Challenges in implementing the many concepts of risk and uncertainty

Toulouse workshop on progress and challenges in applied BCA of government policies

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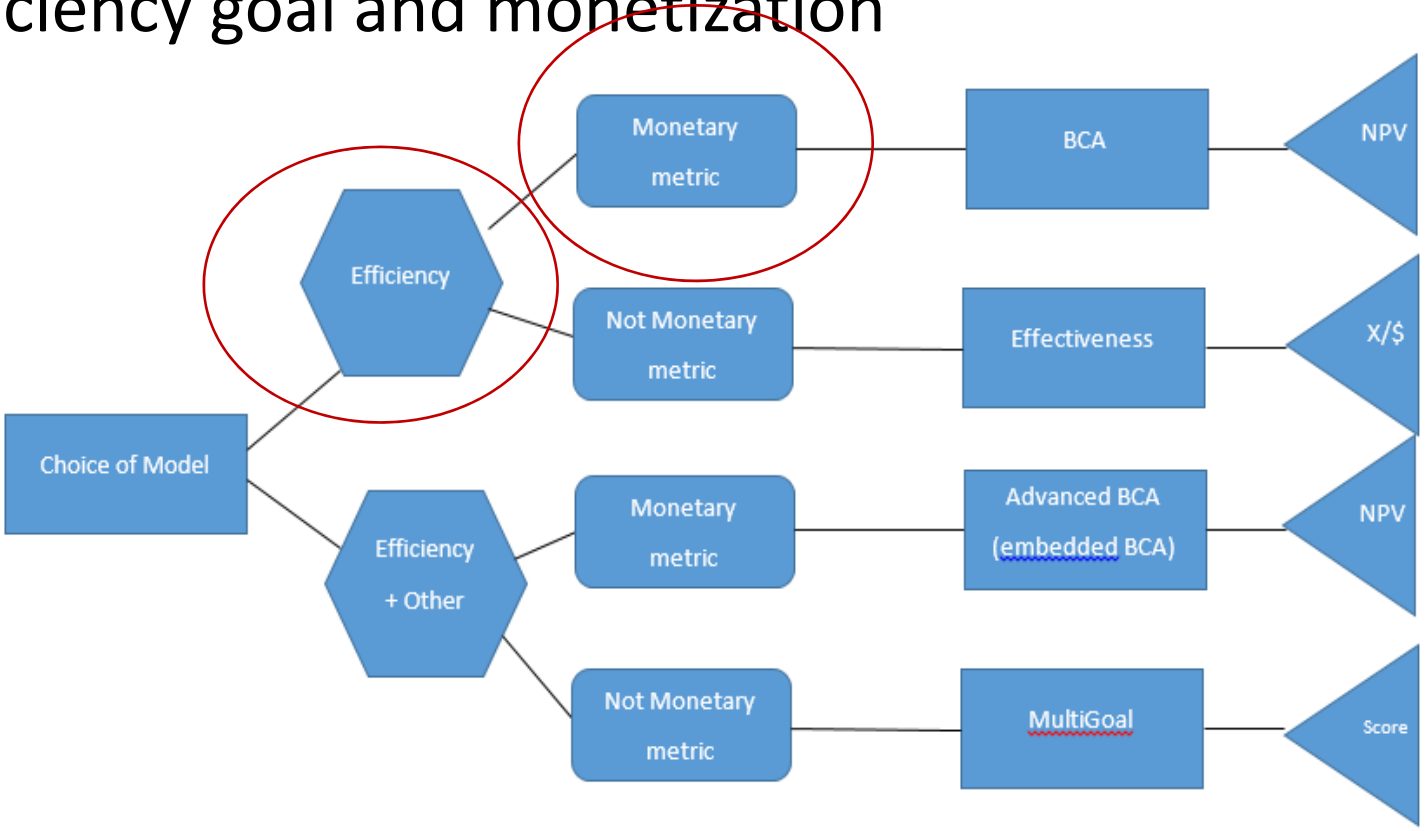
Outline

- Introduction
  - Risks: interpreted broadly from assumptions which could be incorrect to risk preferences of individuals
  - Challenges in applied BCA for Gov't policies (not the only challenges, research challenges as well)
  - My contexts: terrorism, flooding, oil spills, gambling, air and water quality, recreational deaths, risk mgement for USG
- Meta-choice of models—model risks accepted w/BCA
- Risk and Implementation of BCA: "laundry list" but detail on
  - Alternative models of risk preferences: do they matter empirically?
  - Missing pure error term in BCA
- Concluding observations

Before implementing BCA
Meta Choice: Model Risk

- We accept some modeling risks (model could be wrong) when using BCA
- Version I: Vining and Boardman: models distinguished by efficiency goal and monetization

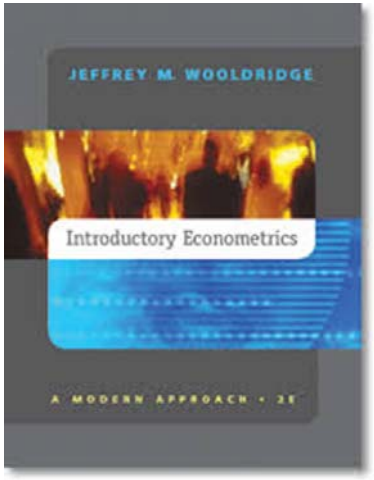


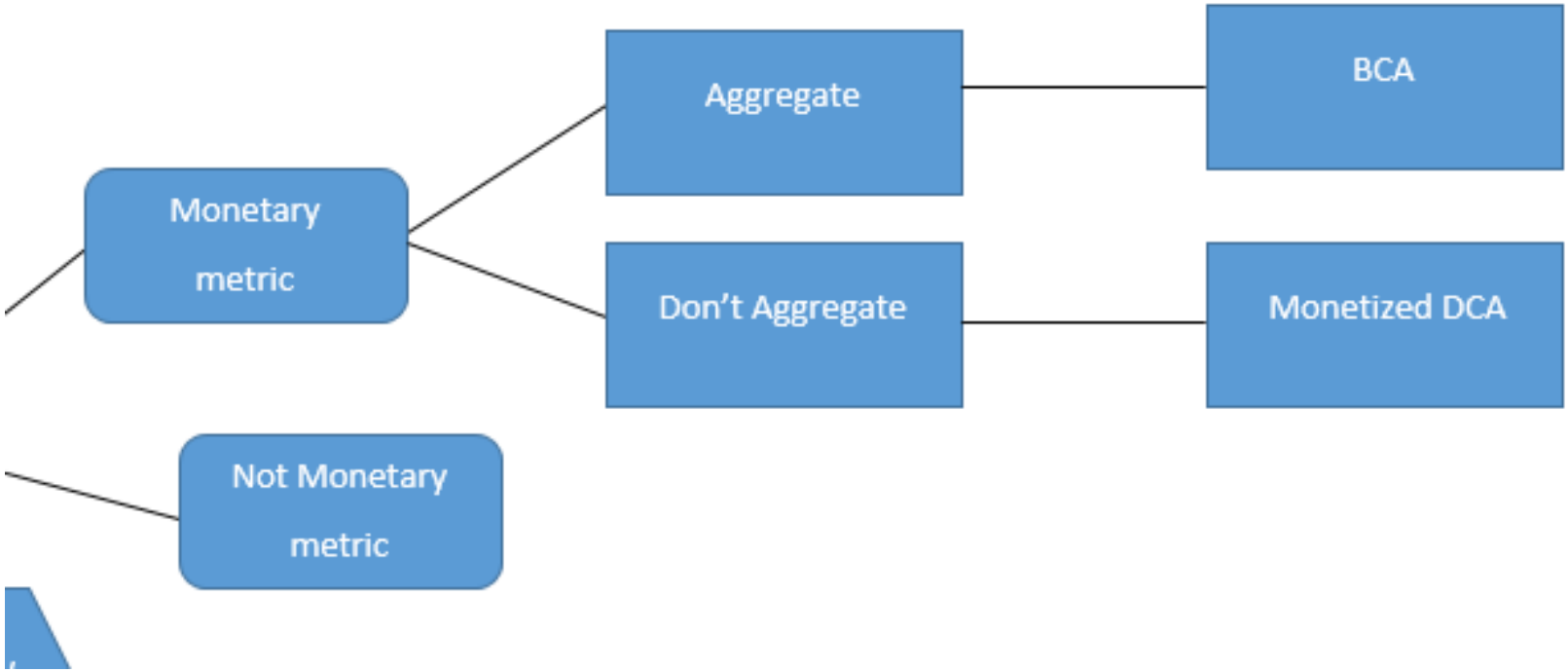
Version 2 (Farrow): Compare assumptions across multiple models (Green common, yellow differ, gray-implement), more dimensions

Assumptions	Impact Analysis	"Std" Decision Analysis	Advanced Decision Analysis (eg MCMA)	Std Benefit-Cost Analysis	Advanced Benefit-Cost Analysis	Econ. Consequence Analysis	Cost-Effect. Analysis	Other models, Notes
Who has standing	Citizens or as otherwise defined	Citizens or as otherwise defined	Citizens or as otherwise defined	Citizens or as otherwise defined	Citizens or as otherwise defined	Citizens or as otherwise defined	Citizens or as otherwise defined	
Whose preferences	Not specified	Decision-maker (s)	Decision-maker (s)	Society	Society	Not specified	Society	
Aggregate preferences	Adding up of natural units; impact may be distributiona l info.	None	None or Some group approach	Equal weight SWF	Unequal weight SWF	Adding up of dollar impacts with other dimensions as mental model	Equal weight SWF (including quantity outcome)	
Weights	None	DM or crowd dollar weighted	DM weighted	"crowd dollar weighted", surplus	"crowd dollar weighted", surplus; subjective distributional	Dollar weighted by price	Mixture dollar weighted and DM or expert weighted	
Independent or interdependent personal preferences	Independent	Independent	Independe nt	Independent	Independent	Independent	Independent	Taking account of system risk or interdependent preferences
Extent of economic interaction across markets	None	Limited	Limited	Usually limited but can be large	Usually limited but can be large	Often large, General Eq.	Usually limited but can be large	

Meta-choice: extended tree (others possible as with risk measures)

Objective: "Econometrics" text approach….assumptions for general model, when violated or restricted, what is the alternative model?





Ok, chosen BCA, now implement

Challenges with risk and implementation of BCA: essentially at every step

- Objective function, decision criteria, market scope
- Preferences and Behavioral Responses
- Randomness

$$(2)\quad Expected\ Present\ Value\ Net\ Benefit = \sum_{i=1}^{n} \sum_{t=0}^{t=} \pi_i \left(\frac{CS_{it} + PS_{it} + GR_{it} + Ex_{it}}{D(t)} \right) + \epsilon$$

Scope challenge: Partial or General Equilibrium?

- Typical partial equilibrium assumptions:
  - 0 cross price elasticity to omit sectors
  - Or no distortions in other markets
  - Often deterministic solution
- Typical empirical General Eq assumptions:
  - Generally fixed coefficients/elasticities for deterministic solution
  - Still aggregation at some level (3, 18, 509 sectors?)
  - Potential for qualitatively different shadow prices: education?, incorporate VSL into wage equation (dwage/drisk= calibrated VSL?);

BCA can be either PE or GE

More on the "error" and cost and skill trade-off?

(Florio, Dreze and Stern, Goulder and Williams, Smith..)

- "Creative use of BCA": Potential for aggregate risks and impact of policies or programs? e.g. reluctance to monetize terrorism risks across risk domains; potential for aggregate residual risk accounting using shadow prices from BCA?

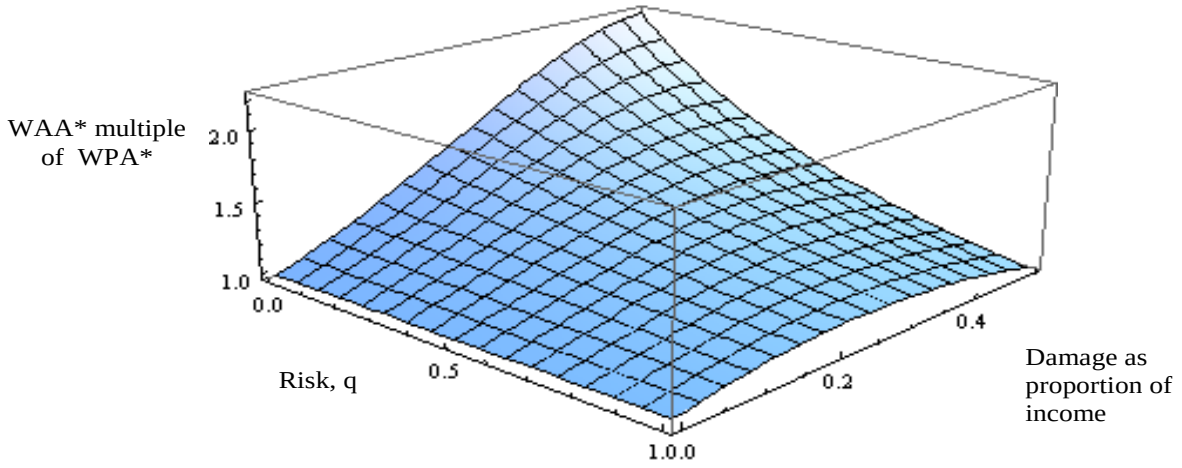
Challenges with Risk Preferences and Behavioral Responses

- Typical default: risk neutral and use EV for indiv. and gov't
- More advanced:
  - Expected utility framework: Include risk preferences so utility modeling with risk aversion or other; option price
  - Non-expected utility modeling: e.g. cumulative prospect theory and evolving behavioral models of risk.
  - Conceptual differences implying empirical differences
  - Discounting: "standard", empirical hyperbolic, with uncertainty?
  - Homeland security setting:
    - not a game against nature but against an adversary, may change risks
    - Historical economic behavioral responses to major events not well understood for how preferences change.
- (Core of "applied" challenge and "research" challenge…apply "normal science"; research positive economics of risk)

One result: Does choice of risk indiv. model preference matter in one continuous state setting? (Farrow and Scott, 2013)

- Motivation: (Freeman), low probability, high consequence events have the greatest adjustment between risk neutral and averse preferences (2 states)

Figure 1: Regression based response surface: Ex-ante multiple of ex-post for varying risk and damage levels, risk aversion equal to 2



Case study result: Flooding, continuous states, concave damages

1. EV pretty good: Minimal difference between base expected damage and using option price.
    1. Difference increases w/ greater risk aversion but < 20%
2. Worst cases (catastrophe?): small impact on mean (Gov't decision—Arrow & Lind). Upper limit of integration has little effect (e.g. 100 or 1000 year flood; note, EV exists here).
3. Cumulative Prospect Theory (non-EU) representative agent are significantly less than expected utility models (utility weight and probability in small flood).

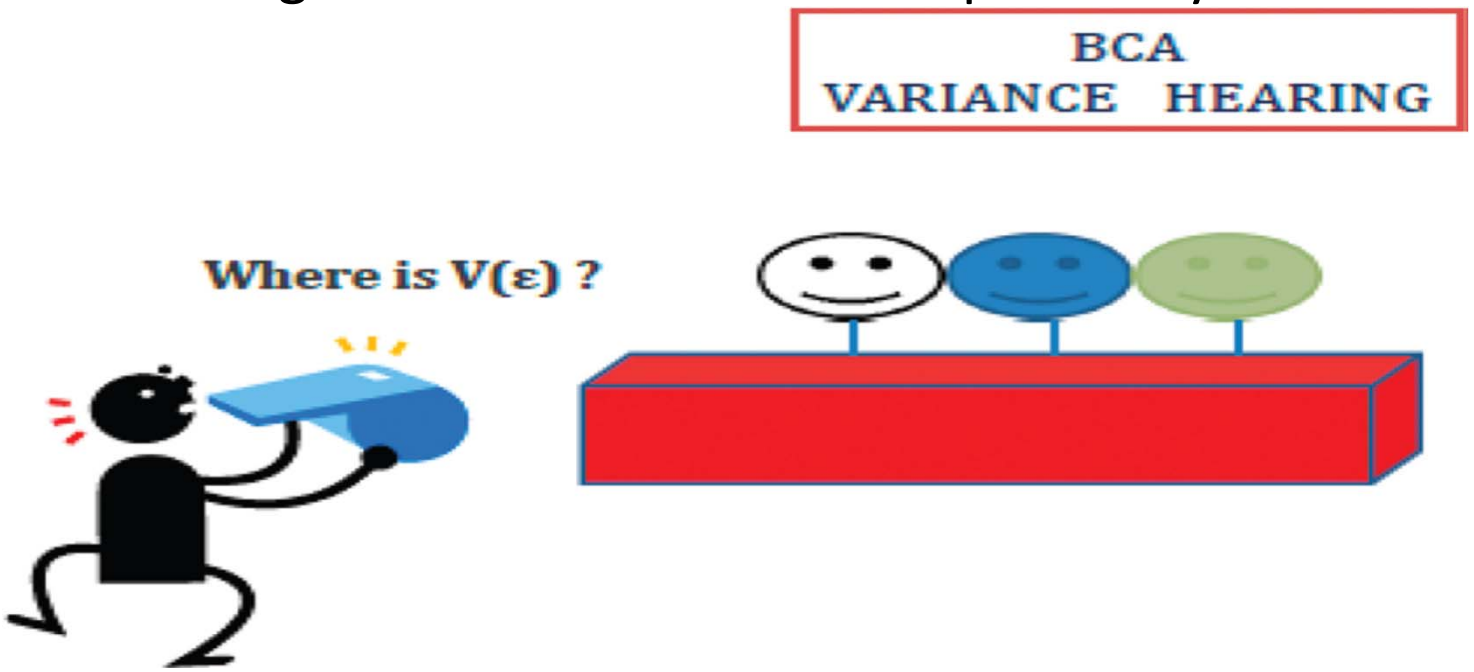
Challenges with empirical randomness
Static and dynamic stochasticity

- Static (variability in parameters)
  - Simulation: now a standard approach to random parameters and variability
    - Implementable on advanced platforms and in Excel
    - Acceptance still slow as standard practice? Issues in choice of statistical distribution and correlations (independence usually assumed)
    - Harder for GE models
  - Omitted variables: "When is some number better than no number". Have we avoided some of the hard shadow price challenges which if omitted, create bias?
- Dynamic
  - Micro capital investment much more standardly considers a real option approach when stochastic information arrives over time and there are irreversible commitments (as seems common).
  - But if randomness is not acknowledged at the static level its hard to consider dynamic randomness

Example: Pure error

$$(2)\quad Expected\ Present\ Value\ Net\ Benefit = \sum_{i=1}^{n}\sum_{t=0}^{t=}\pi_i\left(\frac{CS_{it}+PS_{it}+GR_{it}+Ex_{it}}{D(t)}\right)+\epsilon$$

- Econometrics: what drives the standard statistics is the random error, ε.
- No consideration of random error in BCA
  - Models designed for wide range of problem, some well known some speculative
  - Missing variance of the model captured by ε



Missing error term in BCA

(Farrow, 2012)

- A possible two stage approach to an estimated error variance

1. Do Monte Carlo simulation: then model sum of squares will exist (SSM: squared deviations from mean)
2. Estimate R^2 subjectively or from literature
3. Compute estimated variance and use in 2nd stage Monte Carlo, “expands” estimates to ?better? communicate uncertainty.

$$\hat{\sigma}^2 = \left(\frac{1 - \hat{R}^2}{\hat{R}^2} \right) \frac{\text{SSM}}{N}$$

Concluding observations I

- Surprise at lack of completed BCAs for J. of Benefit-Cost Analysis
- Issues of risk, broadly conceived, occur from meta choice to detailed implementation
- My personal favorites for attention for *Applied BCA for government policy* (basic research is another category)
  1. More imaginative, expansive and relevant shadow price thinking (unemployment is one example, but ed. broadly based; distribution, race instead of so many studies on recreation.)
  2. Partial and GE tools and use (revisit "no secondary impacts" in US?)
  3. Expanded use of Monte Carlo (but garbage in, garbage out)
  4. Recognition of "pure error" term
- (*Research*: positive economics of risk which behavioral econ could be)

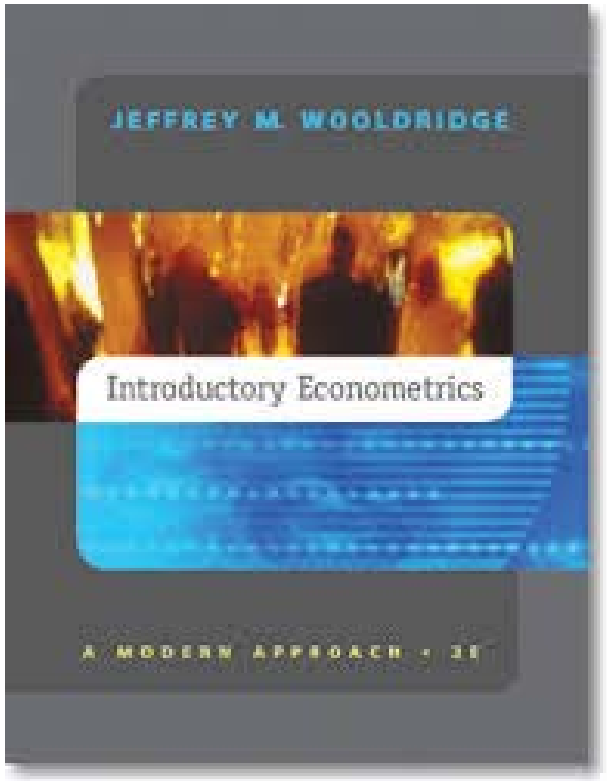
Concluding observations II

(in the hopes I'm still considered an economist)

- Request to consider personal (anecdotal) observations on issues in BCA that cause "administrative headache".
- What can we affect which causes administrative rejection or irrelevance?
  - Communicate some part in everyday language to non-economists: Economic performance (GAO) or environmental economic evaluation (WB) in place of welfare, surplus.
  - Don't let the professional ideal be the enemy of the useful and timely: The legal standard is often to not be "arbitrary and capricious". (why aren't there any economists supporting DHS risk committee?)
  - Internalize core issues into the BCA or supplemental analyses (don't let our intense debates on matters important to us distract from analyzing what is important to others). [Classic example from Banzhaf on start of VSL…..]…… Thank you!

Backup slides

- Risk assessment and risk management metrics



- USG risk management
- DHS risk management context
- Comparison of risk management models

Risk Assessment and Risk management metrics

- Separating risk assessment and risk management ?
  - Risk Assessment: Several steps lead to a quantitative estimate of risk (likelihood that harm will result).
  - Risk Management: Uses information from risk assessment along with (e.g. technical resources, social, econ, political values) to determine an action
    - But if risks are fatalities, does it matter if young, old, male, female? (implicit value issue)
    - If economic impact is XX $, does it matter the industry or who bears the cost or receives the benefit? (implicit value issue)
    - What is aggregate risk?
  - Will see “demand” for risk analytics for risk management.

USG Risk Management

- Central Government (OMB) guidance for budget submissions (A-11) (also agency specific)
  - Fairly general, except for EHS (SHE); additional guidance which “may” be suitable for other areas
- Risk Management Principles (OMB, 2007) for EHS

1. ..agencies should analyze the distribution of the risks and the benefits and costs (both direct and indirect, both quantifiable and non-quantifiable) associated with the selection or implementation of risk management strategies.

2. **In choosing among alternative approaches to reducing risk, agencies should seek to offer the greatest net improvement in total societal welfare, accounting for a broad range of relevant social and economic considerations such as equity, quality of life, individual preferences, and the magnitude and distribution of benefits and costs (both direct and indirect, both quantifiable and non-quantifiable).**

Agencies should refer to Circular A-4 for updated guidance regarding agency best practices for regulatory analysis. (OMB 2007)

DHS Risk Management context

- The safety, security, and resilience of the Nation are threatened by an array of hazards, including acts of terrorism, malicious activity in cyberspace, pandemics, manmade accidents, transnational crime, and natural disasters……. ??Are these environment, health, safety??
- Collectively, these …risks have the potential to **cause loss of life, injuries, negative psychosocial impact, environmental degradation, loss of economic activity, reduction of ability to perform mission essential functions, and loss of confidence in government capabilities.** (DHS Risk Management Fundamentals, 2011)

Threat/Hazard Type	
Animal Disease	Aircraft as a Weapon
Earthquake	Armed Assault
Flood	Biological Terrorism
Human Pandemic	Chemical/Biological Food
Hurricane	Chemical Terrorism
Space Weather	Cyber Attack against Data
Tsunami	Cyber Attack against Physical
Volcanic Eruption	Explosives Terrorism Attack
Wildfire	Dam Failure
Biological Food	Radiological Substance
Chemical Substance Spill	Nuclear Terrorism
	Radiological Terrorism

Comparison of risk management models

- My question: If senior decision-makers are asking for “risk analytics” to combine individual “risks”, in various threats, what are the assumptions of typical risk management metrics they might use?
- Assume they estimate (lots of challenges)
  - Prob and consequence (p_i, x_i) for various scenarios
  - For at least mortality, morbidity, direct economic damage (and would like psych impact and environment)
- What models might they use for risk management?

Possible models

- Impact Analysis (NEPA)
- “Std” Decision Analysis
- Advanced Decision Analysis
- “Std.” Benefit-cost Analysis
- Advanced Benefit-cost Analysis
- Economic Impact or Consequence Analysis
- Cost-Effectiveness Analysis
- Other models?

Approach: list models and key assumptions then identify where differ (not fully researched…"my recollection" which can be wrong"

- Desired endpoint: Econometrics approach of a top level of assumptions that leads to a common model

- Then alternative models when assumptions are changed.

Assumptions	Impact Analysis	"Std" Decision Analysis	Adv Decision Analysis (MCMA) ?	Std Benefit-Cost Analysis	Ad Benefit-Cost Analysis ?	Econ. Consequence Analysis	Cost-Effect. Analysis	Other models, Notes
Who has standing	US citizens or as otherwise defined	US citizens or as otherwise defined	US citizens or as otherwise defined	US citizens or as otherwise defined	US citizens or as otherwise defined	US citizens or as otherwise defined	US citizens or as otherwise defined	
Whose preferences	Not specified	Decision-maker (s)	Decision-maker (s)	Society	Society	Not specified	Society	
Independent or interdependent personal preferences	Independent	Independent	Independent	Independent	Independent	Independent	Independent	Taking account of system risk or interdependent preferences
Extent of economic interaction across markets	None	Limited	Limited	Usually limited but can be large	Usually limited but can be large	Often large, General Eq.	Usually limited but can be large	
Time	Unlikely to discount	Constant discounting or no discounting	?	Discounting (constant)	Variable discounting	System dynamics/resiliency		
Risk Analysis metric (s)	Impacts in natural units	Expected Value	Weighted cardinal utility, non-expected utility	Monetized social expected net present value ESNPV	Risk preference adjusted ESNPV	Impacts in monetary units valued at price	ESPV cost per unit (issue with multiple outcomes)	Movement toward estimation of statistical distribution of outcomes

Where do summaries come from? Still in progress. DCI for BCA

Appendix 2: Assumptions for deterministic(standard) benefit-cost analysis

Based on the first and second theorems of welfare economics being correct: 1) A PC society will be Pareto Optimal, 2) PO point is not unique.

Topic	Assumptions	Notes/Source
Consumer preferences and optimum	"Rational" Complete ordering Transitive Continuous Non-satiation Individual (no inter-personal utility) Max utility subject to budget constraint	
Firm optimum	Given production function Input prices Output price Max profit	
Government	Responds to market failures including public goods; access to either lump sum or optimal taxation	Marginal Excess burden of taxation used as a shadow price; can create compensation.
Nature of goods or services	Homogenous goods, no externalities (see 2nd best), no taxation that distorts markets.	
Time	Discount at a constant rate	Dispute whether risk free, opportunity cost, uncertain, or adjust benefits and costs for risk preferences and social rate of time preference (see risk below)

Topic	Assumptions	Notes/Source
Social welfare function	Additive in individual utility dW/dUi = a (constant and uniform) dUi/dYi= b (marginal utility of income a constant and uniform) dUi/dUj = 0, no interpersonal utility	
Typical decision context: choosing among several alternatives with no budget constraint	Undertake the alternative with the largest PVNB.	Other cases with budget constraint, different scales of activity, etc lead to different decision rules (e.g. rank by B/C ratio; equate MSB=MSC)
Risk and uncertainty	Standard: none Advanced: several places 1. Indiv preferences (risk averse) for risk utlity 2. Variability over parameters. 3. Social welfare function (Arrow and Lind: EV) 4. Discounting: riskless (pure rate of time pref) if indiv risked; USG, risk based 7% real.	
Scope of analysis (partial or general equilibrium)	Include those actions where dQi/DPj not equal to zero (could lead to partial or GE analysis)	

Assumptions	Impact Analysis	"Std" Decision Analysis	Adv Decision Analysis (MCMA) ?	Std Benefit-Cost Analysis	Ad Benefit-Cost Analysis ?	Econ. Consequence Analysis	Cost-Effect. Analysis	Other models, Notes
Risk Management metrics or decision rules	Decision-maker or stakeholders apply mental model to aggregate	Choose highest EV, EU (Health EQALY as special case?)	Highest expected utility	Choose largest sum of "surplus" as EV.	Choose largest sum of "surplus as EV.	GDP and possibly other dimensions	Choose least cost (benefit assumed)	
Risk preference	Not specified	Risk neutral or risk values of DM	Risk neutral or risk values of DM	Risk Neutral	Risk pref. of consumers and/or DM	Risk neutral	Usually risk neutral	Can apply to all of consumers, producers, DM
Aggregate preferences	Typically, adding up of natural units; impact may be distributiona l info.	None	None or Some group approache s	Risk (and distribution) neutral	Distributionally weighted	Adding up of dollar impacts with other dimensions as mental model?	?	
Determination of weights	None	DM weighted	DM weighted	"crowd weighted" Dollar weighted by surplus	"crowd weighted" Dollar weighted by surplus	Dollar weighted by price	DM (or expert) weighted	
Objective (implicit or explicit)	Not specified	Max EV	Max EU (or non EU approache s)	Max expected total surplus	Max risk adjusted total surplus	Max expected dollar value	Min Cost	

Assumptions	Impact Analysis	"Std" Decision Analysis	Adv Decision Analysis (MCMA) ?	Std Benefit-Cost Analysis	Ad Benefit-Cost Analysis ?	Econ. Consequence Analysis	Cost-Effect. Analysis	Other models, Notes
"Rational" or "Behavioral"	Not specified	Rational	Behavioral	Rational	Rational (starting behavioral)			Non-rational pref; cumulative prospect theory, Welfare analysis compared to a Norm; more detailed behavior such as "amplification"
Social welfare function	Not specified	None?	None?	Additive, unweighted	Additive, weighted		Least cost of reaching given objective (or most output for given budget)	

Current summary

- Primarily differ
  - Whose values are being analyzed? (Decision-maker, public)
  - Risk metric: Natural units, EU, Esurplus (present value), Income
  - Aggregation (SWF): Explicit, implicit
- How to make analytic choices clearer for decision-makers.
- Trying to produce that econometrics sequence of assumptions.

Challenges: Objective function and decision

- Objective function and decision criterion
  - Largest EPVNB: standard (PV issues later)
    - Implies unlimited budget, mutually exclusive choices and large risk sharing.
  - Many (most?) Government decisions are budget constrained…risk of wrong model without constraint?
    - Budget constraint: shadow price of budget; acceptable projects EPVNB > 0;…too low a bar
  - Dynamic uncertainty and irreversible risk:
    - Real options: Max stochastic EV
    - Decision rule incorporates learning about stochastic process, more cautious to enter (acting must also cover cost of option value)
  - Decision-maker risk preferences with BCA:
    - Present simulated distribution of PVNB results, D-M apply their risk preferences to the aggregate, monetized values.