

A “Pseudo-endowment” Effect, and its Implications for Some Recent Nonexpected Utility Models

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Abstract

This article describes a modification of the Allais paradox that induces preferences inconsistent with two conditions weaker than the independence axiom, namely *quasi-convexity* (a special case of which is the *betweenness* axiom), and *Hypothesis II* of Machina (also called *fanning-out*). These violations can be formally derived from prospect theory by invoking a nonlinear transformation of probability into decision weight.

This article describes a variation on the Allais paradox that presents difficulties for two widely discussed restrictions on nonexpected utility models, namely, Machina’s *Hypothesis II* (1982), which states that stochastically dominating shifts in distribution increase local risk aversion, and *quasi-convexity*, which implies that a mixture of two distributions may not be strictly preferred to both of its component parts. (An important special case of quasi-convexity is the *betweenness* or *dominance* axiom, which implies, in addition, that the mixture may not be considered strictly worse than the two original gambles (Chew, 1983; Chew and MacCrimmon, 1979; Dekel, 1986; Fishburn, 1983). In terms of indifference curves in the probability simplex, Hypothesis II is consistent with curves that “fan out,” quasi-convexity with curves that are (weakly) concave with respect to the best (top) outcome, while betweenness/dominance generates curves that are straight (though not necessarily parallel) lines (see figure 1).

The list of current theories that assume at least one of these restrictions is long (for excellent surveys, see Machina, 1987; Weber and Camerer, 1987). Betweenness is assumed by the implicit expected utility theory of Chew (1983) and Dekel (1983), Chew and MacCrimmon’s (1979) weighted utility theory. Fishburn’s (1983) skew-symmetric bilinear (SSB) theory, and Guls’s (1988) recent theory of disappointment aversion; Hypothesis II is, of course, advanced in Machina’s articles, but it is also included in Chew and Waller’s (1986) *light* hypothesis, and in a transitive version of Loomes and Sugden’s (1987) regret theory; finally, quasi-convexity is needed to allow for risk aversion in Becker

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and Sarin's (1987) lottery-dependent expected utility, and in rank-dependent models, such as Quiggin's (1982) theory of anticipated utility, Yaari's (1987) dual theory of risk, and the most recent *ordinal independence* model of Green and Jullien (1988).

Our critical focus on betweenness and Hypothesis II, in particular, is motivated also by two more general questions:

1. Are violations of independence principally caused by some systematic relationship between local risk aversion and gamble value?
2. If so, what is the nature of the relationship (i.e., positive, negative, or nonmonotonic)?

The betweenness axiom is equivalent to a yes answer for question 1, since local risk aversion is constant along a given indifference line, but is free to vary as one moves from one line to the next. Hypothesis II accepts question 1, to the extent that gambles are comparable by stochastic dominance, and claims further that the relationship in question 2 is positive.¹

The first section of this article describes a pair of choices (the *pseudo-endowment* effect) that reliably induces preferences inconsistent with Hypothesis II. Next, we show that this pattern, in conjunction with one of the earlier Allais examples (the *common-ratio* effect), creates a strict preference for mixtures, and is hence inconsistent with the betweenness axiom as well. We conjecture that these violations are generic to a well-defined class of gambles, in that they follow from two assumptions about nonlinear sensitivity to probability changes that have been already identified by Kahneman and Tversky (1979). Because these two properties (overweighting of small probabilities, and *subproportionality*) also fit into an explanation of the earlier paradoxes, our examples provide some independent support for prospect theory, in particular, as well as for the general family of separable models that are nonadditive in probabilities (e.g., those developed by Bell (1985), Luce and Narens (1985), Quiggin (1982), Rubinstein (1988), Schmeidler (1984), and Yaari (1987), among others).

The article concludes with a discussion of some recent related experiments by Camerer (1988), Battalio et al. (1988), and Starmer and Sugden (1987a,b), which, taken jointly, contribute to the feeling that no current theory manages an entirely satisfactory account of choice among risky prospects.

1. Hypothesis II and the pseudo-endowment effect

As with examples of Allais, subjects consider matched pairs of gambles, of which the pair below is representative:

Problem 1. Choose between

- | | |
|--|--|
| <p>A: 2% chance of winning \$20,000
 98% chance of winning nothing</p> | <p>B: 1% chance of winning \$30,000
 99% chance of winning nothing</p> |
|--|--|

Problem 2 Choose between

- | | |
|--|--|
| <p>C: 34% chance of winning \$20,000
66% chance of winning nothing</p> | <p>D: 1% chance of winning \$30,000
32% chance of winning \$20,000
67% chance of winning nothing</p> |
|--|--|

The two pairs are constructed by starting out with a common-consequence schema shown in figure 2A, and then filling in the bottom branch, in both gambles, with either $F^* = 0$ (which creates the A-B pair), or the scheme shown in figure 1B (which creates the C-O pair). The independence axiom would require a person to ignore the common F^* or F^{**} component, and hence to choose either A and C, or B and D, depending on whether the certainty equivalent for a 50-50 chance at \$30,000 or nothing was above or below \$20,000.

As table 1 shows, a significant majority of subjects preferred A to B (73%), and D to C (82%).² The majority pair of choices, AD, does violate the independence axiom; more interestingly, however, the violation goes against the direction permitted by Hypothesis II. According to the hypothesis, a person's conditional certainty equivalent for the component of a gamble conditional on some event E (in our case, the 2% chance of landing

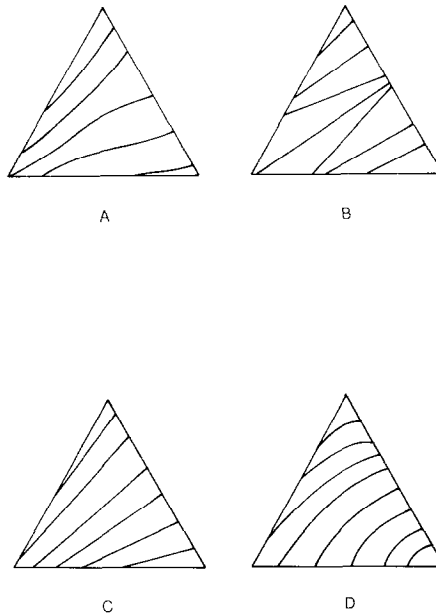


Figure 1. Indifference curves in the probability simplex under four different conditions: **A.** Hypothesis II (or fanning out); **B.** Betweenness (or dominance); **C.** Hypothesis II *and* betweenness; and **D.** Quasi-convexity. The top, left, and right corners of the simplex represent, respectively, the best, intermediate, and worst outcomes, obtained with probability 1.

Table 1. Results from problems 1 and 2

	A	B	
C	18% EU	0% Fanning-out	18%
D	55% Fanning-in	27% EU	82%*
	73%*	27%	

in the upper branch of gambles B/D) should increase as the component complementary to E improves, where improvement is defined by first-order stochastic dominance (Machina, 1982, theorem 5(iii)). Since F^{**} dominates F^* , the conditional certainty equivalent for a 50% chance of \$30,000 should, if it changes at all, *increase* as F^* is replaced by F^{**} . However, subjects who prefer A to B reveal a conditional certainty equivalent above \$20,000, while those who prefer D to C reveal a conditional certainty equivalent below \$20,000, which reverses the direction predicted by Hypothesis II.

As Machina has shown, when there are only three distinct outcomes, Hypothesis II implies that the indifference curves in the probability simplex fan out (see Figure 1A). The configuration of gambles ABCD creates the familiar parallelogram in the simplex; the indifference curves that are consistent with the majority choice pair, AD, would then exhibit *fanning-in*—that is, they would appear to converge (at least initially) as they flow up from the bottom face of the simplex (see figure 3).

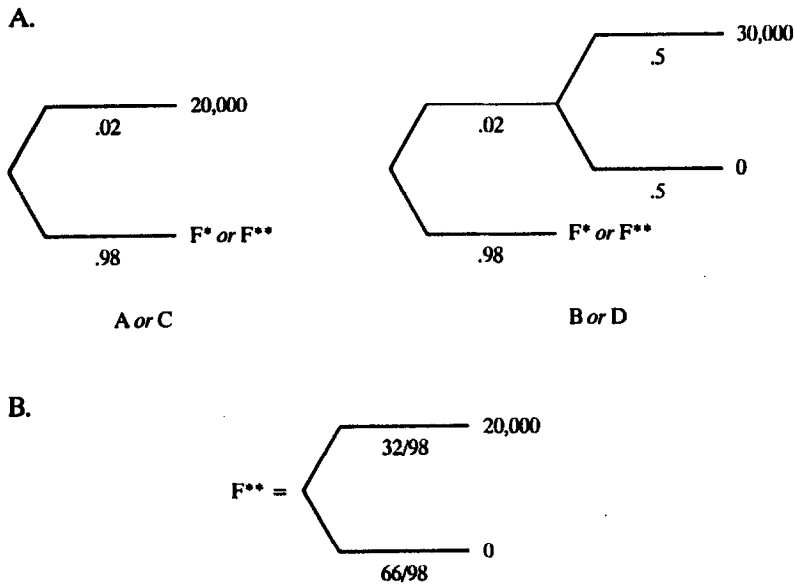


Figure 2. A. Common-sense schema for problems 1 and 2. B. F^{**} values for problems 1 and 2 (see figure 1A).

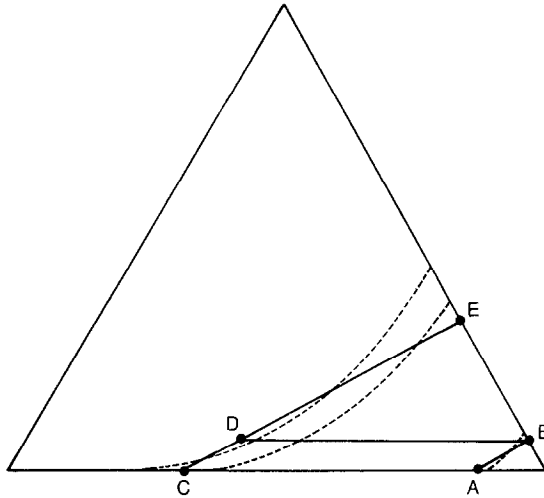


Figure 3. The five generic gambles plotted in the probability simplex, along with indifference curves that rationalize the modal choices.

To construct an informal rationalization of these results, note, first, that both problems ask a person to decide whether a 1% chance of winning a larger prize is worth a 1% reduction in probability of winning any prize at all. We can think of these percentages, for example, as individual tickets in a 100-ticket lottery. In this context, Hypothesis II predicts that a person’s tendency to accept the offer (and exchange two lower-prize tickets for a single higher-prize one) will be greatest when he or she is endowed with only two lower-prize tickets, and will diminish, if it changes at all, as the initial endowment of tickets is increased. This seems counterintuitive, on the grounds that a 1% reduction in overall win probability (which is the cost of the higher-prize ticket) will be perceived as relatively less significant when it reduces, say, a 34% chance to 33%, than when it halves a 2% chance to 1%.

A person with many lottery tickets is wealthier, in a psychological sense, than a person with only a few, and that factor alone might make him or her more likely to take on additional risk. Of course, the probabilistic endowment is not wealth in the sense needed to invoke decreasing Arrow–Pratt risk aversion, which is why we will refer to this choice pattern as a *pseudo*-endowment effect.

2. Test of quasi-convexity and betweenness

A preference for gamble D over C can now be extended into a preference for mixtures (quasi-concavity) in the following way. Consider the gamble E, constructed by extending the CD line in figure 3 until it touches the right side of the simplex. A subject who prefers D to C will prefer E to C, if his indifference sets are quasi-convex (i.e., concave with

respect to the top outcome) or straight (in the case of betweenness). But a choice between C and E, i.e.,

Problem 3. Choose between

- | | |
|-----------------------------------|-----------------------------------|
| C: 34% chance of winning \$20,000 | E: 17% chance of winning \$30,000 |
| 66% chance of winning nothing | 83% chance of winning nothing |

should reveal a preference for C, given that subjects have already exhibited a preference for A over B. This prediction follows from the common-ratio effect, which refers to the well-documented finding (e.g., Kahneman and Tversky, 1979) that subjects who prefer a probability p of winning a standard prize x to a smaller probability q of winning a larger prize y may reverse their preference when both probabilities, p and q , are reduced by a common factor, α to αp and αq . In choosing A over B, our subjects have shown a preference for a 2% chance of \$20,000 over a 1% chance of \$30,000; hence they should have an even stronger preference for a 34% chance of \$20,000 over a 17% chance of \$30,000. If reversals in the opposite direction are indeed precluded by the common-ratio effect, then the proportion of Hypothesis II violations in table 1 (55%) provides a *lower bound* on the proportion of quasi-convexity violations, which is confirmed by the results in table 2.

The proportion of violations observed here (76%) is comparable to that found with the standard Allais problems. Consequently, the restricted form of independence captured by betweenness inherits the vulnerabilities of the unrestricted independence axiom.

In terms of our lottery ticket formulation, the critical issue for this gamble-pair is the following: If a person accepts a two-for-one ticket exchange once, does that imply that he would be willing to exchange his entire endowment of lower-prize tickets at the same two-for-one rate? Our subjects' disagreement with this principle, and, by implication, with quasi-convexity, may be understood, again, as reflecting a nonlinear distortion of probability weight: The first high-prize ticket creates a qualitative change in the gamble, and is therefore of exceptional value; after a certain point, however, additional high-prize tickets may not be worth the sacrifice in overall win probability.

3. Discussion

These informal arguments can be given a more precise expression within the prospect theory framework (Kahneman and Tversky, 1979). In this theory, a *regular* prospect (i.e.,

Table 2. Results from problems 2 and 3

	C	E	
C	18% Betweenness	0% Quasi-convexity	18%
D	76% Quasi-concavity	6% Betweenness	82%*
	94%*	6%	

a gamble with outcomes that are not all strictly positive, or strictly negative) is evaluated by the subjective expected utility (SEU) formula,

$$\sum \pi(p_i)v(x_i),$$

where $\pi(p_i)$ is the decision weight associated with probability p_i , and $v(x_i)$ is the value of outcome x_i . Kahneman and Tversky identify three constraints on the shape of the decision weight function:

- Overweighting:* $\pi(p) > p$ for small p . (1)
- Subcertainty:* $\pi(p) + \pi(1 - p) < 1$. (2)
- Subproportionality:* $\pi(\alpha p)/\pi(\alpha q) > \pi(p)/\pi(q)$, when $p < q$ and $0 < \alpha < 1$ (3)

In order to predict the pattern of majority choices in our three problems, we need to select $p < q$ for which π is superadditive:

$$\pi(p) + \pi(q) > \pi(p + q) \tag{4}$$

Such p, q clearly exist whenever p is overweighted in the sense of (1) above (otherwise, $\pi(p + q) \geq \pi(p) + \pi(q) \geq p + \pi(q) > 1$, for sufficiently large q). In addition, we select $r < p$, and dollar outcomes $x < y$, whose relative value falls in between the two ratios:

$$\frac{\pi(p + q) - \pi(q)}{\pi(r)} < \frac{v(y)}{v(x)} < \frac{\pi(p)}{\pi(r)}. \tag{5}$$

Table 3 defines the generic versions of gambles A,B,C,D,E, and their corresponding valuations, according to the SEU formula. For the specific gambles used in our experiment, $p = .02, q = .32, r = .01, x = 20,000$, and $y = 30,000$.

Generic violations of Hypothesis II, and of quasi-convexity, then follow directly from the prospect theory valuations:

Table 3. The five generic gambles and the corresponding prospect theory valuations

	Prospect	Valuation
A:	x with probability p 0 with probability $1 - p$	$V(A) = \pi(p)v(x)$
B:	y with probability r 0 with probability $1 - r$	$V(B) = \pi(r)v(y)$
C:	x with probability $p + q$ 0 with probability $1 - p - q$	$V(C) = \pi(p + q)v(x)$
D:	y with probability r x with probability q with probability $1 - q - r$	$V(D) = \pi(r)v(y) + \pi(q)v(x)$
E:	y with probability $(p + q)r/p$ 0 with probability $1 - (p + q)r/p$	$V(E) = \pi((p + q)r/p)v(y)$

$$\begin{aligned}
 V(A) - V(B) &= \pi(p)v(x) - \pi(r)v(y) \\
 &> 0 && \text{(by (5), second inequality).} \\
 V(C) - V(D) &= \pi(p + q)v(x) - [\pi(r)v(y) + \pi(q)v(x)] \\
 &= [\pi(p + q) - \pi(q)]v(x) - \pi(r)v(y) \\
 &< 0 && \text{(by (5), first inequality)} \\
 V(C) - V(E) &= \pi(p + q)v(x) - \pi((p + q)r/p)v(y) \\
 &= v(x)\pi((p + q)r/p) \left[\frac{\pi(p + q)}{\pi((p + q)r/p)} - \frac{v(y)}{v(x)} \right] \\
 &> v(x)\pi((p + q)r/p) \left[\frac{\pi(p)}{\pi(r)} - \frac{v(y)}{v(x)} \right] && \text{(by subproportionality)} \\
 &> 0 && \text{(by (5), second inequality).}
 \end{aligned}$$

Subcertainty is not invoked in the derivations, because all five gambles assign a positive probability to the zero outcome. The remaining prospect theory assumptions, about asymmetric treatment of gains and losses, and about the preliminary editing phase of evaluation, also clearly do not play a role.

A similar reconstruction of the observed preference pattern for gambles A–E is possible on the basis of the rank-order models of Quiggin (1982) and Yaari (1987), which apply a nonlinear transformation $f(p)$ to the *decumulative* probability axis, and not to individual (i.e., outcome = specific) probabilities.³ Since the distinction is immaterial for gambles with a single nonzero outcome, the only impact on our derivation would be in the valuation of gamble D, which changes to

$$f(r)v(y) + (f(r + q) - f(r))v(x).$$

The decision weight assigned to an outcome, such as x , is now given by the difference between the values that $f(p)$ takes at the two corresponding cutpoints on the decumulative probability axis (i.e., $r + q$ and r). (For the best outcome, y , this is just $f(r) - f(0) = f(r)$). A preference for A over B, and D over C, then implies

$$f(p) - f(r) > f(q + p) - f(q + r),$$

or, with the specific gambles used

$$f(.02) - f(.01) > f(.34) - f(.33).$$

A .01 probability outcome has more weight when it defines the second-best centile, rather than one that is 34th from the top. This is quite close in spirit to the verbal arguments presented in the earlier sections; it does imply, however, that the $f(p)$ function is convex, which is inconsistent with risk aversion in the context of these models.

4. Related empirical work

Most recently, a number of independent studies have attempted to map out the indifference curves in the probability simplex in a systematic fashion, and have uncovered rather substantial violations of betweenness and, more rarely, some Hypothesis II violations.

In the first study of this kind, Chew and Waller (1984) presented subjects with matched *quadruplets* (rather than pairs) of gambles.⁴ Independence violations generally supported Hypothesis II; of the betweenness violations (27% overall), those involving gambles for positive outcomes were slightly biased toward a preference for mixtures.⁵

More substantial violations of betweenness can be found in Camerer's (1988) article, which is also the most comprehensive exploration of indifference curves conducted so far, listing 24 individual betweenness and 36 Hypothesis II tests. In the domain of gains, the violations show a dislike of mixtures, the one prominent exception being a pair that closely resembles our problem 2-3 configuration. In Camerer's configuration 9-10 (his table 2), the constant gamble in both pairs was a 60% chance of winning \$10,000. In pair 9, the majority of subjects (72%) revealed that they were willing to sacrifice 20% of this probability in order to obtain a 10% chance of \$25,000; in pair 10, however, a majority (78%) also revealed that they would not sacrifice 40% of the \$10,000 in exchange for a 20% chance on the \$25,000 prize. Consequently, the two-for-one probability exchange ratio was acceptable for the first 10% chance at \$25,000, but not for the second.

Camerer found very little fanning-in (only 4 out of the 36 tests), but a great deal of fanning-out. The only *gain* configuration in which the fanning-in violations are significantly higher than fanning-out violations involved a nonregular prospect (i.e., having only positive outcomes). Fanning-in in this region (upper-left part of the simplex), with strictly positive prospects, has also been reported by Battalio et al. (1988). Finally, Starmer and Sugden (1987a) presented 12 tests of fanning-out versus fanning-in, and found a significant bias for fanning-in over fanning-out in two of them, but the overall fraction of subjects exhibiting fanning-in was relatively modest (27% and 15%, respectively).

5. Conclusions

Returning now to the two questions posed at the start of this article, we could summarize all these results in the following way:

1. It is possible to induce both fanning-out and fanning-in patterns of preference; consequently, the relationship between the local attitude to risk and gamble value is, in general, nonmonotonic.
2. It is possible to induce both strictly quasi-convex and strictly quasi-concave preferences; consequently, gamble value does not uniquely determine local attitude to risk.
3. It is definitely easier to generate fanning-out than fanning-in, and perhaps somewhat easier to elicit quasi-convex preferences (a dislike of mixtures) than quasi-concave ones (a preference for mixtures).

All these results are broadly consistent with prospect theory. However, both Camerer (1988) and Starmer and Sugden (1987b) found evidence that the *amount* of expected utility violations interacts with the size and sign of the payoffs, which is not consistent with any theory (including prospect theory) that derives violations through probability rescaling alone.

In a rather pessimistic conclusion to his article, Camerer describes the list of currently known violations of expected utility as “long and depressing,” and points out that no current theory can accommodate them all. Some speculations about why it is so difficult to construct a unified theory are offered below.

One perspective is to view outcome probability as a commodity—a desirable commodity when attached to a positive outcome. This perspective seems especially compelling if the probabilities are made concrete through something like the lottery-ticket scenario. In that context, a person who holds more lottery tickets is indeed “wealthier,” all other things being equal, and will hence be more likely to accept risk-expanding exchanges. This constitutes fanning-in.

The second perspective arises if, in evaluating a gamble, one imagines what it would feel like to endure the uncertainty defined by that gamble over some extended period of time. The adoption of this perspective could take place even if the gamble is to be resolved immediately, provided the person’s original preferences over uncertain outcomes have been forged through the actual experience of bearing uncertainty over time, and not through choices among instantly resolvable gambles. Unlike the commodity perspective described in the last paragraph, which applies to multiattribute preferences generally, this *delayed resolution* perspective is unique to risk.

What sort of expected utility violations would such a view promote? Clearly, if the betweenness condition is violated, it will be in the direction of a dislike of mixtures, since the extra uncertainty in the mixture can only make both financial as well as psychological preparation for the possible outcomes more difficult (Spence and Zeckhauser, 1972). Second, it will also promote fanning-out, because improvements in the gamble raise expectations and leave the individual more exposed to whatever residual risk remains.

There is a close formal analogy here with the problem of making investment or consumption decisions in the face of uncertain future income (Machina, 1984; Spence and Zeckhauser, 1972): As the probability of, say, an investment windfall increases, one will be led to make interim decisions (in the form of consumption choices) that draw more heavily on the still uncertain income that the investment is expected to provide; hence one will become more severely exposed to residual risk, and will pay more to remove it.

So far, the insights afforded by the two perspectives have been modeled by two unrelated families of theories, with prospect theory being representative of the first, and global restrictions like Hypothesis II or quasi-convexity typical of the second. The difficult challenge will be to accommodate both perspectives in a single tractable model.

6. Appendix

The problems in this article were presented in booklet form to Harvard undergraduates. The order and left-right position of gambles were balanced across different versions of the survey.

Along with the three choice problems described in the text, our study contained six other problems, which were constructed to provide three additional tests of Hypothesis II (test 1 is the one described in the text):

Gamble: (probability of receiving nothing is omitted)

Test	A		B		C		D	
#1	2%	20,000	1%	30,000	34%	20,000	1%	30,000
							32%	20,000
#2	5%	1M	1%	5M	25%	1M	1%	5M
							20%	1M
#3	5%	7,000	1%	10,000	45%	7,000	1%	10,000
			4%	2,000	55%	2,000	40%	7,000
							59%	2,000
#4	20%	20,000	5%	100,000	95%	20,000	5%	100,000
							80%	20,000

The fractions of subjects that selected the four possible choice combinations are given below (*Safe* refers to a consistent preference for higher chance of winning, while *Risky* refers to a consistent preference for the gamble with the high prize). Tests #1 and #2 were essentially equivalent, and they produced comparable results, except that the overall proportion of expected utility violations in test #2 was lower due to the relative unattractiveness of the risky alternatives. Test #3 used a slightly more complex configuration of gambles, involving four distinct outcomes. Test #4 had a typographical error (I am grateful to Colin Camerer for pointing this out), and is included here (as it was actually presented) only for completeness.

Test	EU-consistent		Inconsistent	
	Safe AC	Risky BD	Fanning-in AD	Fanning-out BC
#1	.18	.27	.55	.00
#2	.52	.09	.36	.03
#3	.36	.15	.45	.03
#4	.42	.15	.24	.18

Note: $N = 33$.

Notes

1. The concept of a conditional certainty equivalent or CCE, first introduced by Machina, permits us to state these two issues in a perhaps more intuitive way. A CCE is defined as the amount one would be willing to pay to eliminate an uncertainty, when both payment and uncertainty are conditional on some event E . In these terms, Hypothesis II would say that a person's aversion to a conditional element of uncertainty (as revealed by the CCE) becomes more severe with improvements in the larger gamble within which the conditional uncertainty is embedded. The betweenness axiom, while noncommittal about the direction of this relationship, nevertheless implies that the CCE for a subgamble will remain unaffected by changes in other subgames that preserve the value of the entire package. Hence, it singles out the attractiveness of the larger gamble as the only parameter that may cause the conditional certainty equivalent for a fixed subgamble to vary.
2. $* = p < .01$. See the appendix for a complete description of the survey.
3. Yaari's *dual theory* also requires that $v(x)$ be linear in x ; consequently, risk attitude is completely determined by the $f(p)$ function. In Yaari's theory, our results would imply risk-seeking.
4. Out of the 16 possible choice patterns, six were consistent with Hypothesis II, eight with betweenness, four with betweenness *and* Hypothesis II (which Chew and Waller (1984) call the *light hypothesis*), and two with independence. The fractions of answers inconsistent with these four conditions were, respectively, 29%, 27%, 41%, and 73%.
5. Choice patterns $A_{\circ}B_I$, contexts 1a, 2a, and 2b, reported in their table 2.

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