Discounting versus risk aversion:
the effects of time and risk preferences on individual demands for climate change mitigation

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- Expertise: Perl code to run the online climate survey
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Time- and risk-preferences:

- …are KEY considerations in benefit-cost analysis of public policies with large near-term costs and uncertain future benefits (e.g. climate change mitigation policies)
- Typically not directly measurable as individual-specific characteristics
- More typically, preferences for climate change mitigation may be allowed to vary with individual characteristics such as age and gender in a “reduced form”-type specification.
  - E.g. If older people are less willing to pay for mitigation, we might speculate that this is because they probably have bigger discount rates
  - E.g. If women are more willing to pay than men with the same incomes, we might speculate that they may be more risk-averse

Normative policy need…

- What choices would people make about climate change mitigation of they could be induced to act in society's best interests, not just their own?
  - Over-ride individual private discount rates with alternative "social discount rate" of, say, 2% (e.g. Weitzman, 2002 *American Economic Review*)
  - Deny anything beyond risk-neutrality to any risk-loving segment of the population
- Can't do this easily in the usual reduced-form specification where time- and risk-preferences are merely implicit in sociodemographics

Strategy

- Utilize auxiliary choices—beyond the main climate policy choice—to identify distinct individual-specific estimates for:
  - time preference parameter, $\hat{r}_i$
  - risk preference parameter, $\hat{\lambda}_i$
- Use heterogeneity in estimated time- and risk-preferences explicitly, to explain differences in support for climate-change mitigation programs

Available climate policy survey

- 114 instructors at 92 colleges and universities throughout the US and Canada; ~2000 respondents (online convenience sample)
- Key SP choices:
  - discounting and risk aversion
    - You have won a lottery…how would you take your winnings (lump sum now, or payments over time)?
    - You have inherited a sum of money…would you make a secure investment, a risky investment, or neither?
  - climate policy preferences
    - You are asked to vote on implementing a costly climate change mitigation policy (complete mitigation, [partial mitigation], or business-as-usual)?

PROGRESS METER

Climate Policy Survey

Trade-offs involving money over time

Imagine that you have won a lottery.

FAQ

The lottery commission gives you two ways of taking your winnings:

1. **$2,400 each year** for **20 years** (for a total of **$48,000**), with the first payment today, OR
2. A smaller **lump sum** payment today (which you could put into a savings account or invest, or just use it to pay for something you really want or need right now).

For *each* row in the table below, please click *one answer button.*

If your lump sum payment would be:	Would you prefer this lump sum payment, rather than the annual installments?		
	yes	not sure	no
$44,000	○	○	○
$34,000	○	○	○
$27,000	○	○	○
$22,000	○	○	○
$14,000	○	○	○

- One design randomization of the "lottery winnings" choice – emphasizes discount rates
- Utility modeled as Box-Cox in net income

Climate Policy Survey

PROGRESS METER

FAQ

Investments with an element of risk

For **each** of the "Investment Decisions" summarized in the table below, please assume you have just inherited a small amount of money (labeled as "Amount invested this year" in the first two rows of the decision profile). You can use it to make

- a risky investment,
- a "no-risk" investment, or
- neither of these investments (invest elsewhere or just spend the money now).

For **each** of the "Investment Decisions" below, please pick your most-preferred option by clicking on one of the three buttons at the right.

Amount invested this year	Time to payoff	Pay-off amount in constant $ (today's purchasing power)	Most-preferred?
Investment Decision #1			
$300	30 yrs	$2,600 with certainty	
$300	30 yrs	50% chance of $1,900 and 50% chance of $4,100	
$0		Do not make either of these investments	
Investment Decision #2			
$1,200	10 yrs	$2,500 with certainty	
$1,200	10 yrs	50% chance of $2,100 and 50% chance of $4,100	
$0		Do not make either of these investments	

One randomization of the "risky investment" choice – invokes both risk aversion and discount rates

Strategy

- Step 1: use "lottery winnings" and "risky investment" choices in a *joint model* to produce individual-specific estimates of exponential discount rates and risk aversion parameters (utility-theoretic choice model; discounted expected utility)
- Step 2: use "climate policy" choices to explore direct influence of individual time- and risk-preferences on demand
- Step 3: examine consequences of over-riding individual time- and risk-preferences with counterfactual alternatives
  - Risk neutrality (or maybe, no risk-loving preferences)
  - Lower social discount rate (e.g. 2% for all…Weitzman)

Lottery winnings choice submodel

- Indirect utility-difference
  - Risk aversion parameter (curvature--utility as a function of discounted net income; Box-Cox, blue terms, $\hat{\lambda}_i = \hat{\lambda}' W_i$)
  - Discount rate (exponential, red term, $\hat{r}_i = \hat{r}' Z_i$)
  - Marginal utility of net income (just a scaling parameter)

$$\Delta V_i = E\left[V_i^1 - V_i^0\right] = \beta_0 \left\{ \left[\frac{(y_i + L_i)^{\lambda' W_i} - 1}{\lambda' W_i} \right] - \left[\frac{\left(y_i + x_i \sum_{t=0}^{T_i - 1} \frac{1}{(1 + r' Z_i)^t} \right)^{\lambda' W_i} - 1}{\lambda' W_i} \right] \right\} + \varepsilon_i^w$$

  - NB: In estimation, actually use $\hat{r}_i = \exp(\hat{r}' Z_i)$

Risky investment choice submodel

- Indirect utilities, three alternatives

1. Invest with certain payment in T_i years

$$V_i^1 = \beta_0 \left\{ \frac{\left(y_i + \frac{CP_i}{(1+r'Z_i)^{T_i}} \right)^{\lambda' W_i} - 1}{\lambda' W_i} \right\} + \eta_i^r$$

2. Invest with risky payment (low, high) in T_i yrs

$$V_i^2 = 0.5\beta_0 \left\{ \frac{\left(y_i + \frac{RPL_i}{(1+r'Z_i)^{T_i}} \right)^{\lambda' W_i} - 1}{\lambda' W_i} \right\} + 0.5\beta_0 \left\{ \frac{\left(y_i + \frac{RPH_i}{(1+r'Z_i)^{T_i}} \right)^{\lambda' W_i} - 1}{\lambda' W_i} \right\} + \eta_i^r$$

3. Just keep the inheritance as current income

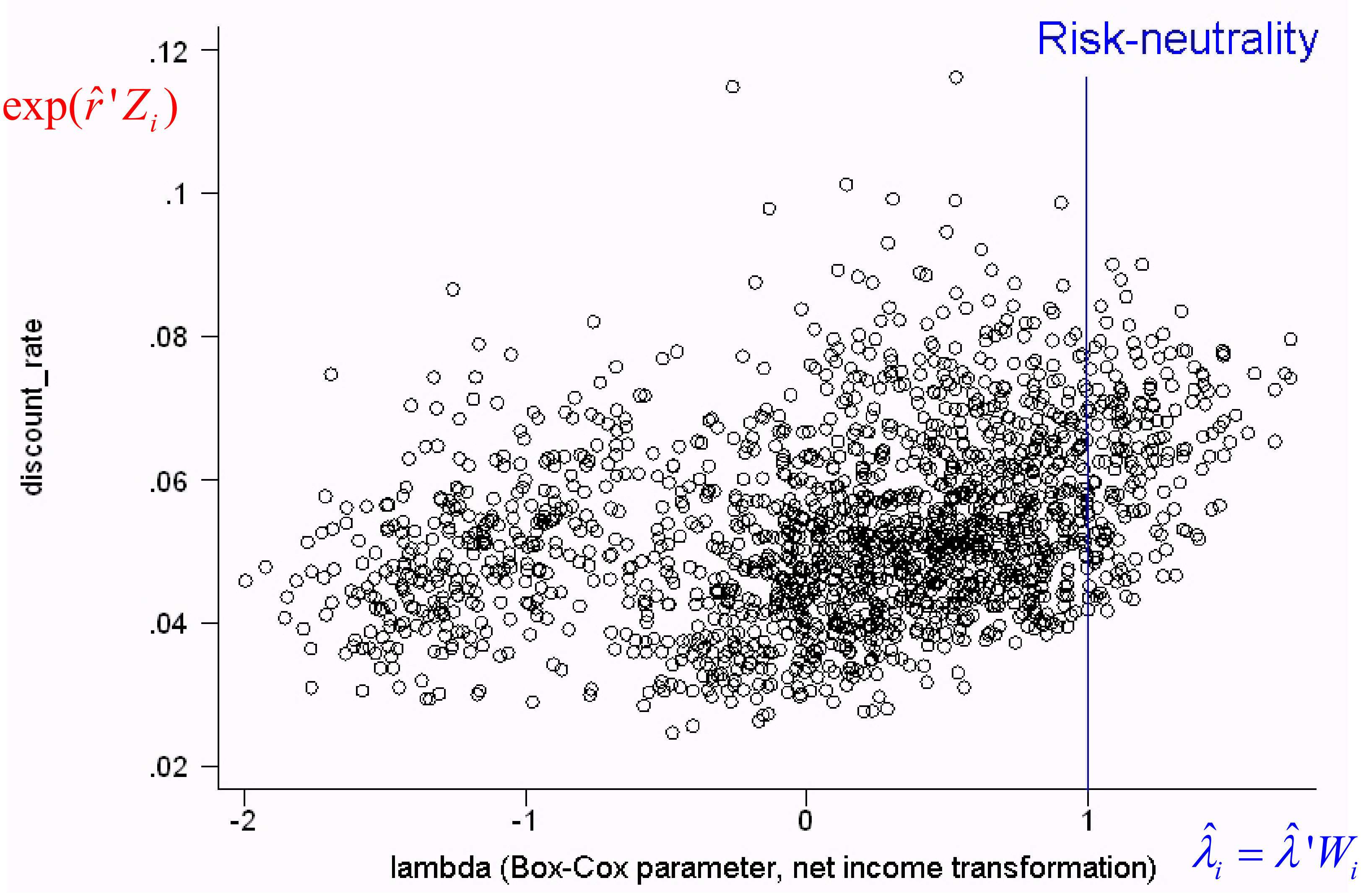
$$V_i^3 = \beta_0 \left\{ \frac{(y_i + IN_i)^{\lambda' W_i} - 1}{\lambda' W_i} \right\} + \eta_i^r$$

- Normalize on V^3 (status quo with inheritance)
- Estimate (independent) "lottery winnings" and "risky investment" choices jointly, via MLE
  - Constrain systematically varying risk and discount parameters to be identical across the places they occur; save fitted indiv. values
  - Allow different error dispersions (scales)
  - Design variations→incidental parameters

Joint discount/risk submodel: sketch of results

- Both the risk parameter and discount rate depend systematically on
  - Age brackets, gender, political ideology, income brackets, years of college, college major
- Risk preferences also depend on
  - Actual lottery-playing habits
- Discount rate also depends on
  - Subjective life expectancy indicators
- Model also involves 14 incidental parameters
- Model produces *individual* point estimates of risk aversion parameter and discount rate parameter

Heterogeneity: time and risk preferences



$\hat{r}_i = \exp(\hat{r}' Z_i)$

$\hat{\lambda}_i = \hat{\lambda}' W_i$

Climate Policy Choice

5 subjective avoided impacts

Costs

Cost Distribution
(little effect in student sample)

	POLICY: **Maximum Prevention** To *completely* prevent your anticipated changes	POLICY: **Business-as-Usual** Just leave the effects at the level you anticipate
Consequences for:	-4 -3 -2 -1 0 +1 +2 +3 +4	-4 -3 -2 -1 0 +1 +2 +3 +4
Oceans, Weather ?	☑ 0	☑ -1
Human health ?	☑ 0	☑ -2
Ecosystems ?	☑ 0	☑ -3, ☑ -1
Agriculture, Water ?	☑ 0	☑ -2, ☑ 0
Equity, Fairness ?	☑ 0	☑ -1
Household cost/month:	**about $ 500/mo ($ 250 to $ 750)**	**about $ 0/mo ($ 0 to $ 0)**
How these higher household costs will be experienced:	20% via ↑energy taxes 10% via ↑income taxes 60% via ↑prices 10% via ↓invest. returns	
How global costs will be shared across countries:	25% US and Japan 10% other industrialized 15% India and China 50% other developing	
I would vote for:	**Maximum Prevention** ○	**Business-as-Usual** ○
	○ **I would not vote**	

Properties of data: online sample

- Some heterogeneous perceived impacts:
  - Ecosystems, equity
    - Strategy: Use individual controls
- Some collinear perceived impacts:
  - Ecosystems, agriculture/water
    - Strategy: Subsume under "ecosystems"
- Some uniformly large perceived impacts:
  - Human health, oceans/weather
    - Strategy: Capture via alternative-specific constant

Several controls for "mischief"

- Control for, then net out, effects associated with respondent:
  - Being unusually <u>un</u>informed, or well-informed, about "environmental issues" (set to neutral)
  - Getting answers wrong on the quiz about climate facts (set to zero errors)
  - Perceiving researcher bias either for, or against, the climate policies in question (set to neutral)
  - Being part of the experimental treatment group that was offered a compromise "partial mitigation" policy (set to "business-as-usual vs. complete mitigation")
  - Claiming, ex ante, to give climate problems either a very low or a very high priority (set to neutral)

For "middle-of-the-road" respondent

profiles of benefits and costs not rich enough for full utility-theoretic specification

	Model 1	Model 5 risk and disc.
net income (= -cost)	.144 (4.15)***	.145 (4.11)***
…* fitted risk parameter $\hat{\lambda}_i = \hat{\lambda}' W_i$	-	.0483 (2.17)**
ecosystem impacts	.161 (3.42)***	.161 (3.39)***
equity impacts	.213 (3.23)***	.207 (3.11)***
1(complete mitigation)	-.308 (1.01)	.602 (1.54)
…* fitted discount rate $\hat{r}_i = \hat{r}' Z_i$	-	-16.5 (3.70)***
Total alternatives	3982	3982
Log L	-1238.727	-1226.028

WTP for complete mitigation?

- Numerator: depends on anticipated…
  - avoided ecosystem impacts
  - avoided equity impacts
  - avoided “other” impacts (alt-specific const.)
    - Influenced signif. by individual discount rate
    - Larger discount rate? lower WTP
- Denominator: given by
  - Marginal utility of income
    - Influenced signif. by individual risk preferences
    - Less risk-averse (larger “risk” parameter)? Higher MU(Y), lower WTP

WTP under specific conditions

Specific conditions:	B	C	D
fitted risk parameter	0.152	1	1
ecosystem impacts	2.021	2.021	2.021
equity impacts	1.167	1.167	1.167
1(complete mitigation)	1	1	1
…* fitted discount rate	0.053	0.05	0.02
Percentiles of fitted WTP distribution (dollars per month for complete mitigation of climate change); across 1000 random draws from parameter joint distribution			
5^{th}	200	176	336
25^{th}	274	238	424
50^{th}	**$ 329**	**$ 284**	**$ 501**
75^{th}	386	330	584
95^{th}	485	406	730

- B = sample mean conditions
- C = risk neutral, 5% discount rate
- D = risk neutral, 2% discount rate

WTP for different eco/equ impacts

Specific conditions:	E	G	I
fitted risk parameter	1	1	1
ecosystem impacts	4	2	0
equity impacts	4	2	0
1(complete mitigation)	1	1	1
…* fitted discount rate	0.02	0.02	0.02
Percentiles of fitted WTP distribution (dollars per month for complete mitigation of climate change); across 1000 random draws from parameter joint distribution			
5th	623	394	79
25th	770	494	183
50th	**$ 890**	**$ 571**	**$ 250**
75th	1047	670	324
95th	1338	829	431

- E = expect severe ecosystem/equity impacts & average "other" impacts
- G = expect moderate ecosystem/equity impacts & average "other" impacts
- I = expect NO ecosystem/equity impacts (just average "other" impacts)

WTP for eco/equ, no "other" impacts

Specific conditions:	J	K
fitted risk parameter	1	1
ecosystem impacts	2.021	0
equity impacts	0	1.167
1(complete mitigation)	0	0
…* fitted discount rate	0	0
Percentiles of fitted WTP distribution (dollars per month for complete mitigation of climate change); across 1000 random draws from parameter joint distribution		
5th	71	47
25th	109	82
50th	**$ 141**	**$ 107**
75th	178	135
95th	246	184

- J = just average ecosystem impacts (includes agric/water), no other impacts
- K = just average equity impacts, no other impacts

Interim Conclusions

- More usual: climate policy preferences depend directly on sociodemographic characteristics (which proxy implicitly for time and risk preferences)
- Problem: makes it difficult to simulate interesting cases of risk neutrality and/or “social” discount rates that differ from private rates
- Have demonstrated feasibility of directly estimating individual-specific time and risk preferences; using these as the main source of heterogeneity in climate policy preferences
- WTP estimates may seem somewhat large (i.e. ~$329), but they are roughly consistent with
  - Viscusi & Zeckhauser (2006) estimates ($375/mo median for student sample) and
  - Lee & Cameron (2006) estimates ($125 - $335/mo for separate general population mail-survey sample)

Extensions/Alternative Specifications

Alternative net Y, risky choices

- Utility in different periods

		Discounted expected utility in future periods		
		Period 0	Periods 1 through T-1	Period T
1	Certain investment pays CP_i in period T_i	$\beta Y_{i0}^{(\lambda)}$	$\sum_{t=1}^{T_i-1} \delta^t \beta Y_{it}^{(\lambda)}$	$\delta^{T_i} \beta \left[Y_{iT_i} + CP_i \right]^{(\lambda)}$
2	Risky investment pays either RPL_i or RPH_i in period T_i with 50-50 chance	$\beta Y_{i0}^{(\lambda)}$	$\sum_{t=1}^{T_i-1} \delta^t \beta Y_{it}^{(\lambda)}$	$\delta^{T_i} \begin{Bmatrix} 0.5\beta \left[Y_{iT_i} + RPL_i \right]^{(\lambda)} \\ +0.5\beta \left[Y_{iT_i} + RPH_i \right]^{(\lambda)} \end{Bmatrix}$
3(a)	Lump sum now, consume in current period	$\beta \left(Y_{i0} + IN_i \right)^{(\lambda)}$	$\sum_{t=1}^{T_i-1} \delta^t \beta Y_{it}^{(\lambda)}$	$\delta^{T_i} \beta Y_{iT_i}^{(\lambda)}$
3(b)	Lump sum now, invest at market risk-free rate r^* in period 0 to produce annuity $A_{r^*}^{T_i}$ over T_i future periods	$\beta \left[Y_{i0} \right]^{(\lambda)}$	$\sum_{t=1}^{T_i-1} \delta^t \beta \left[Y_{iT_i} + A_{r^*}^{T_i} \right]^{(\lambda)}$	$\delta^{T_i} \beta \left[Y_{iT_i} + A_{r^*}^{T_i} \right]^{(\lambda)}$

Alternative assumptions

Alternative feasible assumptions about "lump sum now":

- Consumed entirely in current period, versus conversion into:
  1. alternative investment, yields a single lump-sum payout at T_i
  2. alternative investment, yields a constant annuity for T_i future periods

- Prevailing expected interest rate on alternative investments, r^*:
  a. set to an arbitrary popularly assumed rate (e.g. 3%, 5% or 7%)
  b. set to average U.S. Treasury rate during month of survey-taking
  c. set to Treasury rate on most recent business day prior to survey-taking

More alternative assumptions:

Alternative feasible assumptions about future income:

- Current “household” income may be parental, rather than own household
- For 10-40 year horizon, interpolate and extrapolate subjective predicted income (creates a loop over time for PDV calculations for each individual)