome domains is enough to lead to a switch in choice. For this experiment at the individual choice level, the box on the far right of Panel A of Table 1 shows that 62% of the subjects (in the shaded area) exhibit the ambiguity in loss domain/unambiguity in gains domain (A/U/A) choice pattern as predicted by our hypothesis when combining both IRR and ROI cases. It is also interesting to note that 28% of the subjects avoided the ambiguous options in both cases and only selected the unambiguous option (U/A/U/A): the difference between the percentage choosing A/U/A and U/A/U/A is marginally significant for the IRR case (59% vs. 31%, $z = 1.69, p < 0.091$) and significant for the ROI case (64% vs. 26%, $z = 2.37, p < 0.018$).

Table 1. Individual choice patterns under outcome and probabilistic ambiguity

Panel A. Outcome ambiguity														
IRR <i>Gain</i>					ROI <i>Gain</i>					Both IRR and ROI <i>Gain</i>				
A					A					A				
UA					UA					UA				
A					A					A				
5%					10%					7%				
59%					64%					62%				
64%					74%					69%				
Loss					Loss					Loss				
	UA					UA					UA			
	5%					0%					3%			
31%					26%					28%				
36%					26%					31%				
10%					10%					10%				
90%					90%					90%				
Panel B. Probability ambiguity														
IRR <i>Gain</i>					ROI <i>Gain</i>					Both IRR and ROI <i>Gain</i>				
A					A					A				
UA					UA					UA				
A					A					A				
33%					26%					29%				
32%					33%					33%				
65%					59%					62%				
Loss					Loss					Loss				
	UA					UA					UA			
	5%					8%					6%			
30%					33%					32%				
35%					41%					38%				
38%					34%					35%				
62%					66%					65%				

Shaded box is switching choice pattern conforming with the domain-contingent hypothesis at within-subject level.

In summary, our results at both the aggregate and the individual level support our *Domain-Contingent Outcome Ambiguity Preference Hypothesis*, since we found decision makers tend to select the option with an ambiguous outcome in a loss condition and the option with an unambiguous outcome in a gain situation.¹²

3. Probabilistic ambiguity experiment

In this experiment, we explored the effects of imprecise probabilities on managerial choices. Forty-two MBA students from the same university used in the previous Outcome Ambiguity Experiment participated in this experiment. Of the 42 responses received, two were discarded because the subjects had not completed both phases of the experiment, leaving a final sample of 40 subjects. The experimental design, procedures, and justification for using MBA students as subjects are exactly like those in the previous experiment. The only difference between these two experiments is that rather than varying the ambiguity of outcomes (in the previous experiment), we created the ambiguous options in this experiment with ambiguous probabilities, and the choice was now framed as a decision under risk.

In the ROI case, the target ROI remains 16%. In the loss condition, portrayed in Figure 1, the *ambiguous option* is described as "With option B the staff has different options. They report a 40 to 80% chance that undertaking this option could result in a ROI lower than 16%." The *unambiguous option* is described as: "The staff agrees that if you undertake option A there is a 66% probability your ROI would be lower than 16%." By design, the 60% probability is the midpoint of the range of probabilities from 60% \pm 20% in the ambiguous option. Then, the subjects were asked whether they would select the ambiguous option (with a range from a 40% to 80% chance of falling below the target) or the unambiguous option (with a 60% probability of falling below the target). Similarly, in the gain condition, the subjects were provided with two options. For example, in the ROI case, the *unambiguous option* is described as "All of the staff agree that if you select option C there is a 63% probability of increasing your current ROI of 16%." The *ambiguous option* is manipulated as "With option D the staff disagrees on the effect this will have on your current ROI. Therefore, they have provided a probability of 42% to 84% that the ROI would increase." Note that in the loss condition the focal probability is presented as the chance of a "loss," i.e., being below the target. In the gain condition, the focal probability is the chance of a "gain," i.e., being above the target.¹³

The internal rate of return case had a similar structure, with the target IRR set at 15%. The loss condition compared option A's 65% chance of decreasing the IRR (below 15%) versus option B's 45% to 85% chances of decreasing the IRR. The gain condition compared option C's 68% chance of increasing the IRR (above 15%) versus option D's 47 to 89% chance of increasing the IRR.

Similar to the previous experiment, the subjects' means (standard deviations) of the "participation enjoyment" and the "difficulty" were 4.34 (1.27) and 3.40 (1.33), respectively, suggesting that they enjoyed participating and found it not difficult.

3.1. Results

3.1.1. Manipulation check. Consistent with what has been reported in the previous experiment, the subjects perceived that the two options differed in their risk and ambiguity. The results of the paired comparison *t*-tests show that the "ambiguous" options were perceived to be more ambiguous than the "unambiguous" ones in all four conditions. Specifically, 93–97% of the subjects gave the purportedly ambiguous option a higher ambiguity rating than the purportedly unambiguous option, across the four conditions (ROI or IRR with either gain or loss). The results of the paired comparison *t*-tests show that the "ambiguous" options were perceived to be more risky than the "unambiguous" ones in the gain condition but not in the loss condition. In the loss condition, about 40 (45%) of the subjects perceived the ambiguous option as more (less) risky than that of the unambiguous option and 15% of them judged the perceived risk to be the same for the unambiguous and ambiguous options.¹⁴

3.1.2. Gain/loss domain-contingent effect. A similar logistic regression model as used in the previous experiment was employed here. The logistic regression results reveal that the subjects' choice for ambiguous options was influenced by framing the domain of outcomes as gains or losses and by their perceived risk difference ($\chi^2(1) = 29.069, p < 0.001$). That is, the larger the perceived risk difference between the ambiguous and unambiguous option was, the more likely an unambiguous option was chosen. As expected, the results show that the scenario (IRR or ROI) is not a significant factor in explaining the subjects' responses and was not included in the final regression model. Therefore, for some of the further data analysis, we combined the subjects' responses to the IRR and ROI cases. Descriptive statistics of choice behaviors at the aggregate and individual levels are shown in Panel B of Table 1. Overall, for both the IRR and ROI cases together, 62% of the subjects preferred the ambiguous options in the loss condition and, as hypothesized, fewer (only 35%) of the respondents selected the ambiguous options in the gain condition. Therefore, these results support the *Domain-Contingent Probabilistic Ambiguity Preference Hypothesis*—Options with ambiguous probabilities are chosen by more decision makers in a loss condition than in a gain situation.

We also examine what patterns of choices within an individual lead to the hypothesized aggregate behavior. As shown in Panel B of Table 1, somewhat surprisingly, for both IRR and ROI together, only 33% of the subjects exhibited the "A/U/A" switching pattern with ambiguous in the loss condition and unambiguous in the gain condition as implied by the aggregate pattern in our *Domain-Contingent Probabilistic Ambiguity Preference Hypothesis*. This switching pattern is not significantly different from those who chose "U/A/U/A" (32%), nor significantly different from those who consistently chose "A/A" (29%). Those 33% who switch from A to U/A are key to meeting our hypothesis since they are added to those who are consistent to reveal the aggregate pattern. Thus, the 62% choosing the ambiguous option in the loss condition is, as hypothesized, higher than the 35% choosing ambiguous in the gains domain. If our domain-contingent hypothesis is interpreted narrowly on an individual level that all subjects should switch from A to U/A, it only holds for the 33% who switched.

Table 2. Choices categorized by perceived difference in riskiness of options in probabilistic ambiguity experiment^a

	<i>n</i>	Consistent		Switch	
		U/A/U/A	A/A	A/U/A*	U/A/A
The "Internal Rate of Return" Case					
Low perceived risk difference	21	14%	33%	52%	0%
High perceived risk difference	19	47%	32%	11%	11%
Overall	40	30%	33%	32%	5%
The "Return on Investment" Case					
Low perceived risk difference	21	19%	24%	48%	10%
High perceived risk difference	19	47%	26%	21%	5%
Overall	40	33%	26%	33%	8%

^a *n*: Number of subjects in two subgroups (those reporting low or high perceived risk differences between options) and overall; U/A/U/A: Choose unambiguous options in both the loss and gain conditions; A/A: Choose ambiguous options in both the loss and gain conditions; U/A/A: Choose the unambiguous option in the loss condition and the ambiguous option in the gain condition; A/U/A: Choose the ambiguous option in the loss condition and the unambiguous option in the gain condition. Column with shaded background is the switching choice pattern A/U/A conforming with hypothesis, when interpreted at the within-subjects level.

We explored the responses in more depth by splitting the subjects into two groups, those for whom the difference in the perceived risk for the two options in the loss context was low and those for whom the difference was high.¹⁵ As seen in Table 2, for the IRR (ROI) case, 52% (48) of the low perceived risk difference subgroup displayed the hypothesized switching pattern of A/U/A. In contrast, for the high perceived risk difference group, the modal pattern was to choose consistently the unambiguous option in both domains, with 47% of the high risk difference subgroup choosing U/A/U/A in both the IRR and ROI cases. Perhaps when the perceived risk difference was high, the options were seen as very different. In such a case, subjects tended to select the option with the lower perceived risk, preferring the unambiguous options in both loss and gains domain contexts.

In summary, we found more subjects switching from ambiguity proneness in the loss domain to ambiguity aversion in the gains domain when they had lower differences in perceived risk between options. When the subjects had larger perceived risk differences between options, the modal pattern was ambiguity aversion. Such ambiguity aversion in gains and losses had been found in some previous studies, as described earlier.

4. Written protocol experiment on processing of ambiguous outcome information in decisions under certainty and risk

To better understand the process by which outcome ambiguity is considered in decisions under certainty and under risk, we conducted one additional experiment using a written

protocol approach. In this experiment we recruited graduating MBA students with an average of about 5 years of work experience from the same state university as in the previous two experiments. A total of 16 MBA students volunteered to participate in this experiment and each of them received a \$20 participation fee.

To probe deeper into the decision processes involved, subjects were asked to make investment choices in both gain and loss conditions, and then to write down the main factors behind their decisions. Furthermore, in each condition, subjects were asked to respond to three tasks. For example, in the gain condition, subjects were first asked to choose between an unambiguous-certain (UA_{certain} or UA_c) option (e.g., with an estimated ROI of 18%) and an ambiguous-certain (A_{certain} or A_c) option (e.g., with an estimated ROI of 14% to 22%). This task is the same context as that was used in the outcome ambiguity experiment. The purpose of using this task is to provide insights as to why people make different investment choices in the "certainty" condition in which no probability is specified. (We choose to label this as a decision under certainty frame. Subjects did not see this label.) The second task was to choose between an unambiguous-risky (UA_{risky} or UA_r) option (with a 50% probability of a ROI of 20% and a 50% probability of a ROI of 16%) and an ambiguous-risky (A_{risky} or A_r) option (e.g., with a 50% probability of the ROI between 18% and 22% and a 50% probability of the ROI between 14% and 17.9%). This task is to examine how probabilistic risk affects decision makers' choice of ambiguous/unambiguous outcome options. (This is a new task, not given in the previous experiments, to allow us to further explore the participants' thinking process.) Figure 2 graphically portrays the questions in this experiment. Note that, in comparison with Figure 1, there is no ambiguity about probabilities, allowing us to just look at ambiguous outcomes under certainty and risk. After completing the above two tasks, subjects were asked to consider the four options (i.e., UA_c , A_c , UA_r , and A_r) together and rank order their preference. One of the researchers randomly distributed one of the two versions (the gain condition presented first vs. the loss condition presented first) of the instruments to the participants and also collected the returned surveys.

4.1. Certainty condition: Choice between ambiguous-certain option A_c and unambiguous-certain option UA_c

Table 3 summarizes the choices of participants in this experiment. As seen in Table 3, the results of the first task support what was reported in the outcome ambiguity experiment: Decision makers were generally ambiguity averse, preferring the UA_c option to the A_c option in the gain condition; however, they were ambiguity prone, preferring the A_c option to the UA_c option, in the loss condition. Specifically, in the gain condition all but two subjects desired to have the UA_c option. The written comments suggest that variability, risk aversion, safety, and comfortableness played important roles when subjects make investment choices in the gain condition. The following quotes illustrate these factors.¹⁶

Table 3. Written protocol experiment participants' choices of ambiguous outcome option A or unambiguous outcome option UA under certainty and risk*

Panel A. Decision under certainty			
Loss	Gain		Loss
	A_c	UA_c	
	2	10	12 (75%)
	$S13$	$S12$ $S6$ $S7$	$S1$ $S2$ $S3$ $S4$ $S5$
UA_c	0	4	4 (25%)
	2 (12%)	14 (88%)	$S8$ $S9$ $S10$ $S11$
Panel B. Decision under risk			
Loss	Gain		Loss
	A_r	UA_r	
	2	6	8 (50%)
	$S15$ $S14$ $S16$	$S1$ $S2$ $S3$ $S4$ $S5$	
A_r			
UA_r	2	6	8 (50%)
	$S13$	$S6$ $S7$	$S8$ $S9$ $S10$ $S11$
	4 (25%)	12 (75%)	

* Subjects listed by subject number S#. When a subject is placed close to two cells' border in Panel A, responses moved across the border in the decision under risk in Panel B. Shaded cell shows hypothesized domain-contingent switching behavior at within-subject level. Subjects 1-5 showed expected domain-contingent switch in certainty and risk, subjects 6-7 only switched under certainty but not under risk.

The variability is not worth it. The marginal benefit of the increased potential is not worth the marginal risk of dropping below 16% and losing my performance evaluation and bonus.

I would pick something that is more certain even though it offers lower possible ROI. Playing safe is better in the short run.

The above quotes support the notion of loss aversion that losses are more aversive than equivalent gains are attractive. On the other hand, the two subjects ($S13$ and $S14$)

who chose the A_c option in the gain condition exhibited a clear risk-seeking behavior. Below is one of the explanations behind this choice:

Even though UA_c guarantees a better ROI, the chances are that A_c will be 18% also, but there is also the possibility that A_c could be more than 18%. Although there is the chance, since the lower bound is 14% it does not seem to be likely that it will return less than 16%.

In contrast to the gain condition, in the loss condition a large majority of subjects (12 out of 16) indicated that they preferred the A_c option to the UA_c option. The typical reason that people preferred the A_c option is that despite a high downside risk, the A_c option at least may provide an opportunity to reach the minimum required rate of return. Conversely, the UA_c option for sure will not give them a chance to reach the target. Interestingly, some subjects recognized a shift of their attitude from being risk-averse in the gain condition to being risk-seeking in the loss condition. The following quote illustrates these thoughts:

I would choose the A_c option because it is the only one that has a chance to get the 16%. Choosing option UA_c will for sure not get it, and since the average for the A_c option is the same as the ROI of the UA_c option, that is the only one that makes sense to go with.

The results also show that subjects chose the UA_c option in the loss condition if they were either risk averse or uncomfortable with ambiguity. The typical comments are as follows:

Option A_c has too much downside risk... Because option A_c has the same potential as option UA_c , I am more inclined to select the less risky option UA_c .

Option A_c is potentially far off at 10%. Option UA_c is close to the minimum and with time there is the potential for improvement in the technology and the ROI. There is limited risk—Option UA_c has "guaranteed" ROI which there is wide range in potential ROI for option A_c .

So, even though the decision frame in this certainty condition did not formally involve probabilistic risk, participants mention risk very often in their protocols. Table 4 provides greater detail on these written protocol responses.

4.2. Risky condition: Choice between ambiguous-risky option A_r and unambiguous-risky option UA_r

Similar to that of the above certainty condition, our results show that subjects in the decision under risk condition preferred the unambiguous risky option UA_r to the ambiguous option A_r in the gains domain. As shown in Table 3, 75% (12 out of 16) of the subjects chose the UA_r option. Subjects felt that ambiguity adds uncertainty and risk and hence tended to avoid the ambiguous A_r option. As seen in the following quotes, risk was the most frequently mentioned factor by these subjects:

I tried to choose the path that had the least risk associated with it.

Option UA_r gives safe choice, the least that might happen is the same 16% ROI. Option A_r gives too much variations and uncertainty.

Although a large majority of subjects chose the UA_r option in the gain condition, four subjects still indicated a preference for the A_r option. As shown in the following quotes, subjects either assumed a uniform probability distribution associated with the A_r option or were optimistic that A_r will give them a higher chance of increasing their ROI.

If one divides the 50% across the 4% between 14 and 17.9, one gets 12.5% probability for each percentage. Hence, the probability of not increasing my current return of 16% is 7.5%. That leaves 62.5% probability that option A_r will increase my current ROI. Option UA_r offers only a 50% chance of increasing my ROI.

I would take option A_r because there is still a large percentage chance that it is going to be more than 16%, and there is a greater than 50% that it will be higher than 16%, and probably less than 20% chance that it would be less than 16.

Recall that in the loss condition, a large majority of our earlier subjects preferred to choose an ambiguous option in the certainty condition. However, our protocol results show that when facing a decision under risk in the loss condition, half of the subjects (8 of 16) preferred the unambiguous option to the ambiguous option. Perhaps subjects perceive that the risk associated with the A_r option exceeds their tolerance level, and therefore, do not desire the ambiguous option. The typical explanations for their preference of the UA_r option the A_r option are as follows:

The variations of option A_r is also wider, showing more uncertainty and as a result, risks.

Option UA_r has less risk... Option A_r may have the highest potential in both probabilities, it also has the potential for the lowest of the two alternatives... These are practically the same as option UA_r , so I am more inclined to select the less risky option UA_r .

Still, eight subjects preferred the A_r option. Similar to the explanation that was mentioned in the certainty-framed condition, subjects considered that the A_r option offered a higher possibility of meeting the required rate of return. The following quotes illustrate this explanation:

I would prefer option A_r since it also gives me a chance to increase my bonus if the ROI exceeds 16% (which is not possible with option UA_r).

... Option A_r does not seem to be that much more risky than option UA_r , therefore, I chose option A_r . By choosing option A_r , I have some possibility of being able to have the project yield the required ROI of 16%. None of these projects seem to be all that good, but since I have to make a choice, I went with A_r .

In Table 3, we can see that subjects 1–5 displayed the hypothesized domain-contingent shift (from ambiguity proneness in the loss domain to ambiguity aversion in the gains

domain) in both the decision framed under certainty and under risk. Furthermore, subjects 6 and 7 showed the switching pattern under certainty but were uniformly ambiguity averse in the decision under risk, perhaps because riskiness pushed them towards ambiguity aversion.

4.3. Overall choices rank ordering the four types of options

When subjects were asked to consider the four options together, similar results were observed in the gain condition. Subjects preferred the two unambiguous options. As shown in Table 4, about 63% (10 out of 16) of the subjects exhibited either the "a" or the "b" choice pattern. The preference order "a" is $UA_c > UA_e > A_e > A_c$ and order "b" is $UA_c > UA_e > A_e > A_c$. More specifically, 75% (12 out of 16) of the subjects chose the UA_e option as their first choice and 13% (2 out of 14) of them preferred to have the UA_e option as their first choice. Again, these subjects indicated greatest safety, least risk, and minimum uncertainty as important factors in making choices in the gain condition. The typical comments are:

Safety. I believe the options are ranked in the order . . . Using the statistics of probability, means, and expected ROI, I believe the options will all have a similar expected ROI. Therefore, I rank the options according to safety.

Risk was the first consideration. I tried to choose the highest guaranteed return for the least amount of risk, especially since the return I was getting for no risk was deemed to be satisfactory. After that, I attempted to minimize the risk as much as possible.

Only two subjects indicated that they would choose the ambiguous (A_e) option as the first choice. The written comments suggest that this choice of ambiguous option is due to the subjects' risk-seeking attitude. One quote is as follows:

I feel that the risk to receive a return lower than I want (16%) is much lower than the opportunity that I would have to receive a higher return. I have ranked them in the order that I feel comfortable that the risk of a low return is worth the bigger chance of a higher return. I would rather try for a high return than just be safe.

In contrast, in the loss condition, there are no clear patterns of choice behavior as observed in the gain condition. The results show that 50% (8 out of 16) of the subjects chose the ambiguous option in the certainty frame (the choice patterns are "i" and "j") as their first choice. Also, 75% (12/16) of them indicated the UA_e option would be their last choice. The decision processes involved in ranking the options are illustrated as follows:

Option UA_e is completely out because its ROI is always <16%. Option UA_e is next worse because ROI will either be lower than 16% half the time or equal to 16% rest of the time (so I will never be able to exceed 16%). My second option will be option A_e because it affords me 50% chance of meeting and exceeding 16% if I can manage well to avoid ROI from dropping below 16% (in the 14–18% range). My first option will be A_e because I can attempt to increase the ROI to 16% or more, 100% of time.

Table 4. Descriptive statistics of written protocol experiment

New code	Pattern	Certainty		Risk		Overall choices rank order	
		Gain	Loss	Gain	Loss	**Gain	Loss
S1		UA	A	UA	A	b	i
S2	Domain contingent switchers	UA	A	UA	A	b	i
S3	Domain contingent switchers	UA	A	UA	A	b	k
S4	under certainty and risk	UA	A	UA	A	a	i
S5		UA	A	UA	A	g	j
S6	Switch under certainty only	UA	A	UA	UA	a	j
S7		UA	A	UA	UA	b	j
S8		UA	UA	UA	UA	b	a
S9		UA	UA	UA	UA	b	b
S10	Always choose unambiguous	UA	UA	UA	UA	a	a
S11		UA	UA	UA	UA	a	a
S12		*UA	*A	A	UA	m	e
S13		A	A	A	UA	d	e
S14	Other Patterns	A	A	UA	A	f	i
S15		UA	A	A	A	c	b
S16		UA	A	A	A	d	i

*UA: Unambiguous option		14 (88%)	4 (25%)	12 (75%)	8 (50%)
A: Ambiguous option		2 (12%)	12 (75%)	4 (25%)	8 (40%)

R	**a: UA_e, UA_e, A_e, A_e	4	3
A	b: UA_e, UA_e, A_e, A_e	6	1
N	c: UA_e, A_e, UA_e, A_e	1	0
K	d: UA_e, A_e, A_e, UA_e	1	0
		14	7
O	e: UA_e, A_e, A_e, UA_e	0	2
R	f: UA_e, A_e, UA_e, A_e	1	0
D	g: UA_e, UA_e, A_e, A_e	1	0
E	h: UA_e, A_e, A_e, UA_e	0	1
R	i: A_e, A_e, UA_e, UA_e	0	5
S	j: A_e, UA_e, A_e, UA_e	0	3
	k: A_e, A_e, UA_e, UA_e	1	9
	m: A_e, UA_e, UA_e, A_e	1	0

**UA_e: unambiguous-certain option; A_e: ambiguous-certain option; UA_e: unambiguous-risky option; A_e: ambiguous-risky option.

I was looking for any option that would give me at least the highest minimum ROI. So I chose the options first that would give me a good chance of hitting that ROI target.... I was more interested in hitting the minimum than taking a chance on going over the ROI.

In addition, seven subjects ranked the unambiguous options as their first choice. All the explanations for choosing an unambiguous option in the loss condition are risk-related. Below are some exemplar quotes:

Minimize risk (minimum variation)—Option UA_1 has lowest risk, while option A_1 and A_2 have highest risk.... Options A_2 and A_1 could potentially yield 10%.... There are no available probabilities for option A_1 ; i.e., the probability distribution could be skewed to the left (greater chance of 10% than 18%). For option A_1 , the probabilities are known with more certainty.

Uncertainty is bad because ROI is very important to the decision in this situation. The more uncertainty there is, the less likely we will hit the expected ROI numbers.... Probability of hitting as close to 16% as possible is important. Option A_1 has the least chance since no option has a guarantee of 16%... I think a range is worse than a 50% probability (hence UA_1 over A_1) because with a probability, I can assume worse case and work from that position. At least I can behave as if it will be 12% in the worse case, the range option opens up too many additional questions and possibilities.

In summary, in the certainty condition, a strong domain-contingent switching choice pattern emerges—preferring the unambiguous option in the gain condition but the ambiguous option in the loss condition. However, in the decision under risk condition, while a great majority of subjects chose the unambiguous option in the gain condition, half of them also indicated a preference for the unambiguous option in the loss condition. We suspect that probabilistic risk exacerbates the perceived risk associated with the ambiguous option, which leads to a high level of risk exceeding the subjects' tolerance level. Therefore, they shifted their preference from the ambiguous option in the certainty frame to the unambiguous option in the risk frame, when facing a loss.

5. General discussion

This study examined how managers make choices involving outcome and probabilistic ambiguity in a decision context involving gains or losses with respect to a benchmark performance target level. The experimental results show that in the same managerial contexts, our subjects exhibit somewhat different choice behaviors in the presence of probabilistic and outcome ambiguities. Also, this study provides possible explanations behind managers' investment choices when they face outcome ambiguity in decisions under certainty and under risk.

Specifically, we examined whether managers had domain-contingent ambiguity preferences when considering a benchmark such that above the benchmark is in the gains

domain and below the benchmark is in the loss domain. When facing an ambiguous outcome, the managers, at both aggregate and individual levels, exhibited domain-contingent choice behavior—avoiding ambiguity in the gain condition and being ambiguity prone in the loss condition. This finding is consistent with the "fear" and "hope" effects in Viscusi and Chesson (1999) and the notion of loss aversion that losses appear psychologically bigger and, thus, more aversive and painful than equivalent gains.

Similarly, under the corresponding probabilistic ambiguity condition, this pattern was supported at the aggregate level and was the modal pattern at the individual level for the half of the managers who perceived the difference in riskiness between the options to be low. For the other half, who rated the difference in riskiness to be relatively high, the modal choice pattern was not domain-contingent; managers consistently selected the unambiguous option in both the gain and loss conditions. While our finding is consistent with the notion that ambiguity in probabilities and outcomes affects choices in a somewhat different manner (e.g., Schoemaker, 1989, 1991; Shapira, 1993), it is different from what has been reported in Kuhn and Budescu (1996) that individuals tend to hold congruent attitudes toward ambiguity in the presence of probabilistic and outcome ambiguity.

Most prior studies involving either gain or loss conditions report that decision makers tended to avoid ambiguity (e.g., Gonzalez-Vallejo, Bonazzi, and Shapiro, 1996; Kuhn and Budescu, 1996). However, this study demonstrates that many of the managers were ambiguity prone in the loss condition when either outcome or probabilistic ambiguity was involved. Our findings can be explained by the switch pattern from the "fear" effect leading to ambiguity aversion to the "hope" effect leading to ambiguity seeking behavior reported by Viscusi and Chesson (1999). We conjecture that such differences can be attributable to the different reference points used. In most previous studies involving loss conditions, the subjects' reference point is the unambiguous "no gain and no loss" option. In such cases, subjects were less willing to accept the risk of choosing ambiguous options which may result in loss, greater blame, and regret. By contrast, in our outcome ambiguity study, our subjects were asked to choose between unambiguous options which surely will not meet the target (i.e., a known loss) and ambiguous options which have vague information on whether the outcome will meet the target or result in a loss. In other words, our subjects' focal comparison point may be the unambiguous "known loss" option. Therefore, they may have considered the ambiguous option to be the only opportunity to reach the target and were more willing to tolerate ambiguity.

Kahn and Sarin (1988) suggest that ambiguity accentuates the effect of risk, which is supported by Ghosh and Ray (1997) in a laboratory experiment on sample size. We find some evidence of such accentuation of risk. Our results show that perceived risk affects managers' choices when options involve imprecise probabilities. For example, when managers are provided with imprecise probabilities, their perceived risk of the options influenced their choice of an ambiguous or an unambiguous option, according to our regression analysis of the probabilistic ambiguity experiment. Our findings are thus consistent with Kahn and Sarin's (1988) suggestion that ambiguity accentuates risk. As indicated in our written protocol experiment on outcome ambiguity, participants also considered riskiness a factor in making choices in decisions framed as being under

certainty or risk. Furthermore, when probabilistic risk was added on top of outcome ambiguity, participants seemed to feel the risk was accentuated.

The results of this study suggest that future research should explore the following three issues. First, future studies are needed to further explore the decision processes involved in the probabilistic ambiguity condition to provide a better picture of the role of uncertainty and risk on investment choices. Also, in this study we only examined choice pairs with one option offering the chance of a gain or breakeven outcome and the other option offering no chance of such an outcome. Future studies should examine the sensitivity of ambiguity preferences observed in this study to different sets of options (e.g., none of the options offer a breakeven possibility). Also, in today's dynamic business environment, managers are required to periodically review and revise their targets at the individual, divisional or company level. Future studies may also explore how moving targets affect managers' ambiguity preference.

Second, in the business world, management not only uses single-figure measures as benchmarks due to critical external factors (e.g., projected demands of the marketplace and the behavior of current and projected competitors), but also uses interval benchmarks (with an acceptable range of outcomes) to measure managers' performance (Horngren, Foster, and Datar, 1997; Lentini, 1993). This study used a single benchmark to assess the effect of ambiguity on managerial investment choices. More studies could examine the effects of different types of benchmarks, uncertainty and ambiguity on managerial choices. For example, we have extended this study to use an interval benchmark context to assess how ambiguity affects managers' variance investigation decisions (Ho, Keller, and Keltzka, 2001).

Finally, in this study, managers were either faced with outcome ambiguity or with probabilistic ambiguity but not both. Further, the probability values in this experiment may have appeared slightly more precise in the gains domain (i.e., 63%) than in the loss domain (i.e., 60%, ending in zero). Future studies should confront subjects with both forms of ambiguity and with varying levels of numerical precision.

Appendix 1. Excerpts of sample experimental instruments (ROI Case)

Panel A. Loss condition

You are the manager of an investment center. Your job performance is based on several different components including return on investment (ROI).

Because of an increased demand for the services provided by your investment center, the president of the company has asked you to develop an expansion plan. Your staff has gathered information to compute a ROI on two expansion options, A and B. Both are within the budget and meet your expansion objectives.

The staff agrees that undertaking option A would result in a ROI of 14%. With option B the staff has different opinions and has provided a range of 10 to 18% for the ROI. You have always received high performance evaluations and maintaining this record is important to you. Your current ROI is 16%. If you are unable to maintain or improve

your ROI, you could have a lower performance evaluation and a reduced year-end bonus. But, not providing for the expansion could have negative long-term consequences for the center.

1. Given this information, if you must choose one option, which would you select?

_____ I would select option A with an estimated ROI of 14%.

_____ I would select option B with an estimated ROI of 10% to 18%.

Panel B. Gain condition

You were not satisfied with options A and B and asked your staff to review other options. They provided options C and D for your consideration. Both fulfill your expansion requirements and are within the expansion budget. All of the staff agree that option C would have an estimated ROI of 18%, but they disagree with option D and the ROI ranges from 9% to 27%.

2. Given this information, if you must choose one option, which would you select?

_____ I would select option C with an estimated ROI of 18%.

_____ I would select option D with an estimated ROI of 9% to 27%.

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Notes

1. In the decision theory literature, ambiguity and vagueness are used interchangeably. We use the term ambiguity throughout this paper.
2. In a decision under certainty frame, no probabilistic uncertainty is presented. For example, a person could be told: "Congratulations, you have earned your bonus. It will be somewhere in the range of 5-10% of your base salary." There is certainty (probability = 1.0) that the bonus has been earned, but vagueness about the monetary amount. We will label such a situation with a vague outcome as "outcome ambiguity."
3. Kahn and Meyer (1991) use the term riskless ambiguity for this case.
4. In a notable exception, Kahn and Meyer (1991) developed and empirically tested a formal theory of multi-attributed judgments where there is uncertainty or ambiguity associated with attribute-importance weights in various "riskless" consumer choice contexts.
5. Viscusi and Chesson (1999) note that for ambiguous small probabilities of gains (losses), the prevalent gains (loss) domain preference for ambiguity aversion (proneness) switches to proneness (aversion). Our study examines large probabilities ($p > .3$).
6. The MBA Program's admission requires that students have a minimum of two years of business-related experience. An exception was made for two high honors students admitted directly from the University's undergraduate programs.

6. Each subject was asked to respond to the two cases and the presentation order of these two cases was randomized.
7. Since we were concerned that subjects responding to a gain condition first would have no motivation to respond to a loss, all participants were presented the loss scenario first, followed by the gain scenario. Nevertheless, results from an additional study show there was no significant presentation order effect.
8. The subjects were told that risk is defined as "when the decision maker does not know for certain what the ultimate outcome will be." And ambiguity is defined as "the decision maker doesn't know the process by which the outcomes were determined. The likelihood of the events affecting the payoff cannot be specified with precision."
9. In the outcome ambiguity experiment, 100% of the subjects gave the purportedly ambiguous option a higher ambiguity rating than the purportedly unambiguous option; except in the ROI loss condition, one subject gave the reverse order.
10. More specifically, 95% to 100% of the subjects rated the ambiguous option to be more risky than the unambiguous option.
11. We chose to use the measures based on differences in perceived risk on two options and differences in perceived ambiguity on two options, even though difference scores can be prone to numerous methodological problems, particularly if differences in scores for two distinct concepts are involved (Edwards, 1994; Johns, 1981). In our case we only calculate differences on the same dimension between two alternatives. Our aim was to have a single measure to indicate how far apart a participant saw the two choices to be.
12. Our original experimental design had high ambiguity ($\pm 9\%$ spread) in the gains domain and moderate ambiguity ($\pm 4\%$ spread) in the loss domain in both the IRR and ROI cases. To rule out possible artifacts of the original experimental design, we conducted a follow-up experiment with another group of 53 MBA students. Subjects were asked to respond to ROI cases with high ambiguity ($\pm 9\%$ spread) and IRR cases with moderate ambiguity ($\pm 4\%$). Our results show a choice pattern similar to that found in our main study. In the IRR (ROI) case, the A/D/A pattern was displayed by 59% (64%) in the original and 60% (54%) in the additional experiment. Thus, these results rule out the possibility that our results in the main study were due to an artifact of our original design.
13. In both conditions there is actually a range of possible ROI values, as shown by the vertical bars in the left side of Figure 1. There is thus ambiguity about what the precise ROI will be in both the ambiguous probability and unambiguous probability options. Since our focus here is on varying the ambiguity of probabilities, vagueness of ROI outcomes is held equal across options.
14. Perhaps just being in the loss domain leads to a perception of high enough risk that extra ambiguity adds no more risk for many subjects.
15. The logistic regression revealed that the difference in perceived risk of the two options significantly affected the choice. For the IRR (ROI) case, 21 (21) subjects had a low difference in perceived risk for the two loss domain options, with an average absolute difference of .643 (.500), which is the absolute value of the difference between the risk of the ambiguous option and the risk of the unambiguous option. The difference ranges from 0 to 6. The remaining 19 (19) subjects had a high difference in perceived risk, with an average absolute difference of 2.013.
16. We have recoded the option names from A and B which subjects saw to our coding, U_{A_i} or A_{j_i} , in all protocols. In Task 2, options C and D were recoded to U_{A_i} and A_{j_i} .

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