Fairness in Cost-Benefit Analysis: Equity-Enhanced Mean Variance Rules

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Cost-benefit analysis of social risks

- Example: evaluation of a public project (e.g. nuclear power plant)
  - Construction costs
  - Pollution reduction and lower energy costs
  - But ethical issues due to radioactive contamination risk:
    - acceptable level of individual health risk for *local* population?
    - correlation with background risk? (quality of the environment, social status)
    - possibility of a catastrophic accident? (with respect to many small accidents)
- Standard cost-benefit analysis is insensitive to distributive justice considerations (who will suffer more and how many people will suffer at the same time?)

Regulatory agencies' practice

- Some regulatory agencies do care about distributive justice:
  - environmental justice and social gradient hypothesis (US Executive Orders, 1993-1994; EPA issues, but no specific tool)
  - individual fatality risk thresholds (e.g. regulation of carcinogens and radiation in US or UK; no interest in the distribution)
  - QALY-based inequality metrics for health risks ($\sim$ Gini coefficient, Atkinson index, ...)
  - societal fatality risk thresholds, with higher weighting for large accidents (UK, Netherlands, Norway, Switzerland)
- But these instruments for equity analysis are not well-grounded conceptually:
  - only one dimension of equity and no link with pre-existing risks or social status
  - application left to the discretion of the policy maker: weight w.r.t. efficiency considerations (cost vs benefit)?

Objective of the paper

Develop a ***simple, theoretically sound*** cost-benefit rule for public risky policies such that:

- it is based on few, easily computable equity metrics as the ones currently used;
- the weight of each component is not arbitrary but depends on exogenous assumptions;
- it can account for the heterogeneity in individual risks created by the policy and/or the collective risk induced by the policy and resulting heterogeneity in actual returns;
- it can account for any relation between the risk induced by the policy and pre-existing conditions.

Methodology: social choice theory + risk theory

- Social Welfare Function approach:
  - policy $A \succeq$ policy B iff $W(A) \geq W(B)$
- Rule based on the approximated welfare effects of a policy:
  - definition of a ***social certainty equivalent***;
  - quadratic approximation to build the **equity-enhanced mean variance rule**.

Extension of the classic Arrow-Pratt approximation of the (private) certainty equivalent to a social framework with risk and equity concerns.

What is the object of fairness?

- Should we evaluate the equity effects of a policy before or after the resolution of uncertainty?
  - **ex-ante approach** $\iff$ focus on individual risks
    $\Rightarrow$ equalization of individual chances
  - **ex-post approach** $\iff$ focus on collective risk
    $\Rightarrow$ equalization of actual outcomes
- Common (e.g. utilitarian) social welfare functions are neutral to equity in individual risks and to the presence of collective risk
- In the paper, analysis of **3 alternative welfare criteria**: utilitarianism; equality of prospects approach (ex-ante); expected equally distributed equivalent approach (ex-post)

Overview of the main results

- The **Equity-enhanced mean variance rule** depends on:
  - few, fairly tractable measures:
    - expected average returns of the policy,
    - index of volatility of the individual/collective returns
    - index of inequality in returns
  - taste parameter (coefficient of risk aversion, A_u) and ethic parameter (coefficient of inequality aversion, A_v), that determine the best balance between efficiency and fairness
- If utilitarianism, no index of inequality (only 'mean-variance' of average agent)
- If ex-ante or ex-post, index of inequality (the form depends on the approach) whose weight depends on $A_v - A_u$

Related literature

- Ex-ante vs ex-post social welfare criterion (ex: Diamond 1967, Epstein and Segal 1992, Hammond 1983, Broome 1991, Adler and Sanchirico 2006, Adler 2012, Grant et al. 2010, Fleurbaey 2010, Grant et al. 2012, Bommier and Zuber 2008). Differences:
  - consumption and mortality risk
  - fairness in allocation of resources (Fleurbaey and Zuber 2014)
- Economic implications of ex-ante/ex-post approaches (Adler et al. 2014, Bovens and Fleurbaey 2012, Adler and Treich 2014, Fleurbaey and Zuber 2015)
- Inequality metrics in risk regulation (ex: Gakidou et al. 2000, Gajdos and Maurin 2004, Keeney 1980, Keeny and Winkler 1985, Sarin 1985, Fishburn and Sarin 1991); distributional weighting
- Catastrophic risks (Barro 2009, Weitzman 2009, Martin and Pindyck 2015)
- Ex-ante/ex-post in behavioral economic theory (Fudenberg and Levine 2012, Saito 2013)

Outline of the presentation

Example

Comparison of two social risky situations, A and B (e.g. how to allocate resources to improve the safety of existing hazard facilities)

A	s_1	s_2	s_3	s_4
$\theta = 1$	4	4	0	0
$\theta = 2$	4	0	4	0
p_s	$\frac{13}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$

B	s_1	s_2
$\theta = 1$	4	4
$\theta = 2$	4	0
p_s	$\frac{3}{4}$	$\frac{1}{4}$

Society with two individuals θ, and two consumption levels $c = \{0, 4\}$

Question: which situation is preferable?

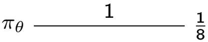
- **Efficiency**: in both cases, on average $\frac{1}{8}$ of the population will suffer a loss
- **Fairness**: equalization of individual risks (ex-ante) or equalization of consequences (ex-post)?

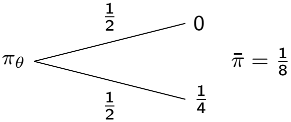
Risk inequity

Comparison of individual risks:

A	s_1	s_2	s_3	s_4
$\theta = 1$	4	4	0	0
$\theta = 2$	4	0	4	0
p_s	$\frac{13}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$

B	s_1	s_2
$\theta = 1$	4	4
$\theta = 2$	4	0
p_s	$\frac{3}{4}$	$\frac{1}{4}$





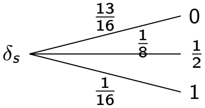
- Situation B is **more risk inequity** than situation A
- **Risk inequity aversion (love)**: The SP likes (dislikes) to have all individuals suffer the same average probability of loss rather than to have individuals with different probabilities of suffering a loss (she dislikes mean preserving spreads in the distribution of π_θ)

Collective risk and ex-post inequality

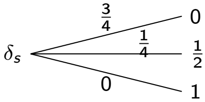
Comparison of consequences:

A	s_1	s_2	s_3	s_4
$\theta = 1$	4	4	0	0
$\theta = 2$	4	0	4	0
p_s	$\frac{13}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$

B	s_1	s_2
$\theta = 1$	4	4
$\theta = 2$	4	0
p_s	$\frac{3}{4}$	$\frac{1}{4}$



$\bar{\delta} = \frac{1}{8}$



$\bar{\delta} = \frac{1}{8}$

- Situation A is **collectively more risky** and **less ex-post unequal** than situation B
- **Correlation acceptance (aversion)**: the SP likes (dislikes) to be uncertain about the state that will realize rather than knowing for sure the distribution of outcomes. In other words, the DM likes situations that lead to low ex-post inequality (she likes mean-preserving spreads in the probability distribution of δ_s)

Utilitarianism is risk inequity neutral and correlation neutral

A	s_1	s_2	s_3	s_4
$\theta = 1$	4	4	0	0
$\theta = 2$	4	0	4	0
p_s	$\frac{13}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$

B	s_1	s_2
$\theta = 1$	4	4
$\theta = 2$	4	0
p_s	$\frac{3}{4}$	$\frac{1}{4}$

- Total welfare as the sum of individual expected utilities or the expected sum of individual realized utilities:
  - $W_A^U = \frac{1}{8}u(0) + \frac{7}{8}u(4)$
  - $W_B^U = \frac{1}{2}u(4) + \frac{1}{2}\left[\frac{1}{4}u(0) + \frac{3}{4}u(4)\right] = \frac{1}{8}u(0) + \frac{7}{8}u(4)$
- Only the average proportion of people suffering a loss matters (expected individual probability of loss)
  - Example: $u(c) = \sqrt{c} \Rightarrow W_A^U = W_B^U = \frac{7}{4}$

Equality of prospects approach

To represent risk inequity, total welfare as the ***average felicity of individual expected equivalents***:

- Individual certainty equivalent: $CE_\theta = u^{-1}\left(\pi_\theta u(0) + (1-\pi_\theta)u(4)\right)$
- $W^{EoP} = \frac{1}{2}v(CE_1) + \frac{1}{2}v(CE_2)$

A	s_1	s_2	s_3	s_4
$\theta = 1$	4	4	0	0
$\theta = 2$	4	0	4	0
p_s	$\frac{13}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$

B	s_1	s_2
$\theta = 1$	4	4
$\theta = 2$	4	0
p_s	$\frac{3}{4}$	$\frac{1}{4}$

- Example: $u(c) = \sqrt{c} \quad \Rightarrow \quad CE_1^A = CE_2^A = \frac{49}{16}$ while $CE_1^B = 4$ and $CE_2^B = \frac{9}{4}$
- Example 1: $v(CE) = CE^{0.25} \quad \Rightarrow \quad W_A^{EoP} = 1.12 > W_B^{EoP} = 1.09$
- Example 2: $v(CE) = CE^{0.75} \quad \Rightarrow \quad W_A^{EoP} = 2.31 < W_B^{EoP} = 2.33$

Index of risk inequity aversion

Note that:

- $v(c) = CE^{0.25}$ is more concave than $u(c) = \sqrt{c} \quad \Rightarrow \quad W_A^{EoP} > W_B^{EoP}$
- $v(c) = CE^{0.75}$ is less concave than $u(c) = \sqrt{c} \quad \Rightarrow \quad W_A^{EoP} < W_B^{EoP}$

where situation A is less risk inequity than situation B

Lemma 1.

The social planner is risk inequity averse (lover) $\iff$ v is more concave (convex) than u.

Expected equally distributed equivalent approach

To represent concerns for the collective risk and ex-post inequality, total welfare as the ***expected utility of equally distributed equivalents***:

- Equally distributed equivalent: $c_s^{EDE} = v^{-1}\left(\delta_s v(0) + (1-\delta_s)v(4)\right)$
- $W^{EEDE} = \sum_s p_s u(c_s^{EDE})$

A	s_1	s_2	s_3	s_4
$\theta = 1$	4	4	0	0
$\theta = 2$	4	0	4	0
p_s	$\frac{13}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$

B	s_1	s_2
$\theta = 1$	4	4
$\theta = 2$	4	0
p_s	$\frac{3}{4}$	$\frac{1}{4}$

- Example 1: $v(c) = c^{0.25} \quad \Rightarrow \quad c_{1,A}^{EDE} = 4 \quad c_{2,A}^{EDE} = c_{3,A}^{EDE} = 0.25 \quad c_{4,A}^{EDE} = 0$ while $c_{1,B}^{EDE} = 4$ and $c_{2,A}^{EDE} = 0.25$
  with $u(c^{EDE}) = \sqrt{c} \quad \Rightarrow \quad W_A^{EEDE} = 1.687 > W_B^{EEDE} = 1.625$

Expected equally distributed equivalent approach

To represent concerns for the collective risk and ex-post inequality, total welfare as the ***expected utility of equally distributed equivalents***:

- Equally distributed equivalent: $c_s^{EDE} = v^{-1}\left(\delta_s v(0) + (1-\delta_s)v(4)\right)$
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- Example 1: $v(c) = c^{0.25} \quad \Rightarrow \quad c_{1,A}^{EDE} = 4 \quad c_{2,A}^{EDE} = c_{3,A}^{EDE} = 0.25 \quad c_{4,A}^{EDE} = 0$ while $c_{1,B}^{EDE} = 4$ and $c_{2,A}^{EDE} = 0.25$
  with $u(c^{EDE}) = \sqrt{c} \quad \Rightarrow \quad W_A^{EEDE} = 1.687 > W_B^{EEDE} = 1.625$

- Example 12: $v(c) = c^{0.75} \quad \Rightarrow \quad c_{1,A}^{EDE} = 4 \quad c_{2,A}^{EDE} = c_{3,A}^{EDE} = 1.59 \quad c_{4,A}^{EDE} = 0$ while $c_{1,B}^{EDE} = 4$ and $c_{2,A}^{EDE} = 1.59$
  with $u(c^{EDE}) = \sqrt{c} \quad \Rightarrow \quad W_A^{EEDE} = 1.78 < W_B^{EEDE} = 1.81$

Index of correlation acceptance

Note that:

- $v(c) = CE^{0.25}$ is more concave than $u(c) = \sqrt{c} \quad \Rightarrow \quad W_A^{EEDE} > W_B^{EEDE}$
- $v(c) = CE^{0.75}$ is less concave than $u(c) = \sqrt{c} \quad \Rightarrow \quad W_A^{EEDE} < W_B^{EEDE}$

where situation A is collectively more risky and less ex-post unequal than situation B

Lemma 2.

The social planner is correlation prone (averse) $\iff$ v is more concave (convex) than u

Discussion

- Concerns for equity ex-ante and ex-post are always in conflict with concerns for the collective risk
- Both risk inequity aversion and correlation acceptance are characterized by function v (inequality aversion) more concave than function u (risk aversion)

Utilitarianism

- Harsanyi's theorem: total welfare as the sum of individual expected utilities or the expected value of individual realized utilities

$$W^U = \int_\Theta (1-\pi_\theta) \int_\mathbb{Z} u(c) d\Pi_\theta(c) dQ(\theta) = \int_\mathbb{S} (1-\delta_s) \int_\mathbb{Z} u(c) d\Delta_s(c) dP(s)$$

- $\iff$ total welfare as the expected well-being of the representative agent:

$$W^U = (1-\bar{\pi}) \int_\mathbb{Z} u(c) F(c)$$

$$= (1-\bar{\pi}) Eu(c)$$

Equality of Prospects approach

- Total welfare as the average felicity of individual certainty equivalents:

$$W^{EoP} = \int_{\Theta} v\left(u^{-1}\left((1-\pi_\theta)\int_{\mathbb{Z}} u(c)d\Pi_\theta(c)\right)\right)dQ(\theta)$$

$$= E_\theta v\left(u^{-1}\left((1-\pi_\theta)E_s[u(c)|\theta]\right)\right)$$

- v more concave than u $\iff$ risk inequity aversion = aversion to mean preserving spreads in the distribution of individual expected utilities $U_\theta = (1-\pi_\theta)\int_{\mathbb{Z}} u(c)d\Pi_\theta(c)$
- Coefficient of ***absolute risk inequity aversion*** at $c \in \mathbb{Z}$:

$$\alpha(c) = \frac{1}{u'(c)}\left(-\frac{v''(c)}{v'(c)} + \frac{u''(c)}{u'(c)}\right) \geq 0$$

Expected Equally Distributed Equivalent Approach

- Total welfare as expected utility of equally distributed equivalents

$$W^{EEDE} = \int_{\mathbb{S}} u\left(v^{-1}\left((1-\delta_s)\int_{\mathbb{Z}} v(c)d\Delta_s(c)\right)\right)dP(s)$$

$$= E_s u\left(v^{-1}\left((1-\delta_s)E_\theta[v(c)|s]\right)\right)$$

- u is less concave than $v \iff$ correlation acceptance = acceptance of mean preserving spreads in the distribution of average felicities $V_s = (1-\delta_s)\int_{\mathbb{Z}} v(c)d\Delta_s(c)$, which leads to an increase in the probability of more (positively) correlated outcomes (=less ex-post inequality)
- Coefficient of ***absolute correlation acceptance*** at $c \in \mathbb{Z}$:

$$\beta(c) = \frac{1}{v'(c)}\left(-\frac{v''(c)}{v'(c)} + \frac{u''(c)}{u'(c)}\right)$$

Definition

- ***Social certainty equivalent***. Sure uniform monetary amount that yields the same total welfare as the social risky situation

$$W^U = (1 - \bar{\pi})Eu(\tilde{c}) = u(Ec - \tau^U)$$

$$W^{EoP} = E_\theta v\left(u^{-1}\left((1 - \pi_\theta)E_s[u(c)|\theta]\right)\right) = v(Ec - \tau^{EoP})$$

$$W^{EEDE} = E_s u\left(v^{-1}\left((1 - \delta_s)E_\theta[v(c)|s]\right)\right) = u(Ec - \tau^{EEDE})$$

- τ: ***social risk premium***
- policy $A \succ$ policy $B \iff Ec(A) - \tau(A) \geq Ec(B) - \tau(B)$
- Assumption: no correlation between consumption risk and mortality risk

Utilitarianism

$$\tau^{U} \simeq \frac{1}{2}\, A_u(\omega)\ \sigma_c^2$$

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absolute risk aversion

Utilitarianism

$$\tau^U \simeq \frac{1}{2} A_u(\omega) \sigma_c^2$$

variance of average individual risk conditional on being alive ($\tilde{c} \sim \bar{\Pi} = \bar{\Delta}$)

absolute risk aversion

Utilitarianism

$$\tau^U \simeq \frac{1}{2} A_u(\omega)\, \sigma_c^2 \;+ FR_u(\omega)\, \bar{\pi}$$

variance of average individual risk

conditional on being alive

$(\tilde{c} \sim \bar{\Pi} = \bar{\Delta})$

absolute risk aversion

Utilitarianism

fear of ruin coefficient (Aumann and Kurz 1977)

$FR = \frac{u'(\omega)}{u(\omega)} \propto VSL$

$$\tau^U \simeq \frac{1}{2} A_u(\omega)\, \sigma_c^2 + FR_u(\omega)\, \bar{\pi}$$

variance of average individual risk

conditional on being alive

$(\tilde{c} \sim \bar{\Pi} = \bar{\Delta})$

absolute risk aversion

Utilitarianism

fear of ruin coefficient (Aumann and Kurz 1977)

$$FR = \frac{u'(\omega)}{u(\omega)} \propto VSL$$

$$\tau^U \simeq \frac{1}{2} A_u(\omega) \sigma_c^2 + FR_u(\omega) \bar{\pi}$$

expected number of fatalities

variance of average individual risk

conditional on being alive

$(\tilde{c} \sim \bar{\Pi} = \bar{\Delta})$

absolute risk aversion

Equality of Prospects approach

$$\tau^{EoP} \simeq \quad \frac{1}{2}A_u(\omega)\sigma_c^2 + FR_u(\omega)\bar{\pi} \quad + [A_v(\omega) - A_u(\omega)]\ \frac{1}{2}\left\{\sigma^2_{E_s[c|\theta]} + FR_u^2(\omega)\sigma^2_{\pi_\theta}\right\}$$

Equality of Prospects approach

$$\tau^{EoP} \simeq \quad \frac{1}{2}A_u(\omega)\sigma_c^2 + FR_u(\omega)\bar{\pi} \quad + [A_v(\omega) - A_u(\omega)]\ \frac{1}{2}\left\{\sigma^2_{E_s[c|\theta]} + FR_u^2(\omega)\sigma^2_{\pi_\theta}\right\}$$

Equality of Prospects approach

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index of inequality in

individual expected consumption

Equality of Prospects approach

$$\tau^{EoP} \simeq \frac{1}{2}A_u(\omega)\sigma_c^2 + FR_u(\omega)\bar{\pi} + [A_v(\omega) - A_u(\omega)]\,\frac{1}{2}\left\{\sigma^2_{E_s[c|\theta]} + FR_u^2(\omega)\sigma^2_{\pi_\theta}\right\}$$

index of inequality in
individual mortality likelihoods

index of inequality in
individual expected consumption

Equality of Prospects approach

$$\tau^{EoP} \simeq \frac{1}{2}A_u(\omega)\sigma_c^2 + FR_u(\omega)\bar{\pi} + [A_v(\omega) - A_u(\omega)]\,\frac{1}{2}\left\{\sigma^2_{E_s[c|\theta]} + FR_u^2(\omega)\sigma^2_{\pi_\theta}\right\}$$

$[A_v(\omega) - A_u(\omega)]$: $\sim$ absolute risk inequity aversion

$\sigma^2_{E_s[c|\theta]}$: index of inequality in individual expected consumption

$\sigma^2_{\pi_\theta}$: index of inequality in individual mortality likelihoods

Expected Equally Distributed Equivalent approach

$$\tau^{EEDE} \simeq \quad \frac{1}{2}A_v(\omega)\sigma_c^2 + FR_v(\omega)\bar{\pi} \quad + [A_u(\omega) - A_v(\omega)]\ \frac{1}{2}\left\{\sigma^2_{E_\theta[c|s]} + FR_v^2(\omega)\sigma^2_{\delta_s}\right\}$$

Expected Equally Distributed Equivalent approach

$\sim$ social value of mortality risk reduction

$$\tau^{EEDE} \simeq \frac{1}{2}A_v(\omega)\sigma_c^2 + FR_v(\omega)\bar{\pi} + [A_u(\omega) - A_v(\omega)]\,\frac{1}{2}\left\{\sigma^2_{E_\theta[c|s]} + FR_v^2(\omega)\sigma^2_{\delta_s}\right\}$$

absolute inequality aversion

Expected Equally Distributed Equivalent approach

$\sim$ social value of mortality risk reduction

$$\tau^{EEDE} \simeq \frac{1}{2}A_v(\omega)\sigma_c^2 + FR_v(\omega)\bar{\pi} + [A_u(\omega) - A_v(\omega)]\ \frac{1}{2}\left\{\sigma^2_{E_\theta[c|s]} + FR_v^2(\omega)\sigma^2_{\delta_s}\right\}$$

absolute inequality aversion

variance of
average consumption

Expected Equally Distributed Equivalent approach

$\sim$ social value of mortality risk reduction

$$\tau^{EEDE} \simeq \tfrac{1}{2} A_v(\omega)\sigma_c^2 + FR_v(\omega)\bar{\pi} + [A_u(\omega) - A_v(\omega)]\ \tfrac{1}{2}\left\{\sigma^2_{E_\theta[c|s]} + FR_v^2(\omega)\sigma^2_{\delta_s}\right\}$$

absolute inequality aversion

variance of the mortality rate

variance of average consumption

Expected Equally Distributed Equivalent approach

$\sim$ social value of mortality risk reduction

$$\tau^{EEDE} \simeq \frac{1}{2}A_v(\omega)\sigma_c^2 + FR_v(\omega)\bar{\pi} + [A_u(\omega) - A_v(\omega)]\frac{1}{2}\left\{\sigma^2_{E_\theta[c|s]} + FR_v^2(\omega)\sigma^2_{\delta_s}\right\}$$

absolute inequality aversion

$\sim$ absolute correlation aversion

variance of the mortality rate

variance of average consumption

Equity-enhanced mean variance rules

Value of a project whose effects are uncertain and heterogeneously distributed:

EoP		**EEDE**	
expected monetary benefits	(+)	expected monetary benefits	(+)
monetary value of the expected lives lost	(-)	monetary value of the expected lives lost	(-)
variance of consumption risk for the average agent (A_u)	(-)	variance of consumption risk for the average agent (A_v)	(-)
variance of individual expected consumption ($A_v - A_u$)	(-)	variance of the average benefit that will eventually realize ($A_v - A_u$)	(+)
variance of individual mortality risks ($A_v - A_u$)	(-)	variance of the mortality rate ($A_v - A_u$)	(+)

Our example again

Assume $u(c) = \sqrt{c}$ and $v(c) = c^{0.25}$ $\Rightarrow$ $A_u = 0.5$ and $A_v = 0.75$

A	s_1	s_2	s_3	s_4
$\theta = 1$	4	4	0	0
$\theta = 2$	4	0	4	0
p_s	$\frac{13}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$

B	s_1	s_2
$\theta = 1$	4	4
$\theta = 2$	4	0
p_s	$\frac{3}{4}$	$\frac{1}{4}$

- Utilitarianism: only efficiency consideration $\Rightarrow$ $\tau_A = \tau_B \sim VSL * \frac{1}{8}$
- Equality of Prospects: heterogeneity in individual probabilities of loss:

  $\sigma_A^2 = 0$ $\quad$ $\sigma_B^2 = 0.0156$

  $\tau_A \sim VSL * \frac{1}{8} < \tau_B \sim VSL * \frac{1}{8} + \frac{1}{2}\left(\frac{1}{4}\right) VSL^2 * 0.0156$
- Expected Equally Distributed Equivalent approach: collective risk:

  $\sigma_A^2 = 0.078$ $\quad$ $\sigma_B^2 = 0.046$

  $\tau_A \sim VSL * \frac{1}{8} * \xi - \frac{1}{2}\left(\frac{1}{4}\right) \xi^2 VSL^2 * 0.078 < \tau_B \sim VSL * \frac{1}{8} * \xi - \frac{1}{2}\left(\frac{1}{4}\right) \xi^2 VSL^2 * 0.046$

  with ξ larger than 1.

Calibration issues

- From financial choices, $A_u(\omega)\omega \in [2, 4]$
- A_v: ethical choice, difficult to estimate:
  - revealed-preference methods (Stern 1977; Young 1990; Gouveia and Strauss 1994; Evans 2005; Aristei and Perugini 2010)
  - stated-preferences surveys (Amiel et al. 1999; Carlsson et al. 2002, 2005; Pirttilä and Uusitalo 2008)
- From existing studies, $A_v(\omega)\omega \in (0, 3]$
- $A_v - A_u \gtrless 0$? No clear result:
  - experimental literature on private behavior supporting aversion to both ex-ante and ex-post inequality (Konow 2000; Brock et al. 2013; Lopez-Vargas 2014)
  - risk inequity aversion in chocolate bar game (Kroll and Davidovitz 2003)
  - literature on mortality risks: correlation prone behavior (Tversky and Kahneman 1981; Fischhoff 1993; Carlsson et al. 2012)

Extensions

- The rule is based on an approximation. Does the same ranking hold with large risks?
- Utility depends only on consumption. How to include other attributes? Equivalent consumption
- What happens if preferences are heterogeneous?
  - in the EoP case, no distortion if there is no relation between being more at risk and being more adverse
  - in the EEDE case, overestimation of the social risk premium
- Are the first two moments of the probability/frequency distribution a sufficient statistic for the distribution itself?
  - effect of rare disasters à la Weitzman (2009) with negative skewness and fat tails
  - effect of highly positive skewed distribution of wealth à la Piketty (2014)

Conclusions

- The paper develops a fairly tractable cost benefit rule that merges efficiency considerations and distributive justice
- Methodology: risk theory tools applied to a social welfare function that disentangles risk and equity concerns:
  - ex-ante approach: risk inequity preferences
  - ex-post approach: preferences for the collective risk and resulting inequality
- Equity-enhanced mean variance rules is based on:
  - easily measurable inequality and risk indices
  - preference metrics, that are independent of the problem at hand and that determine the importance of each component

Future work

- Alternative inequality measures: Gini index (rank-dependent expected felicity functions); ex-ante + ex-post in a single index; population ethics
- Pricing of long-run social risks (e.g. climate change)
- Calibration of risk inequity aversion and correlation acceptance
- Responsibility issues?