Risky Research

Timely Research

New Work on Risk, Time, and Risk over Time.

James Andreoni

UCSD

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Five Papers

- Estimating Time Preferences from Convex Budgets
- Risk Preferences are Not Time Preferences: Discounted Expected Utility with a Disproportionate Preference for Certainty
- Certain and Uncertain Utility: The Allais Paradox and Five Decision Theory Phenomena
- Uncertainty Equivalents: Testing the Limits of the Independence Axiom
  - All four with Charles Sprenger, UCSD
- Unexpected Utility: Experimental Tests of Five Key Questions about Preferences over Risk.
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Three Papers Today

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What is New in this Line of Work?

- New Ideas:
  - None
  - The core ideas have been around since Allais in 1953
  - Other elements have appeared in disparate places, often without testing.
  - At the center of all the analysis is the Certainty Effect of Allais.
  - Far from certainty, expected utility does fine and utility follows an EU function $u(x)$.
  - But in the neighborhood of certainty, people display a disproportionate preference for certainty, and utility follows a function $v(x)$, with $v(x) \geq u(x)$.
  - This $u - v$ model of preferences is a "useful simplification" of a more continuous process.
  - $u - v$ is a generalization of Disappointment Aversion that allows dominance violations.

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- New Experimental Methods:
  - We introduce several innovations we believe eliminate some confounding effects of prior experimental methods.
  - This is true for both risk and time measures.
  - In time preferences we take several new measures to create confidence in future payments.
  - Since the future is both less convenient and more risky than the present, this is crucial to get right.
  - We also introduce a new method for eliciting time preferences that can identify discounting and utility function curvature with a single instrument–*Convex Time Budgets*
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- New Data: Time Preferences and Discounted Expected Utility
  - Our data on time preferences finds reasonable discount rates which are correlated with recent studies.
  - However our measure of curvature is smaller and completely uncorrelated with prior methods.
  - Moreover, our estimates of utility predict well out of sample.
  - Our results are consistent with a model in which the future is risky, and individuals have $u - v$ preferences
  - Most importantly, our data is *inconsistent* with a $\beta - \delta$ model of present bias.
  - Either our experiment had too much front-end delay, or a lot of prior results of present bias were mistaken attributions of a certainty bias.
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  - This is the case with CPT Probability Weighting.
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  - Our data provide a clear contradiction of CPT Probability Weighting in Uncertainty Equivalents, and strong support of $u - v$ preferences when combined with Certainty Equivalents.
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Thaler, Richard, “Some Empirical Evidence on Dynamic Inconsistency,” *Economics Letters*, 8, 1981, 201-207.

- Hypothetical experiment in Thaler’s class.
- **Findings:** For 3 month delay, discount rates of 62-277%

Real money experiments would be interesting but seem to present enormous tactical problems. (Would subjects believe they would get paid in five years?)- Thaler(1981)

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Tactical Problems:

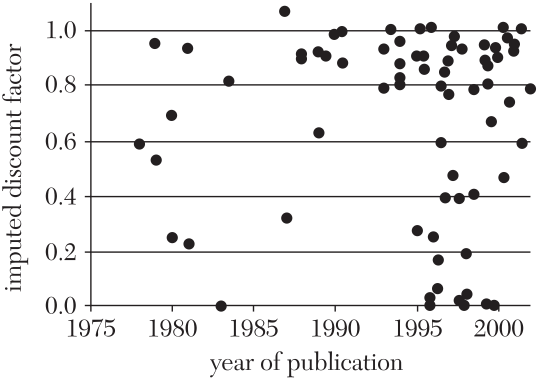

Figure 2. Discount Factor by Year of Study Publication

(Frederick, Loewenstein, O'Donoghue, 2002)

Wide Historical Variation in Preferences

Why are estimates so varied?

- Subjects may be sensitive to methods
- People cannot consistently report time preferences
- It is hard to make 'all else equal'
  - Transaction costs of getting paid
  - Trust that the future payments will be made

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Estimating Time Preferences

Experiments now often use
Multiple Price List (MPL) methodology

- Coller and Williams, *ExEc* (1999)
- Harrison et al. *AER* (2002)

Choices between a smaller, sooner reward and a larger, later reward.

Example: Option A (TODAY) or Option B (IN A MONTH)

Decision 1: $ 49 guaranteed **today** - $ 50 guaranteed **in a month**
Decision 2: $ 47 guaranteed **today** - $ 50 guaranteed **in a month**
Decision 3: $ 44 guaranteed **today** - $ 50 guaranteed **in a month**
Decision 4: $ 40 guaranteed **today** - $ 50 guaranteed **in a month**
Decision 5: $ 35 guaranteed **today** - $ 50 guaranteed **in a month**
Decision 6: $ 29 guaranteed **today** - $ 50 guaranteed **in a month**
Decision 7: $ 22 guaranteed **today** - $ 50 guaranteed **in a month**

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MPLs and Parameter Estimates

Experiments—including many MPLs–generally yield very high discount rates, often over 100% per year.
MPLs and others 'assume' linear preferences.
Individuals solve:

$$max_{c_t, c_{t+k}} \; U(c_t, c_{t+k})$$

s.t. the discrete budget:

$$\{(1+r)c_t, c_{t+k})\} \in \{(m, 0), (0, m)\}$$

Restriction to corner solutions.

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Price list switching point reveals $u(c_t) \approx \delta^k u(c_{t+k})$

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Allowing curvature means:

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will yield a bias, $\delta_C - \delta_L$.

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Proposed Solutions

Proposed solutions (Frederick et al., 2002):

1. Elicit utility rankings(attractiveness) at different points in time.
2. Compare temporally separated prospects. Exploit linearity-in-probability of EU (e.g., Anderhub et al. 2001).
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Rethinking the Standard MPL

If corner solution restrictions create a bias... why not connect the dots?
To identify convex preferences on c_t and c_{t+k} use a convex budget:

$$\max_{c_t, c_{t+k}} U(c_t, c_{t+k})$$

subject to

$$(1+r)c_t + c_{t+k} = m$$

This is simply a future value budget constraint.

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$$\max_{c_t, c_{t+k}} U(c_t, c_{t+k})$$

subject to

$$(1 + r)c_t + c_{t+k} = m$$

This is simply a future value budget constraint.

Convex Time Budget methodology (CTB)

CTBs and Parameter Estimates

The CTB:

$$\max_{c_t, c_{t+k}} U(c_t, c_{t+k})$$

$$\text{s.t.} \quad (1 + r)c_t + c_{t+k} = m$$

In a single, simple instrument, CTBs allow for identification of:

- Discounting at the individual and aggregate levels.
- Curvature at the individual and aggregate levels.
- Dynamic inconsistency (e.g., hyperbolic discounting)

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Paper 1: Estimating Time Preferences from Convex Budgets

Outline

- Experimental Design
- Aggregate Results
- Individual Results

Design: The CTB

In the CTB:

- Subjects are given a budget of 100 tokens.
- Tokens convert to dollars sooner at r_1 and later at r_2. So

$$\frac{r_2}{r_1} = (1 + r)$$

- 45 convex budgets.
- $(t = 0, 7, \text{ or } 35 \text{ days}) \times (k = 35, 70, \text{ or } 98 \text{ days}) = 9$ t-k cells.
- $r_2 = 0.20$ or 0.25; $r_1 \in [0.10, 0.20]$.
- 97 subjects. All freshmen and sophomores at UCSD
- 1 budget chosen for payment.

Design: Supplemental Data

- Also collected standard DMPL data
  - 3 Standard MPLs
  - 2 Holt-Laury risk price lists
- Post questionnaire, including question on expenditures.

Experimental Payments

To equate transaction costs of sooner and later payments:

- Pre-tested forms of payment: i) emailed gift cards at Amazon, ii) PayPal, iii) Triton Cash, iv) Personal check from 'Professor Andreoni' drawn on campus bank.
- All payments by check.
- All studies done in January...school ends in June.
- Possible payment dates chosen to avoid high and low money demand times: Valentines Day, Spring Break +/- 1 week, final exams.

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To equate transaction costs, continued...

- \$10 Thank-you payment split in two–\$5 sooner and \$5 later.
- Subjects addressed two envelopes to themselves.
- Wrote amount owed, and dates, inside flap of each envelope.
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- Given Andreoni’s business card and told to call or email if check doesn’t arrive. OMG!!
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The Decision Environment

University of California San Diego, Economics Department

Decision

January 2009

				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	**21**	22	23	24
25	26	27	**28**	29	30	31

February 2009

1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

March 2009

1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

April 2009

			1	2	3	4
5	6	7	**8**	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

May 2009

					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

June 2009

	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

July 2009

			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

August 2009

						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

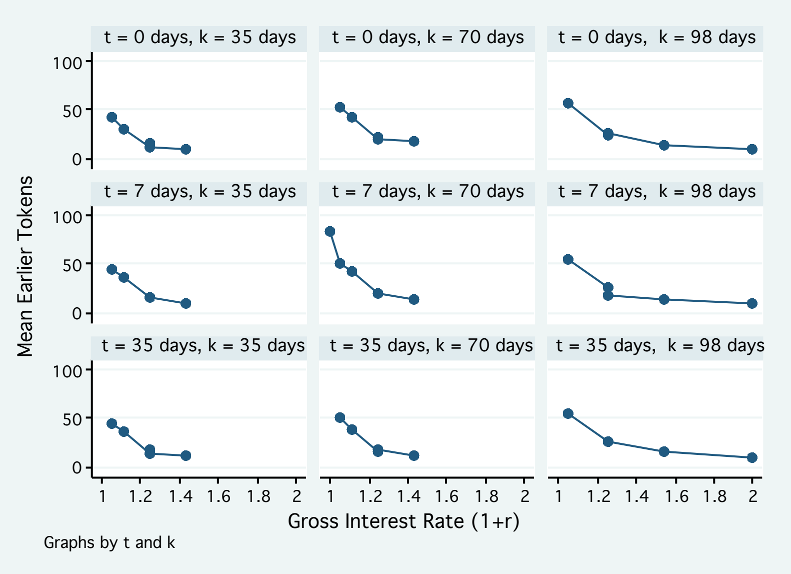
Please, be sure to complete the decisions behind each group-size tab before clicking submit.
You can make your decisions in any order, and can always revise your decisions before submitting them.

January 21, February 25 | January 21, April 1 | January 21, April 29 | January 28, March 4 | January 28, April 8 ▶

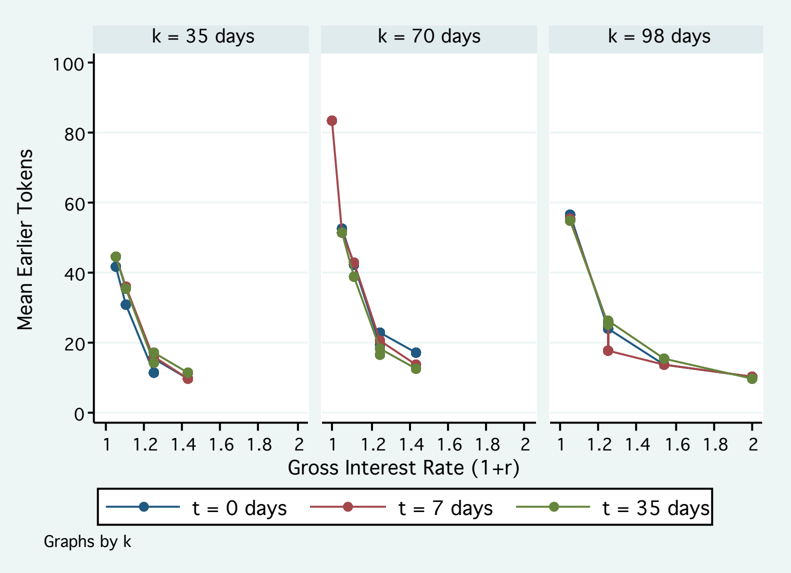
	Divide Tokens between January 28 (1 week(s) from today), and April 8 (10 week(s) later)	January 28	April 8
1	Allocate 100 tokens: 83 tokens at $0.20 on January 28, and 17 tokens at $0.20 on April 8	$16.60	$3.40
2	Allocate 100 tokens: 51 tokens at $0.19 on January 28, and 49 tokens at $0.20 on April 8	$9.69	$9.80
3	Allocate 100 tokens: 43 tokens at $0.18 on January 28, and 57 tokens at $0.20 on April 8	$7.74	$11.40
4	Allocate 100 tokens: 21 tokens at $0.16 on January 28, and 79 tokens at $0.20 on April 8	$3.36	$15.80
5	Allocate 100 tokens: 14 tokens at $0.14 on January 28, and 86 tokens at $0.20 on April 8	$1.96	$17.20

Submit Decisions <--Clicking this button will submit ALL your decisions behind every tab

Results: Aggregate Behavior



Results: Dynamic Consistency



Estimating Time Preferences

$$max_{c_t, c_{t+k}} \; U(c_t, c_{t+k})$$

subject to

$$(1 + r)c_t + c_{t+k} = m$$

Assume time-separable dynamically consistent CRRA:

$$U(c_t, c_{t+k}, \cdot) = (c_t - \omega_1)^{\alpha} + \beta\delta^k(c_{t+k} - \omega_2)^{\alpha}$$

- c_t, c_{t+k} are experimental earnings.
- ω_1, ω_2 are parameters—Stone-Geary minima or negative background consumption.

Consumer Optimization

Optimization implies $MRS = (1 + r)$
Substituting in the budget constraint, and rearrange to get Linear Demand for c_t:
If $t = 0$:

$$c_t = [\frac{1}{1 + (1+r)(\beta\delta^k(1+r))^{(\frac{1}{\alpha-1})}}]\omega_1 + [\frac{(\beta\delta^k(1+r))^{(\frac{1}{\alpha-1})}}{1 + (1+r)(\beta\delta^k(1+r))^{(\frac{1}{\alpha-1})}}](m - \omega_2)$$

If $t > 0$:

$$c_t = [\frac{1}{1 + (1+r)(\delta^k(1+r))^{(\frac{1}{\alpha-1})}}]\omega_1 + [\frac{(\delta^k(1+r))^{(\frac{1}{\alpha-1})}}{1 + (1+r)(\delta^k(1+r))^{(\frac{1}{\alpha-1})}}](m - \omega_2)$$

Time Preference Estimates

- This is non-linear in many parameters of interest.
- Easily estimate parameters of via non-linear least squares.
- Estimate annual discount rate = $(\frac{1}{\hat{\delta}})^{365} - 1$.

Estimation

	(1)	(2)	(3)	(4)
Annual Discount Rate	0.300	0.377	0.371	0.2467
	(0.064)	(0.087)	(0.091)	(0.162)
Present Bias Parameter: $\hat{\beta}$	1.004	1.006	1.007	1.026
	(0.002)	(0.006)	(0.006)	(0.008)
Curvature Parameter: $\hat{\alpha}$	0.920	0.9212	0.897	0.706
	(0.006)	(0.006)	(0.009)	(0.017)
$\hat{\omega}_1$	1.368			
	(0.275)			
$\hat{\omega}_2$	-0.085			
	(1.581)			
$\hat{\omega}_1 = \hat{\omega}_2$		1.3506	0	-7.046
		(0.278)	-	-
R-Squared	0.4911	0.4908	0.4871	0.4499
N	4365	4365	4365	4365

Individual Estimates

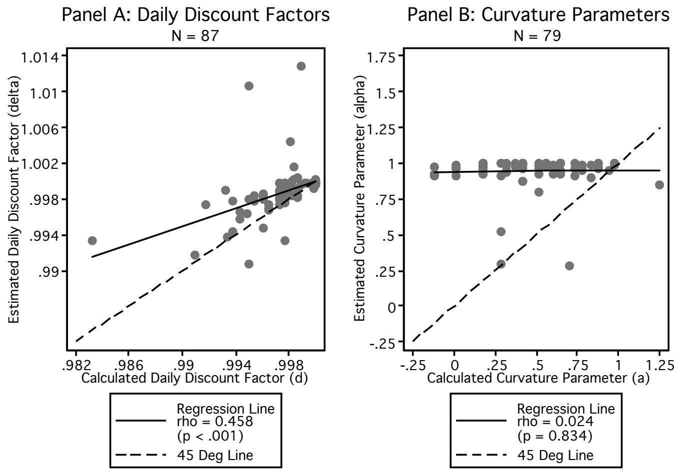
Discounting and curvature estimable for 89/97 individuals. Assuming $\omega_1 = \omega_2 = 0$

	Median	5th %ile	95th %ile	Min	Max
Annual Disc	.4076	-.0178	5.618	-0.9949	35.355
Daily Disc $\hat{\delta}$	.9991	.9948	1.0005	0.9902	1.014
Pres't Bias $\hat{\alpha}$	1.0011	0.9121	1.1075	.7681	1.3241
Curvature $\hat{\alpha}$	.9665	0.7076	0.9997	-0.1331	0.9998

Comparison with DMPL Results

- Discount rates much lower than generally obtained.
- Curvature much closer to linear utility than DMPL estimates. Andersen et al. $\hat{\alpha} \approx 0.25$
- Analysis on DMPL: 3 standard MPLs and 2 Holt-Laury risk price list tasks.
- Calculate $d =$ daily discount factor and $a =$ CRRA parameter following standard practice.
  - Median $d = 0.9976 \rightarrow$ Annual rate $\approx 137\%$. (N = 87)
  - Median $a = 0.5125$. (N = 79)

Correlation of CTB and DMPL Results



Bias Graphic

Summary of Paper 1

We estimate discounting and curvature from a single instrument, the CTB.

1. Lower discount rates than previously obtained. $\rightarrow$ curvature matters. $\hat{\delta}$ correlates with *d*. Bias correlates with $\hat{\alpha}$.
2. Less aggregate present bias than previously obtained. $\rightarrow$ transaction costs? reproducibility?
3. Find limited, though significant, utility function curvature. No correlation between $\hat{\alpha}$ and *a*. $\rightarrow$ differential stimuli? Should we be using risk experiments to identify curvature?

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What Happened?

- Did we do something *wrong*?
  - Did we bias behavior *toward* time consistency?
- Did we do something *right*?
  - Did we actually succeed in equalizing transactions cost?
  - Did we actually succeed in assuring future payments would be received?

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Risk and Time

Observations:

- The present is known, but the future is inherently uncertain
- Many violations of Expected Utility come when one option is certain and one is uncertain.
  - Allais' Paradox of common consequence, the "certainty effect".
  - Tversky and Fox's Probability Weighting
  - Rabin's Calibration Theorem, excessive risk aversion over small gambles
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What Did Allais Say?

What did Allais say about the Certainty Effect?
From *The New Palgrave, 2008:*

> *"When I read the Theory of Games in 1948, (the Independence Axiom) appeared to me to be totally incompatible with the conclusions I had reached in 1936 attempting to define a reasonable strategy ... for games with mathematical expectations.... This lead me to derive some counter-examples. One of them, formulated in 1952, has become famous as the 'Allais Paradox.' Today it is as widespread as it is misunderstood." (p. 4-5)*

What Did Allais Say?

"Limiting consideration to the mathematical expectations of the B_i involves neglecting the basic element characterizing psychology vis-a-vis risk, ...in particular when very large sums are involved....(there is a) very strong preference for security in the neighborhood of certainty."(p.6)

"To have a marked preferences for security in the neighborhood of certainty is not more irrational than preferring roast beef to chicken." (p. 7)

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Interpreting Allais

Put this in modern terms.

- “Near” certainty preferences are governed by utility $v(x)$
- “Away from” certainty preferences may be valued differently, say $u(x)$
- Let $\psi = 1$ in “the neighborhood of certainty.”
- Define $U(x;\psi)$ as utility, Then perhaps

$$v(x) = U(x;1)$$

$$u(x) = U(x;0)$$

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- So EU is discontinuous in p
- Perhaps u depends on p as well, so preferences are continuous in p, but the Independence Axiom fails.

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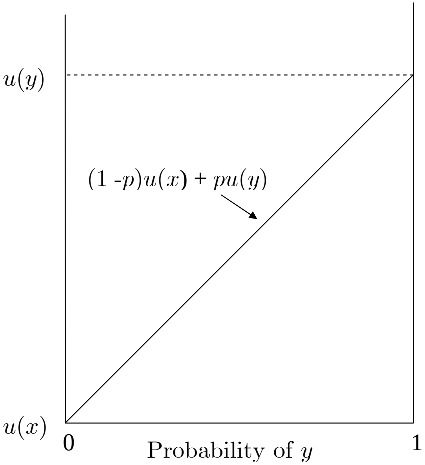
$$u(x) = U(x; 0)$$

$$v(x) > u(x)$$

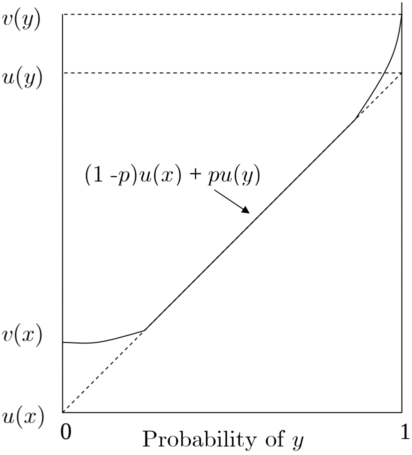
- So EU is discontinuous in p
- Perhaps u depends on p as well, so preferences are continuous in p, but the Independence Axiom fails.

Interpreting Allais



Expected Utility

Interpreting Allais



Violating the Independence Axiom in the Neighborhood of Certainty

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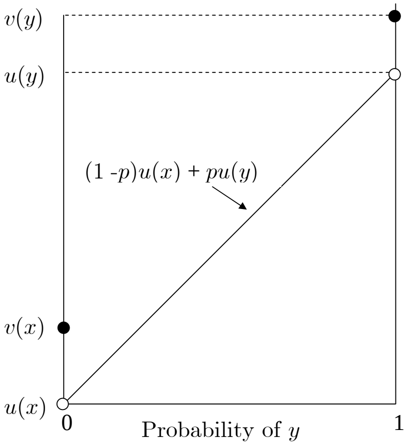

Violating the Continuity (and IA) in the Neighborhood of Certainty

What if Allais is Right?

- Could it be that the excessive preference (for money) sooner is due to Allais' certainty effect?
- Utility for x in "the neighborhood of certainty" is different than "far from certainty"?
  - Hints of this idea in the literature
  - Halevy (AER 2008), Weber and Chapman (OBHDP 2005)
- How can this hypothesis be tested?
  - We can add risk back into our problem, both in the present and the future.
  - Do we find evidence of two utility functions, $u(x)$ under risk and $v(x)$ under certainty?

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Paper 2: Risk Preferences are Not Time Preferences

Systematically add risk to intermporal choice.

Motivation: When Risk Preferences *ARE* Time Preferences

In general Discounted Expected Utility (DEU) means

$$\max p_1 u(c_t) + p_2 \delta^k u(c_{t+k}) \;\; s.t. \;\; (1+r)c_t + c_{t+k} = m$$

Optimization means

$$\frac{u'(c_t)}{\delta^k u'(c_{t+k})} = \frac{p_2}{p_1}(1+r)$$

Define

$$\theta = \frac{p_2}{p_1}(1+r)$$

Whenever θ and r are the same, choices should be the same— *even when one or both p's is 1*

Experimental Design

- Paper-and-pencil
- $t = 7, k = 28, 56$, always front end delay.
- Within subject, N = 80.
- Allocate 100 tokens worth \$0.20 in the later date, and \$0.14 to \$0.20 earlier.
- Risk Conditions: “Pr(paid sooner)-Pr(paid later)”
  - 100%-100% Always paid
  - 50%-50% each period paid 50%
  - 50%-40%
  - 40%-50%
  - 100%-80%
  - 80%-100%

Experimental Design, Cont.

Same protocol as Paper 1

- Recruit from dorms
- $10 Thank You payment, $5 sooner and $5 later
- Paid by check
- Address two envelopes to themselves
- Given Andreoni's business card
- Paid for one decision at end.
- Roll 0, 1, or 2 10-sided die.

2009 Calendar						
S	M	T	W	Th	F	S
April						
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		
May						
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						
June						
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

IN EACH ROW ALLOCATE 100 TOKENS BETWEEN

PAYMENT A (1 week from today) **AND** **PAYMENT B** (4 weeks later)

Date A: April 8, 2009	Date B: May 6, 2009
Chance A Sent: 40%	Chance B Sent: 50%

No.	A Tokens		Rate A $ per token	Date A	&	B Tokens		Rate B $ per token	Date B
1.	________	tokens at	$.20 each	on April 8	&	________	tokens at	$.20 each	on May 6
2.	________	tokens at	$.19 each	on April 8	&	________	tokens at	$.20 each	on May 6
3.	________	tokens at	$.18 each	on April 8	&	________	tokens at	$.20 each	on May 6
4.	________	tokens at	$.17 each	on April 8	&	________	tokens at	$.20 each	on May 6
5.	________	tokens at	$.16 each	on April 8	&	________	tokens at	$.20 each	on May 6
6.	________	tokens at	$.15 each	on April 8	&	________	tokens at	$.20 each	on May 6
7.	________	tokens at	$.14 each	on April 8	&	________	tokens at	$.20 each	on May 6

PLEASE MAKE SURE A + B TOKENS = 100 IN EACH ROW!

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S	M	T	W	Th	F	S
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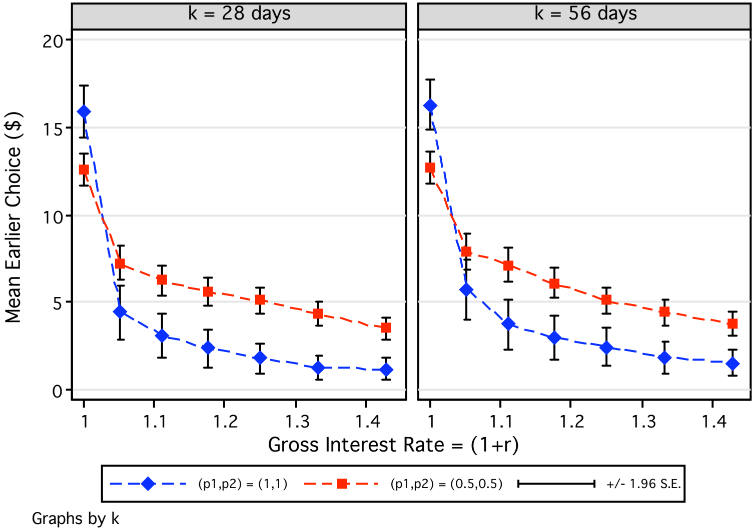
Strategy

- Compare choices with common θ to see if choices are similar
- Estimate $v(x)$ and δ from 100%-100%
- Estimate $u(x)$ and δ from 50%-50%
- Are utilities and discount factors the same?
- Use utility estimates to predict out-of-sample for remaining treatments.

Results: Certain and Uncertain Utility



Parameter Estimates

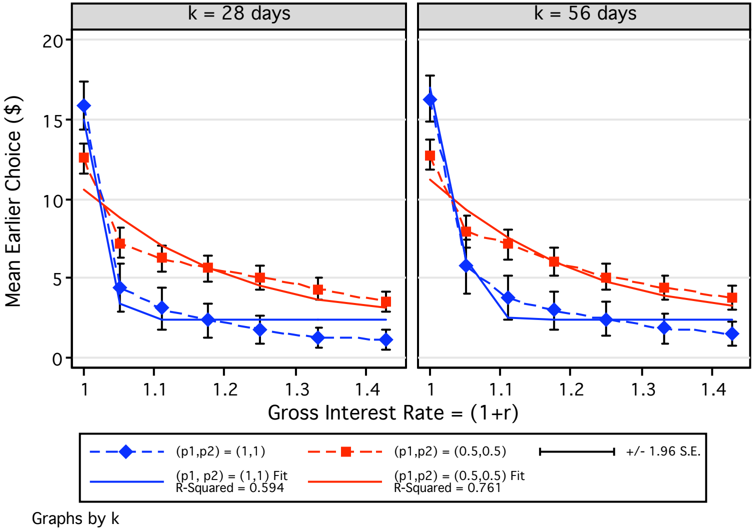
	(1)	(2)	(3)
$\hat{\alpha}$	0.982		
	(0.002)		
$\hat{\alpha}_{(1,1)}$		0.988	0.988
		(0.002)	(0.002)
$\hat{\alpha}_{(0.5,0.5)}$		0.885	0.883
		(0.017)	(0.017)
Annual Rate	0.274		0.284
	(0.035)		(0.037)
Annual $\text{Rate}_{(1,1)}$		0.282	
		(0.036)	
Annual $\text{Rate}_{(0.5,0.5)}$		0.315	
		(0.088)	
$\hat{\omega}$	3.608	2.417	2.414
	(0.339)	(0.418)	(0.418)
R^2	0.642	0.673	0.673
N	2240	2240	2240
Clusters	80	80	80

Parameter Estimates

Summary:

- Same discounting as before $\approx$ 30% per year in both cases.
- Certain α: 0.988
- Uncertain α: 0.883. Difference is significant.
- Good fit to the data.

Results: Certain and Uncertain Utility



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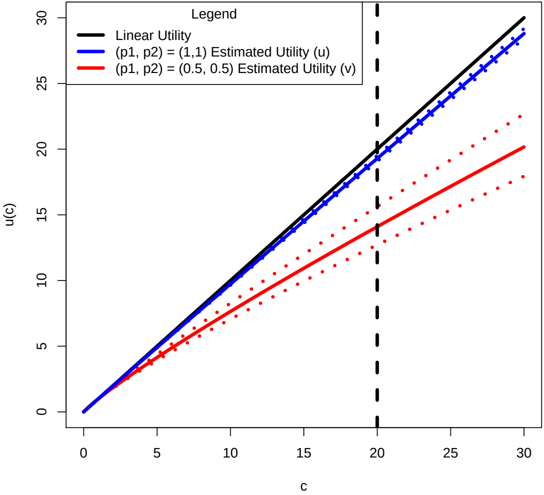
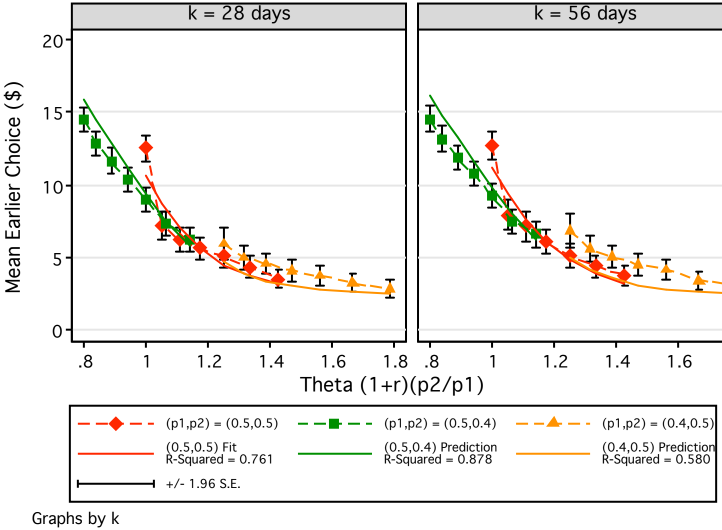
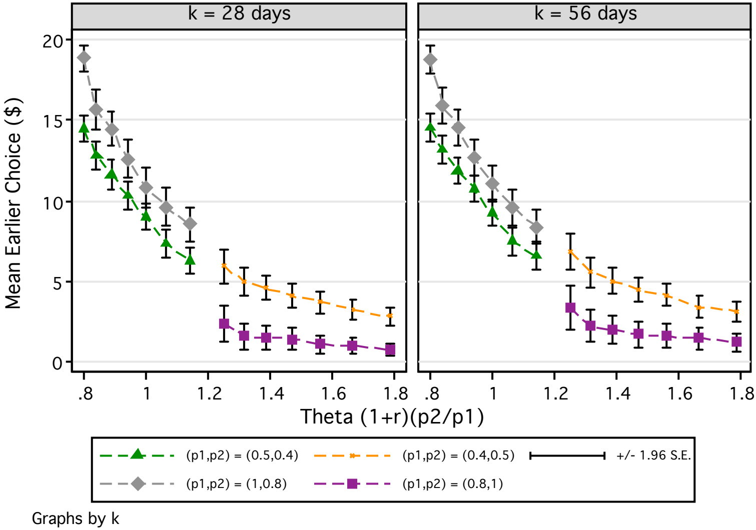


Results: All Uncertainty & OOS Prediction



Results: Hybrid Certainty and Uncertainty



Summary of Paper 2

- In "the neighborhood of certainty" people prefer security
- But "far from certainty" they behave as consistent DEU maximizers
    - When θ is the same, choice favors certainty.
- It appears as if two different utility functions govern certainty and risk

When Certainty and Uncertainty Mix

- Notice whenever certainty and uncertainty mix, if $u-v$ preferences are correct then there will be a misspecification.
- For instance, assume $U(x) = x^a$ and elicit a through a Certainty Equivalent.
- Researchers often find $a \approx 0.5$ to 0.6, while we estimate $\alpha = 0.88$
- Example: $X = 50$, $p = 0.5$.
- $CE^{0.99} = pX^{0.88} \rightarrow CE = 16.07$
- Find the a that solves $CE^a = pX^a \rightarrow a = 0.61$
- Misspecification leads to conclusion of excessive risk aversion.

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  - For $X = 50, p = 0.9; \pi(p) = 0.652 \rightarrow$ downweighting.
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Question: We know from the Allais Paradox that the Independence Axiom fails, but when does it fail, how does it fail, and for whom does it fail?

The ideal test would

- Not rely on functional form assumptions for utility or probability weights.
- Rely solely on the Independence Axioim's implication of linearity in probability
- Allow for separation between
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  2. Disappointment Aversion
  3. $u - v$ preferences

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The Uncertainty Equivalent

Experimental Environment

Consider a p-gamble which pays $\$X$ with probability p and $\$Y > \$X$ with probability $(1-p)$: $(p; X, Y)$.

- Certainty Equivalent: What value $\$C$ with certainty makes you indifferent to this p-gamble?
- Uncertainty Equivalent: What q-gamble over $\$Y$ and \$0, $(q; Y, 0)$, makes you indifferent to this p-gamble?
- q is a utility index for the p gamble.
- Linearity in probabilities: p and q must be linearly related.
- C and q have identical dynamics. More risk averse $\rightarrow$ lower C, higher q. C is problematic under $u - v$ preferences.

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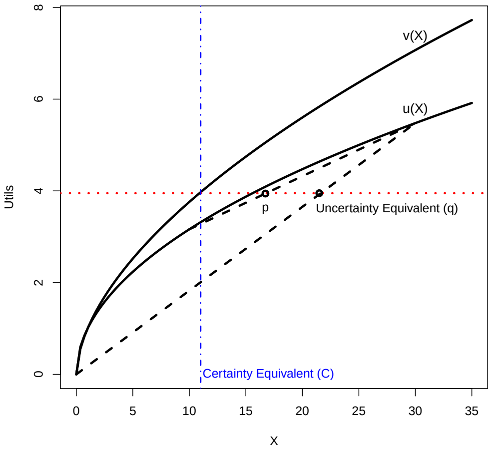
Motivation for the Uncertainty Equivalent



Empirical Predictions

- Expected Utility: Linear, negative relationship between q and p.
- $u - v$ Preferences: Linear, negative relationship between q and p until $p = 1$. At $p = 1$, q will discontinuously *increase*. Increase associated with violations of stochastic dominance a la Gneezy et al. (2006).
- Probability Weighting: Non-linear, concave negative relationship between q and p. Why?
  At p close to 1, p of $\$X$ downweighted and $1 - p$ of $\$Y$ upweighted. Need high q to compensate for upweighting of $\$Y$. When $p = 1$, upweighting disappears $\rightarrow$ q decreases precipitously.

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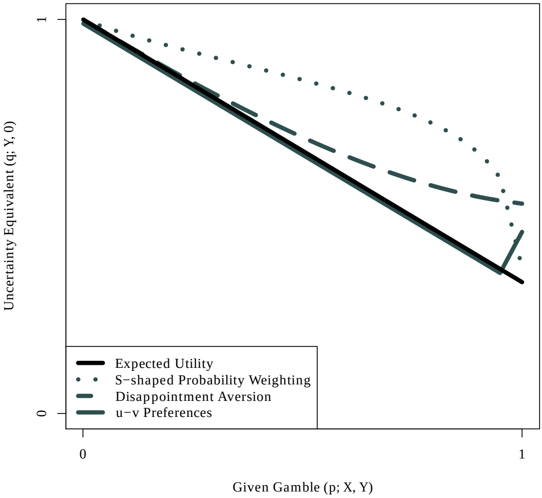
Empirical Predictions

- Disappointment Aversion:
  - Bell (1985); Loomes and Sugden (1986); Gul (1991)
  - DA is general class of reference-dependent models with expectations-based reference points.
  - A gamble's outcomes are evaluated relative to the gamble's EU certainty equivalent.
  - Recently, Koszegi and Rabin(2006, 2007) extend this notion of reference points to reference distributions.

Empirical Predictions



Design Details

- Uncertainty Equivalents
  - Three payment sets. $(X, Y) \in \{(10, 30), (30, 50), (10, 50)\}$
  - $p \in \{0.05, 0.10, 0.25, 0.50, 0.75, 0.90, 0.95, 1\}$
- Certainty Equivalents of gambles over \$0 and \$30.
  - $p \in \{0.05, 0.10, 0.25, 0.50, 0.75, 0.90, 0.95\}$
  - Probabilities chosen to reproduce Tversky & Kahneman (1992) , Tversky & Fox (1995).
- Paper-and-pencil price lists. Packets with increasing *p*.
- Two orders. UE-CE; CE-UE. No order effects.
- One task, one question chosen for payment.
- Uncertainty resolved immediately at end of experiment.

Design Details

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  - Three payment sets. $(X, Y) \in \{(10,30),(30,50),(10,50)\}$
  - $p \in \{0.05, 0.10, 0.25, 0.50, 0.75, 0.90, 0.95, 1\}$
- Certainty Equivalents of gambles over \$0 and \$30.
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Sample Task: Uncertainty Equivalents

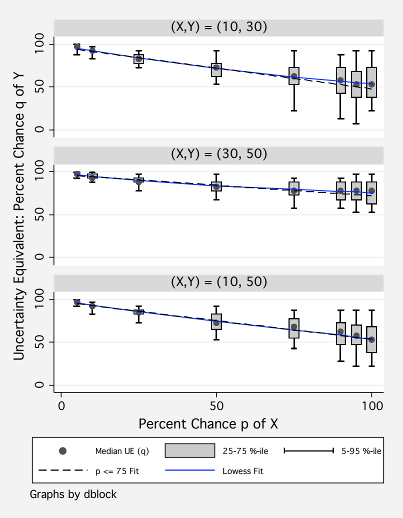
TASK 4

On this page you will make a series of decisions between two uncertain options. Option A will be a 50 in 100 chance of $10 and a 50 in 100 chance of $30. Option B will vary across decisions. Initially, Option B will be a 95 in 100 chance of $0 and a 5 in 100 chance of $30. As you proceed down the rows, Option B will change. The chance of receiving $30 will increase, while the chance of receiving $0 will decrease.

For each row, all you have to do is decide whether you prefer Option A or Option B.

	Option A			*or*	Option B		
	Chance of $10	Chance of $30			Chance of $0	Chance of $30	
	50 in 100	50 in 100	☑	*or*	100 in 100	0 in 100	☐
1)	50 in 100	50 in 100	☐	*or*	95 in 100	5 in 100	☐
2)	50 in 100	50 in 100	☐	*or*	90 in 100	10 in 100	☐
3)	50 in 100	50 in 100	☐	*or*	85 in 100	15 in 100	☐
4)	50 in 100	50 in 100	☐	*or*	80 in 100	20 in 100	☐
5)	50 in 100	50 in 100	☐	*or*	75 in 100	25 in 100	☐
6)	50 in 100	50 in 100	☐	*or*	70 in 100	30 in 100	☐
7)	50 in 100	50 in 100	☐	*or*	65 in 100	35 in 100	☐
8)	50 in 100	50 in 100	☐	*or*	60 in 100	40 in 100	☐
9)	50 in 100	50 in 100	☐	*or*	55 in 100	45 in 100	☐
10)	50 in 100	50 in 100	☐	*or*	50 in 100	50 in 100	☐
11)	50 in 100	50 in 100	☐	*or*	45 in 100	55 in 100	☐
12)	50 in 100	50 in 100	☐	*or*	40 in 100	60 in 100	☐
13)	50 in 100	50 in 100	☐	*or*	35 in 100	65 in 100	☐
14)	50 in 100	50 in 100	☐	*or*	30 in 100	70 in 100	☐
15)	50 in 100	50 in 100	☐	*or*	25 in 100	75 in 100	☐
16)	50 in 100	50 in 100	☐	*or*	20 in 100	80 in 100	☐
17)	50 in 100	50 in 100	☐	*or*	15 in 100	85 in 100	☐
18)	50 in 100	50 in 100	☐	*or*	10 in 100	90 in 100	☐
19)	50 in 100	50 in 100	☐	*or*	5 in 100	95 in 100	☐
20)	50 in 100	50 in 100	☐	*or*	1 in 100	99 in 100	☐
	50 in 100	50 in 100	☐	*or*	0 in 100	100 in 100	☑

Uncertainty Equivalents Results



Model Separation: The Relationship Between q and p

	(1) $(X, Y) = (\$10, \$30)$	(2) $(X, Y) = (\$30, \$50)$	(3) $(X, Y) = (\$10, \$50)$
Dependent Variable: Interval Response of Uncertainty Equivalent ($q \times 100$)			
$p \times 100$	-0.660***	-0.376***	-0.482***
	(0.060)	(0.035)	(0.047)
$(p \times 100)^2$	0.002***	0.002***	0.001
	(0.001)	(0.000)	(0.000)
Constant	98.122	97.866	97.439
	(0.885)	(0.435)	(0.642)
# Observations	608	608	607
# Clusters	76	76	76

Level of significance: $^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Violations of Stochastic Dominance

84 opportunities to violate stochastic dominance → obtain individual level violation rates.

Violation Rates:

- (63) Away from certainty: 0.043 ($s.d. = 0.064$)
- (21) Involving certainty: 0.097 (0.158), ($t = 3.88,\ p < 0.001$)
- (3) Comparing $p = 1$ to $p' = 0.95$: 0.175 (0.258), ($t = 3.95,\ p < 0.001$)
- 38 percent of subject demonstrate at least one violation between $p = 1$ and $p' = 0.95$, → *Violators*.

Following $u - v$ preferences, violations of stochastic dominance are prevalent and localized close to certainty. Focus attention on violators and non-violators.

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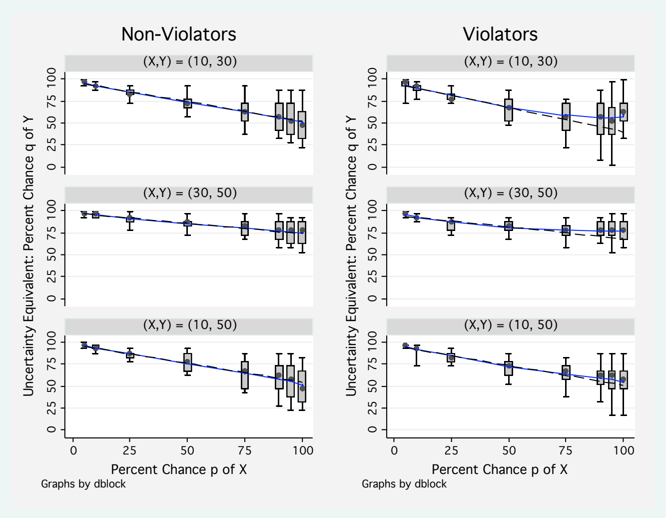

Experimental Risk Aversion and Probability Weighting

Generally, in certainty equivalents we see....

- Small-stakes Risk Aversion: Use some intermediate probability ($p \sim 0.5 - 0.75$). Any risk aversion over small stakes violates expected utility (Rabin 2000).
- Probability Weighting: Use spectrum of probabilities. For fixed stakes, probability weighting $\rightarrow$ risk loving at low probabilities, risk averse at higher probabilities.

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Risk Averse, Loving, Neutral

*All Subjects** *(N=70)*			
p	Proportion Risk Averse	Proportion Risk Neutral	Proportion Risk Loving
0.05	0.13	0.30	0.57
0.10	0.10	0.27	0.63
0.25	0.24	0.36	0.40
0.50	0.43	0.29	0.29
0.75	0.53	0.24	0.23
0.90	0.50	0.24	0.26
0.95	0.29	0.53	0.18

*Six potentially confused, extremely risk-loving (every task) subjects not reported with average risk premia of -109% of gamble's expected value.

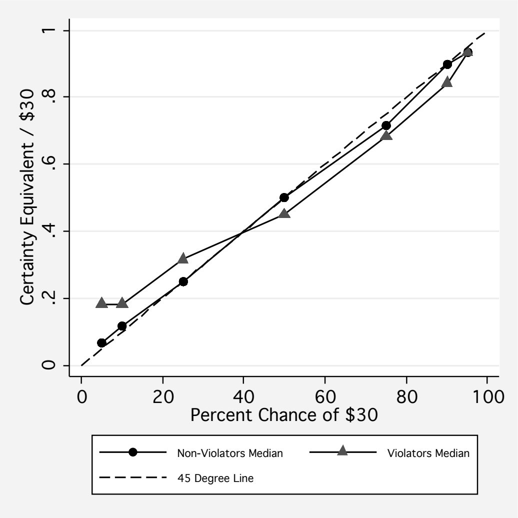
Risk Averse, Loving, Neutral

Panel B: Violators (N=26)			
p	Proportion Risk Averse	Proportion Risk Neutral	Proportion Risk Loving
0.05	0.08	0.23	0.69
0.10	0.04	0.12	0.85
0.25	0.19	0.27	0.54
0.50	0.50	0.12	0.38
0.75	0.58	0.08	0.35
0.90	0.54	0.19	0.27
0.95	0.36	0.36	0.28
Panel C: Non-Violators (N=44)			
0.05	0.16	0.35	0.49
0.10	0.14	0.36	0.50
0.25	0.27	0.41	0.32
0.50	0.39	0.39	0.23
0.75	0.50	0.34	0.16
0.90	0.48	0.27	0.25
0.95	0.26	0.63	0.12

Violators Drive Phenomena

	(1) All p	(2) $p \leq 0.25$	(3) $p > 0.25$
Multinomial Logit: Risk Averse, Neutral or Loving Classification			
Risk Loving			
Violator (=1)	1.248***	1.090**	1.336***
	(0.373)	(0.449)	(0.473)
$p \times 100$	-0.016***	-0.033**	-0.018*
	(0.004)	(0.015)	(0.009)
Constant	0.386	0.572	0.637
	(0.303)	(0.368)	(0.782)
Risk Averse			
Violator (=1)	0.716*	-0.044	1.001**
	(0.392)	(0.654)	(0.445)
$p \times 100$	0.010**	0.029	-0.014*
	(0.004)	(0.021)	(0.008)
Constant	-0.768**	-1.108**	1.081*
	(0.365)	(0.553)	(0.655)
# Observations	487	209	278
# Clusters	70	70	70

Median Certainty Equivalents Data



Probability Weighting Estimates

Standard Procedure:

$$u(C) = \pi(p)u(30)$$

Assume

- $u(X) = X^{\alpha}$
- $\pi(p) = p^{\gamma}/(p^{\gamma} + (1-p)^{\gamma})^{1/\gamma}$

Estimate:

$$C = [p^{\gamma}/(p^{\gamma} + (1-p)^{\gamma})^{1/\gamma} \times 30^{\alpha}]^{1/\alpha} + \epsilon$$

Median Data:

- $\hat{\alpha}_V = 1.101\ (0.049)\ ;\ \hat{\gamma}_V = 0.743\ (0.033)$
- $\hat{\alpha}_N = 0.987\ (0.049)\ ;\ \hat{\gamma}_N = 0.929\ (0.057)$
- $H_0:\ \gamma_V = \gamma_N\ ;\ F_{1,10} = 8.04,\ p < 0.05.$

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Summary

- Independence performs well away from certainty, but breaks down at $p = 1$.
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- 38 percent of subjects violate stochastic dominance.
- These violators drive the failures of the Independence Axiom
  - Rejects strict forms of Disappointment Aversion, since these preclude dominance violations. Supports $u - v$.
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