A Behavioral Analysis of Stochastic Reference Dependence

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Motivation

Expected utility (EU) theory

- Extremely tractable
- Individuals care only about final outcomes
- Inconsistent with behavior and psychological intuitions
  - Allais's Paradox
  - Rabin's Critics
  - ....

Motivation

- Evidence suggests
  - Reference point matters
  - Losses loom larger than gains (loss aversion)

Motivation

- Prospect Theory (Kahneman and Tversky, 1979)
  - Preferences over gains and losses
  - Loss aversion
  - Accommodates observed behavior
  - Drawback: Unclear what is reference point

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- Kőszegi-Rabin (2007), endogenize reference point
  - Expectation is the reference point
  - "Workhorse" model in behavioral economics

Heidhues and Kőszegi (2008, 2012), Herweg, Muller and Weinschenk (2010), Sydnor (2010), Abeler, Falk, Goette and Huffman (2011), Crawford and Meng (2011), Karle and Peitz (2012), Pope and Schweitzer (2011), Eliaz and Spiegler (2012)

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- What to like about the model?
  - No probability distortion of objective probabilities
  - Koszegi and Rabin (2007) note

We assume that a person correctly predicts her probabilistic environment and her own behavior in that environment, so that her beliefs fully reflect the true probability distribution of outcomes.

- Many other non-EU models distort probabilities

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- What *not* to like about the model?
  - Kőszegi-Rabin (2007) difficult to understand
    - Not clear what behavior it allows or prohibits
    - Difficult to test against alternative hypotheses of behavior

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Motivation

- Other models of reference dependence: Bell-Loomes-Sugden (1985, 1986) and Gul (1991)
    - Similar psychological motivation
    - Similar functional forms
    - Different reference points
- Not clear whether they generate similar behavior

Our Contribution

- Understand behavioral implications of Kőszegi-Rabin
  - Focus on choice-acclimating personal equilibria ($\mathbb{CPE}$)
  - Relate $\mathbb{CPE}$ to other non-EU models
- Demonstrate benefits
  - Link choice behavior to $\mathbb{CPE}$'s parameters
  - Extend the range of applications
  - Test model using experimental evidence

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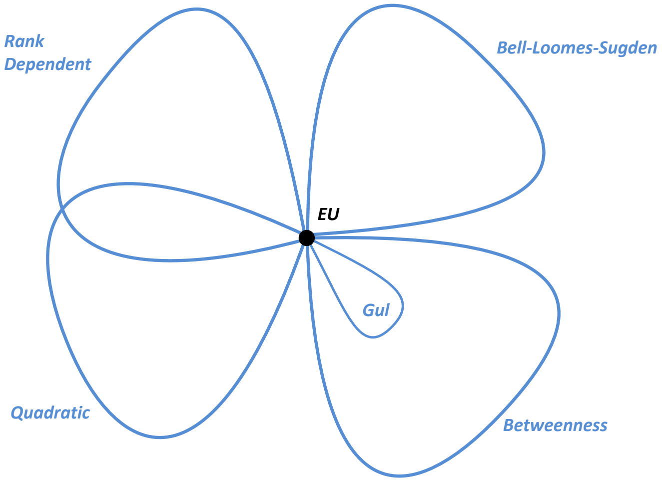
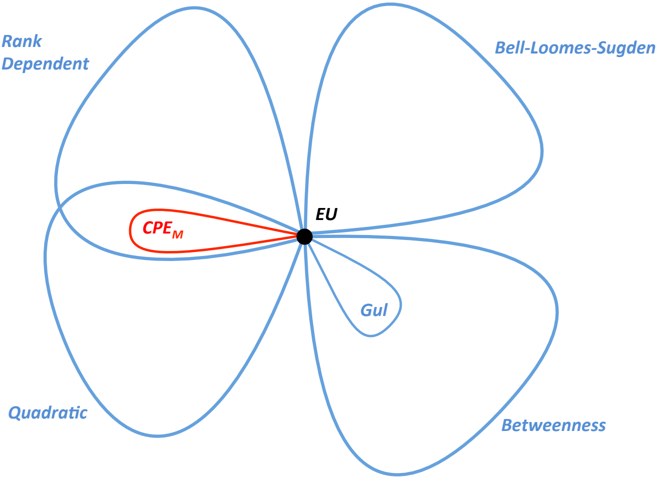
The Space of Models



Our Results


Rank
Dependent
Bell-Loomes-Sugden
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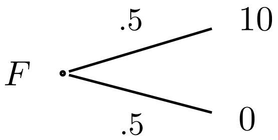
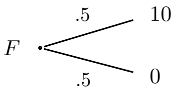
A Simple Lottery

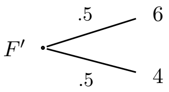
- Lottery F gives
  - 10 with probability .5
  - 0 with probability .5



Kőszegi and Rabin (2007)

- Two lotteries
  - Consumption lottery: F
  - Reference lottery: F'





Kőszegi and Rabin (2007)

- Two sources of utility
  - Consumption utility: $\sum_x u(x)F(x)$
  - Gain-loss utility: compares F to F'

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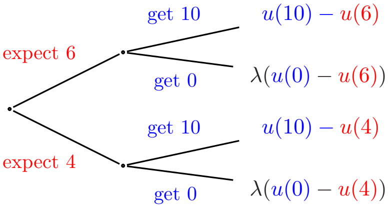


Kőszegi and Rabin (2007)

- Value of F given reference F'

$$U(F|F') = \underbrace{\sum_x u(x)F(x)}_{\text{consumption utility}} + \underbrace{\sum_x \sum_y g(u(x) - u(y))F(x)F'(y)}_{\text{gain-loss utility}}$$

- u is over final wealth
- Assume g is linear:

$$g(z) = \begin{cases} z & \text{if } z \geq 0 \\ \lambda z & \text{if } z < 0 \end{cases}$$

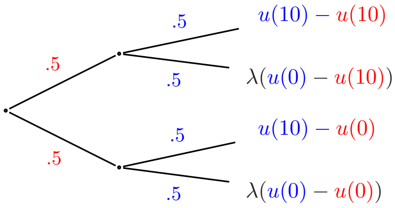
- $\lambda \geq 1$ measures loss aversion

Kőszegi and Rabin (2007)

- Focus on choice-acclimating equilibria: $\mathbb{CPE}$
  - F' is expectations
  - Enough time to "acclimate" to plans
  - Expectations are consistent with choice: $F = F'$
- Choose F over G iff $U(F|F) \geq U(G|G)$
- Choice made well in advance of resolution of uncertainty
  - At time of resolution, reference point is choice
- No intransitivities (unlike $\mathbb{PPE}$)

Kőszegi and Rabin (2007)

- $V_{\mathbb{CPE}}(F) = U(F|F)$



- $U(F|F) = \frac{1}{2}(2 - \lambda)u(10)$ if $u(0) = 0$

Kőszegi and Rabin (2007)

- If λ is large enough then $U(F|F) < 0$

Proposition

Assume $\succsim$ is in $\mathbb{CPE}$. Then $\succsim$ respects first order stochastic dominance if and only if $1 \leq \lambda \leq 2$.

- Denote $\mathbb{CPE}_M$ if $1 \leq \lambda \leq 2$

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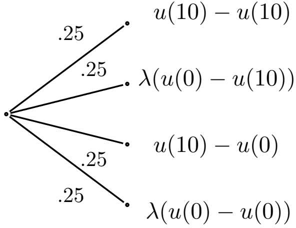
Quadratic Utility (Chew, Epstein and Segal, 1991)

- Let focus on gain-loss utility



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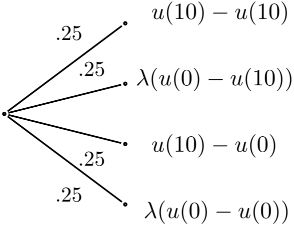

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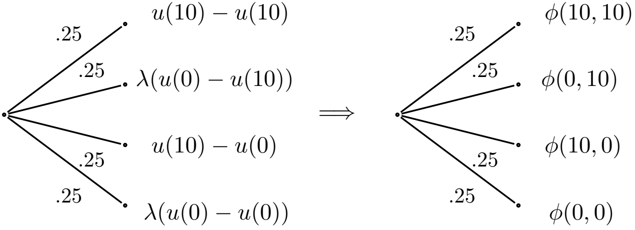

- ϕ captures a comparison between x and y

$$V_{\mathbb{Q}}(F) = \sum_x \sum_y \phi(x, y)\ F(x)F(y)$$

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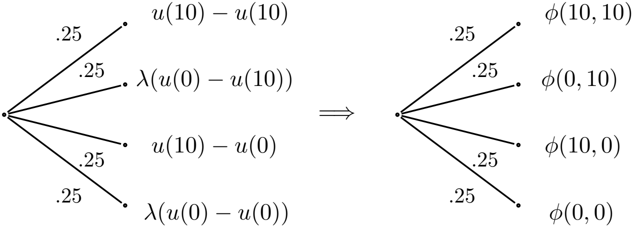

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Quadratic Utility

Proposition

$\mathbb{CPE}_M$ is a proper subset of $\mathbb{Q}$.

Proof: $V_{\mathbb{CPE}}(F)$

$$= \sum_x u(x)F(x) + \sum_x \sum_y g(u(x) - u(y))F(x)F(y)$$

$$= \sum_x \sum_y \underbrace{\left(\frac{u(x) + u(y)}{2} + \frac{(1-\lambda)|u(x) - u(y)|}{2} \right)}_{\phi(x,y)} F(x)F(y)$$

$\square$

Rank Dependent Utility (Quiggin, 1982)

- Distortion objective probabilities to weights ($\pi(x)$),
- Value of lottery: $\sum_x u(x)\pi(x)$,
- FOSD is satisfied,
- $\pi(x)$ depends only on $F(x)$ and rank of x,

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Rank Dependent Utility (Quiggin, 1982)

Then $\exists$ strictly increasing w ($w(0) = 0$, $w(1) = 1$) such that

$$V_{\mathbb{RDU}}(F) = \sum_x u(x) \underbrace{\left[w\left(\sum_{y \geq x} F(y) \right) - w\left(\sum_{y > x} F(y) \right) \right]}_{\pi(x)}$$

- π is determined by marginal contribution to weighted cdf

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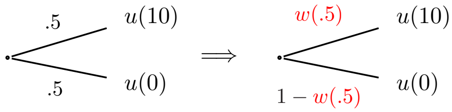

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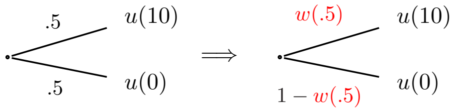

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$\mathbb{CPE}_M$ is a proper subset of $\mathbb{RDU}$.

- Let $\succsim$ be in $\mathbb{CPE}_M$.
- $\succsim$ has two representations:
  - (u, λ) and (u', w)
- How these two representations related?

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Rank Dependent Utility

- How (u, λ) and (u', w) related?
  - $u = u'$
  - $w(z) = (2 - \lambda)z + (\lambda - 1)z^2$

Proposition

For any preference $\succsim$ in $\mathbb{CPE}_M$ with a representation (u, λ), there exists a function w_λ such that (u, w_λ) is a RDU representation of $\succsim$. Moreover, w_λ is a convex function for $1 \leq \lambda \leq 2$,

$$w_\lambda(z) = (2 - \lambda)z + (\lambda - 1)z^2$$

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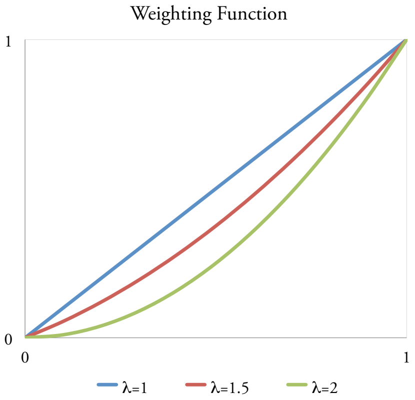

Loss Aversion or Pessimism?

- Choice behavior can not distinguish between
  - Expected utility "plus" gain-loss utility (Loss Aversion)
  - Expected utility "plus" probability distortions (Pessimism)

Other Reference-Dependent Models

- Bell-Loomes-Sugden (1985, 1986)
- Gul (1991)
  - Similar psychological motivation
  - Similar functional forms
  - Different reference points

Bell-Loomes-Sugden's (1985, 1986) Disappointment Aversion

- Reference point is expected consumption utility of lottery
- Total value of lottery is consumption utility plus gain-loss utility

$$V_{\mathbb{BLS}}(F) = \sum_x u(x)F(x) + \sum_x g(u(x) - E_u(F))F(x)$$

Gul's (1991) Disappointment Aversion

- Experience losses due to disappointing outcomes
- Reference point is total value of lottery
- Total value of lottery is consumption utility plus disappointment

$$V_{\mathbb{G}}(F) = \sum_{x} u(x)F(x) + \beta \sum_{x \leq u^{-1}(V_{\mathbb{G}}(F))} \left(u(x) - V_{\mathbb{G}}(F)\right) F(x)$$

- $\beta > 0$

Betweenness (Chew, 1983; Dekel, 1986)

- Generalizes Gul (1991)

$$V_{\mathbb{B}}(F) = \sum_x \nu(x, V_{\mathbb{B}}(F))F(x)$$

- Linear indifference curves (not necessarily parallel)

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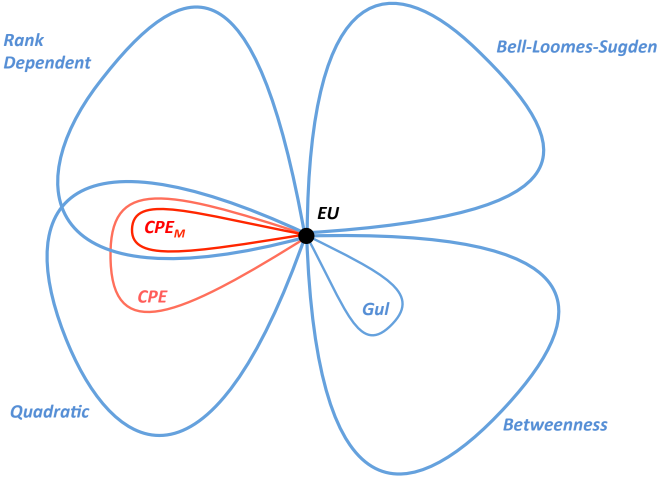
Other Reference-Dependent Models

Proposition

$\mathbb{CPE} \cap \mathbb{B} = \mathbb{CPE} \cap \mathbb{G} = \mathbb{CPE} \cap \mathbb{BLS} = \mathbb{EU}.$

- Same psychological intuitions for different models: reference dependence
- Distinct behavioral predictions
- Distinct models of reference point formation

Summary



Rank
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Bell-Loomes-Sugden
EU
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CPE
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Characterization

- $\mathbb{CPE}_M$ is in the intersection of $\mathbb{Q}$ and $\mathbb{RDU}$
- What additional restrictions are needed?
- Mixture Aversion (MA):

  If $F \sim G$, then $\alpha F + (1-\alpha)G \precsim F$ for all $\alpha \in [0,1]$
- $\mathbb{CPE}$ satisfies Mixture Aversion

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Characterization

- What else?

Theorem

$\succsim$ satisfies MA and is in $\mathbb{Q} \cap \mathbb{RDU}$ if and only if it is in $\mathbb{CPE}_M$.

- u is unique up to affine transformation, λ unique

Characterization

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Now

- Risk aversion
- Comparative Risk Aversion
- How to identify u and λ

Risk Aversion

- How does "risk aversion" translate into parameters?
- Risk aversion = Aversion to mean preserving spreads
- The functional form *suggests* risk aversion has two sources
  - concavity of u
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- When $\lambda > 2$

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Comparative Risk Aversion

- How risk aversion vary across individuals?
- Assume $\succsim_A, \succsim_B$ are in $\mathbb{CPE}_M$.

Proposition

Individual A is more risk averse than B if and only if

- u_A *is more concave than* u_B *and*
- λ_A *is larger than* λ_B

- λ and u are not behavioral substitutes

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Indifference Curves

- $\mathbb{Q}$ indifference curves are conic sections in Marshak-Machina triangle
- $\mathbb{CPE}$ indifference curves are concentric ellipses:

$$(1-m)\left(\frac{2-\lambda}{2(1-\lambda)}-q\right)^2+m\left(\frac{\lambda}{2(\lambda-1)}-p\right)^2=\bar{u}$$

  - p is probability assigned to worst outcome
  - q is probability assigned to best outcome
  - m is utility of middle outcome

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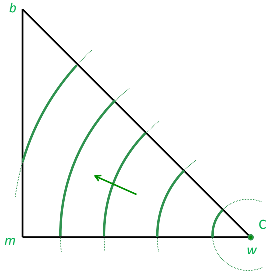
Indifference Curves

- Center always on best-worst outcome line
- Axes parallel to best-to-middle outcome edge and worst-to-middle outcome edge



Indifference Curves

- Center varies with λ, but not u:

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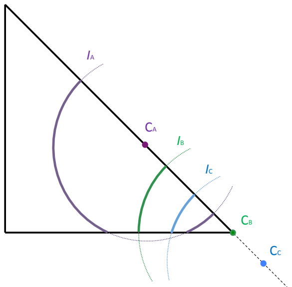

Indifference Curves

- Relative length of axes varies with u, but not λ

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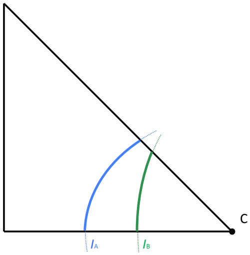

IDENTIFICATION OF λ

- λ measures loss aversion
  - Maps to risk premium for small-stakes lotteries
  - Difficult to know when stakes are small enough
- λ decides the location of 'center' of indifference curves (c_i)
  - A is more loss averse than B if and only if c_A is closer than c_B to the best outcome
  - Maps to the curvature of indifference curves

Identifying λ

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◂ Identifying λ

Identification of u

- u measures concavity of utility over degenerate outcomes
- Concavity of u determines orientation of indifference curves
  - Fixing λ, u maps to the 'slopes' of the indifference curves
- Assume outcome evenly spaced (i.e. 0, 1, 2)
  - Risk neutrality — concentric circles
  - Risk aversion —- long axis parallel to middle-to-best outcome edge
  - Risk loving — long axis parallel to middle-to-worst outcome edge

◂ Identifying u ◂ Sketch of Sufficiency

Applications

- Rabin's Critique
  - Plausible small-scale risk aversion implies improbably large stakes risk aversion
- Safra and Segal (2005) demonstrate $\mathbb{RDU}$ suffer from critique
- $\mathbb{CPE}_M$ satisfy Safra and Segal's conditions
  - u has either increasing or decreasing absolute risk aversion
  - Refuses small-stakes lottery when facing background risk over range of wealth levels
- $\mathbb{CPE}$ not immune to calibration arguments

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- $\mathbb{CPE}_M$ satisfy Safra and Segal's conditions
  - u has either increasing or decreasing absolute risk aversion
  - Refuses small-stakes lottery when facing background risk over range of wealth levels
- $\mathbb{CPE}$ not immune to calibration arguments

Applications

- $\mathbb{CPE}$ not immune to calibration arguments

$$0 \ \succsim \ \begin{array}{l} \xrightarrow{.5} 110 \\ \xrightarrow[.5]{} -100 \end{array} \qquad \Longrightarrow \qquad 0 \ \succsim \ \begin{array}{l} \xrightarrow{.9946} 100,000-\zeta \\ \xrightarrow[0.0054]{} -20,000 \end{array}$$

Applications

- Small stakes and large stakes lottery choices inconsistent
  - Need to be careful when using it in applications
- Solution: gain-loss utility must be sufficiently non-linear
  - Less tractable

◂ Preferences for Information

Experimental Evidence: Existing Evidence

- Existing tests of mixture aversion
  - Betweenness violated near 'edges' of Machina-Marshak triangle
  - Violations support both mixture loving and mixture aversion
- Existing tests of $\mathbb{RDU}$
  - w typically inverse-S shaped
- Existing tests of $\mathbb{CPE}$ can shed light on $\mathbb{Q}$ and $\mathbb{RDU}$
  - Abeler et al. (2011) find support for $\mathbb{CPE}$'s predictions in labor supply experiment
  - Data can also be rationalized by $\mathbb{Q}$ and $\mathbb{RDU}$ models
  - $\mathbb{Q}$ and $\mathbb{RDU}$ models can generate patterns of labor supply different than $\mathbb{CPE}$.

Generalizations

- Can accommodate non-linear gain-loss utility

$$V_{\mathbb{GCPE}}(F) = \sum_{x \in F} p(x)u(x) + \sum_{x \in F}\sum_{y \in F} g(u(x) - u(y))F(x)F(y)$$

where

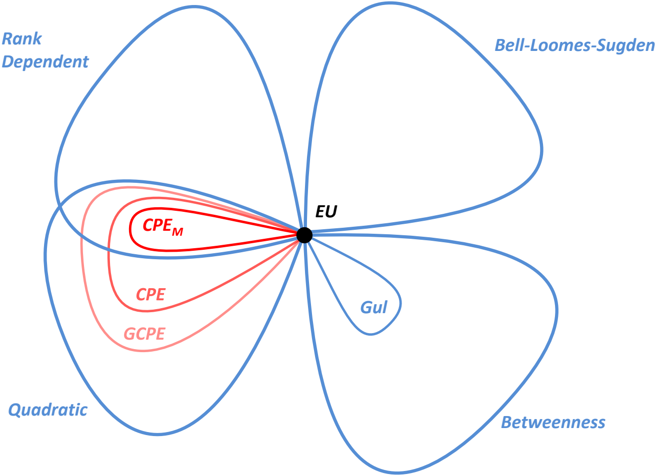
$$g(z) = \begin{cases} f(z) & \text{if } z \geq 0 \\ -\lambda f(-z) & \text{if } z < 0 \end{cases}$$

Generalizations

- $\mathbb{GCPE}$ subset of $\mathbb{Q}$, but not of $\mathbb{RDU}$
- Intersection with $\mathbb{B}$ is only $\mathbb{EU}$
- If $\succsim$ in $\mathbb{GCPE}$ then satisfy mixture aversion
- If $f(x) = w^2$ then we have mean-variance preferences

$$V_{\mathbb{GCPE}}(F) = \sum_x u(x)F(x) + (1-\lambda)(Var_F(u(x)))$$

Summary



Rank
Dependent
Bell-Loomes-Sugden
EU
CPE_M
CPE
GCPE
Gul
Quadratic
Betweenness

Generalizations

- Can extend analysis to: 'Preferred Personal Equilibrium'
  - Two stage choice process
  - First involves maximizing with respect to multiple $\mathbb{EU}$ preferences
  - Second stage is $\mathbb{CPE}$
- Non-separable consumption and gain-loss utility
  - Preferences may not be quadratic

Conclusions

- We provide the complete behavioral implications of $\mathbb{CPE}$
- Important to understand how models relate to one another
  - Some psychological biases generate equivalent behavior
  - But important distinctions between models of references dependence
- Understanding behavior and relationships can lead to insights in a variety of applications
- Learn what models best match actual behavior

THANK YOU!