Characterizing Social Preferences for Health and Environmental Risks

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Risk Assessment & Risk Management

Risk Assessment

- Identify and characterize risk
  - Human health, ecosystems
- Dependence on exposure to hazardous agent
  - Quantity, timing, exposure to other agents
- Variability (differential susceptibility)
- Uncertainty

Risk management

- Decision making & tradeoffs
  - Improvement on some attributes (risk), decrements on others (costs)
  - Benefits to some, harms (forgone benefits) to others

Outline

Example: alternative bus fuels

Economic evaluation: BCA, CEA, & alternatives

Costs & benefits (health)

Uncertainty & value of information

Example: Urban Bus Fuels

Diesel vehicles are major source of urban air pollution

Many cities switching to

- Emission controlled diesel (ECD)
- Compressed natural gas (CNG)

Should they? To which alternative?

J.T. Cohen, J.K. Hammitt, and J.I. Levy, “Fuels for Urban Transit Buses: A Cost-Effectiveness Analysis,” *Environmental Science and Technology* 37: 1477-1484, 2003.

Qualitative Ranking by Attribute

(1 = best)

	Cost	PM	Cancer	Ozone	Climate (CO_2, CH_4)	Safety (fire)	Other
CD	1	3	3?	3	1	1	?
ECD	2	2	2?	2	2	1	?
CNG	3	1	1?	1	3	2	?

No alternative dominates; need to quantify tradeoffs

Incremental Benefits & Costs v. CD

($1,000 per bus-year)

	Cost	PM	Cancer	Ozone	Climate	Other	Net
ECD	-1.7	3.4	0.2	0	4×10^{-6}	?	1.9
CNG	-18	4.3	0.4	0.5	-3×10^{-5}	?	-12.8

Cost and PM dominate

Cancer, ozone, climatic effects negligible

Uncertainty: magnitudes, other effects?

The Risk-Management Problem

Balance

- Benefits of action
  - Reduced target risk (avoided damages)
  - Ancillary benefits
- Costs of action
  - Opportunity cost (forgone benefits)
  - Countervailing risks

Complications

- Uncertainty
  - Weigh benefits and costs by probability of occurrence
  - Value of information – increase chance of choosing decision that is actually best
- Distribution across population

Distribution: Tradeoffs Among People

Fundamental question of social policy:

When is it permissible to impose harms on some (or to forgo benefits to some) to benefit others?

Economics assumes there is no objective method to compare incremental effects on individual utility or well-being

- Who suffers more from the "same" level of pain?

Practical methods for interpersonal comparison

- Money → Benefit-cost analysis (BCA)
- QALYs → Cost-effectiveness analysis (CEA)

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Benefit-Cost Analysis (BCA)

- Benefits and costs measured in a common unit, typically monetary
  - Defined by willingness to pay for benefit, willingness to accept compensation for cost / harm
- Allows identification of the “optimal” level of control
- Benefits and costs may be difficult to measure in monetary units
- Non-quantifiable factors may receive inadequate attention

Cost-Effectiveness Analysis (CEA)

Benefits measured in some "natural" unit

- Health effect (e.g., "lives saved," asthma cases)
  - QALYs, DALYs
- Exposure (e.g., peak ozone concentration)
- Emissions (e.g., tons of NOx)

Allows comparison of costs per unit benefit (efficiency)

Judgment of whether benefits justify costs (and optimal level of control) is external to analysis

Justifications for BCA or CEA

Kaldor-Hicks compensation test

- If value of benefits exceeds value of harms, winners could compensate losers leaving everyone better off
- Compensation not necessary; better accomplished through tax system

Utilitarian

- Monetary values (or QALYs) approximate equivalent changes in utility

Coherence

- If BCA or CEA routinely used, winners and losers average out and all are better off in long run
- Compared with what alternative decision rule?

Alternatives to BCA / CEA

- “Policy Heuristics:” useful, but incomplete & potentially misleading
- Sustainable development
- Precautionary principle
- Technology standards (e.g., BACT, ALARA)
- "Single-factor" approaches
  - Acceptable risk (negligible benefit)
  - Worst-case analysis (or best-case analysis)

Sustainable Development

"Sustainable development seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future"

- Our common future: The World Commission on Environment and Development (Bruntland report, 1987)

What specific guidance?

- No use of exhaustible resources?
- No loss of opportunities for production (i.e., no net loss of environmental + physical + human capital)?
- John Locke – one may take from nature as long as he leaves as much and as good for others – is this realistic?

Precautionary Principle

"A precautionary approach ... may require action ... even before a causal link has been established by absolutely clear scientific evidence."

- Ministerial declaration on protection of the North Sea, 1987

How precautionary?

- "Where potential adverse effects are not fully understood, the activities should not proceed"
  - UN World Charter for Nature, 1982
- Countervailing risks – against which risk should we exercise precaution?
  - Nuclear power – waste, proliferation v. climate
  - Diesel, gasoline, CNG motor vehicles – fine particulates, CO_2

Technology Standards

BACT: Best available control technology

ALARA: As low as reasonably achievable

Questions:

- Definition of "available," "reasonably achievable"
  - Implicit balancing of costs, countervailing risks?
- What if risk, after control, exceeds benefit of product?

“Single-Factor” Approaches

- Probability: “acceptable” or *de minimis* risk
  - 1 in a million (per lifetime)
  - Exposure below limits of detection
- Consequence: worst-case analysis
- Guidance based on only one factor is generally inadequate
  - Low-probability risks are worth reducing, if the cost is small enough
  - High-consequence risks are worth running, if the probability is small enough

Probabilities Alone are Inadequate

- Probability of a serious automobile accident is very small (1 per 1 million trips)
  - Almost every time we fasten a seatbelt, we are wasting our time

Consequences Alone are Inadequate

"Worst-case analysis is limited only by our imagination" – Lester Lave

- For want of a nail, a horseshoe was lost, a knight was lost, a battle was lost, a kingdom was lost

Palsgraf v. Long Island Railroad (1928)

- A railroad worker helped a man rush aboard a departing train, who dropped his package, which contained fireworks, which exploded, which knocked over a scale far down the platform, which fell on and injured Mrs. Palsgraf
- Judge Cardozo wrote for the 5-4 majority that injury was not "reasonably foreseeable" and so LIRR was not liable

Comprehensiveness & Complexity of Analysis

Consequences of regulation can affect many economic sectors, far into future

- “When we try to pick out anything by itself, we find it hitched to everything else in the universe.” – John Muir

Which effects must be included in analysis?

- Those that are quantitatively significant

Sequential analysis

- Begin with "back of envelope" calculation
- Consider refinements
  - Test whether they may affect result (bounding analysis)
  - Include if (and only if) they do affect result

Description v. Prescription

- BCA justified as describing whether a population judges itself better off with, or without, a project
  - Benefits & costs based on individual preferences
  - "Objective" risk assessment
- Individual behavior and perceptions sometimes inconsistent with economic model
  - Cognitive errors or richer conception of issue?
- How should BCA incorporate departures from model?
  - Populism v. paternalism?

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Costs & benefits (health)

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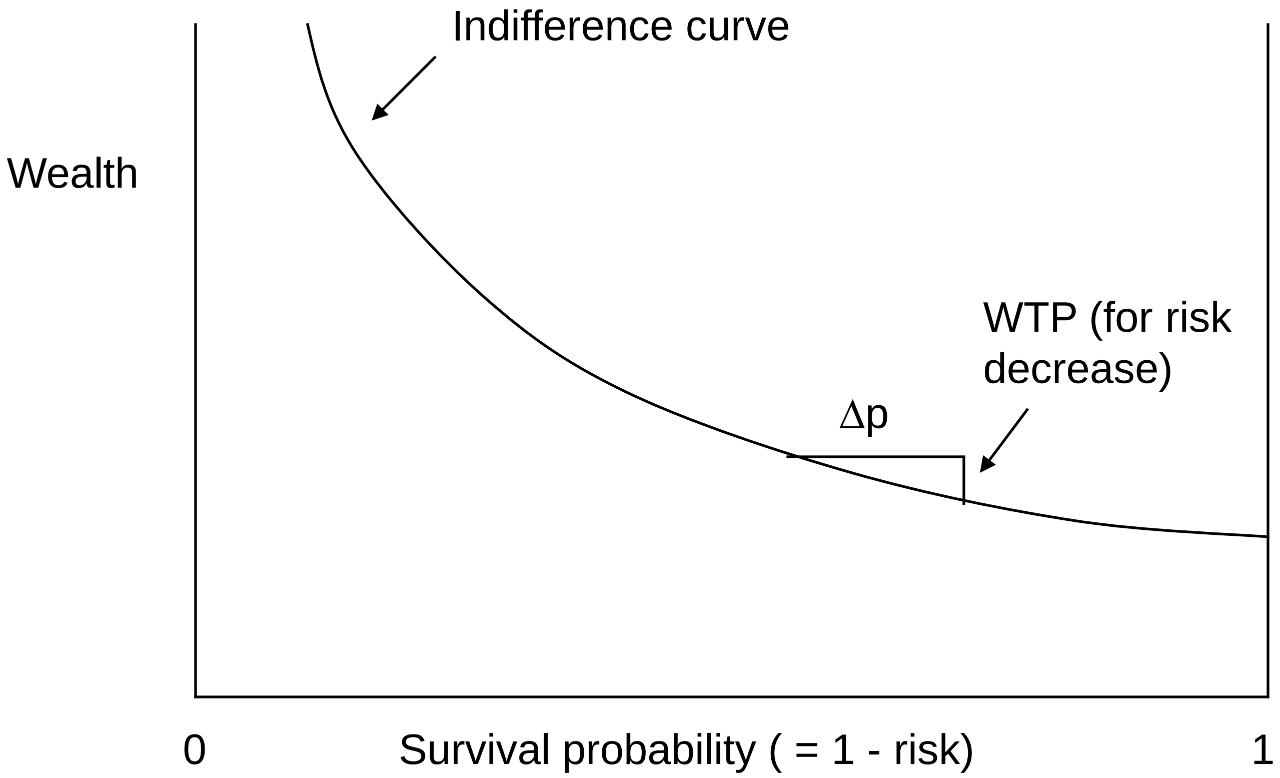
Costs

- Real resource costs
  - Value of the resources consumed by the activity
  - Value determined by opportunity cost
    - Value of use in best alternative
- Transfers
  - Cost to one party, but benefit to another
    - Taxes
    - Economic rents (e.g., monopoly profits)

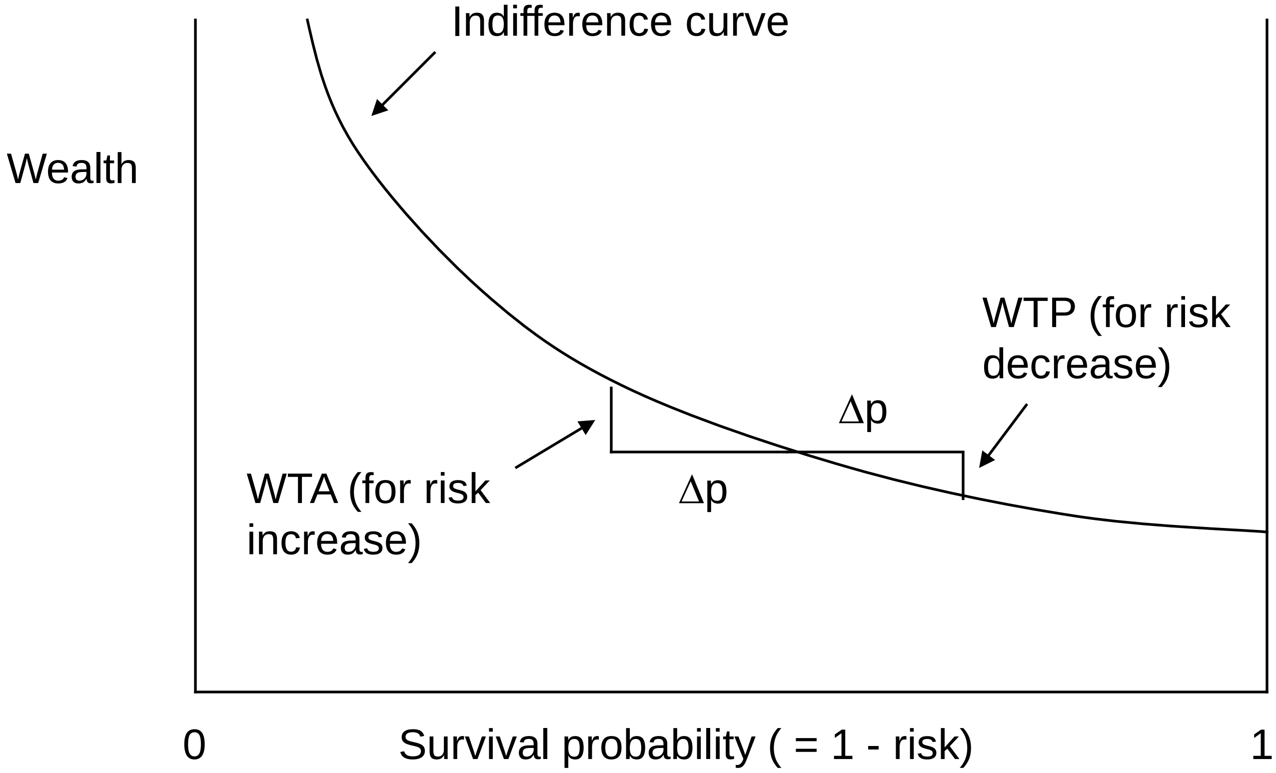
Benefits: Human Health Risk

- Monetary values
  - – Private willingness to pay (WTP) or willingness to accept (WTA)
  - – Supplemented by public resources costs (e.g., insured medical care)
  - – Usually money value of small change in risk (e.g., value per statistical life)
- Quality-adjusted life years (QALYs)
  - – Disability-adjusted life years (DALYs)

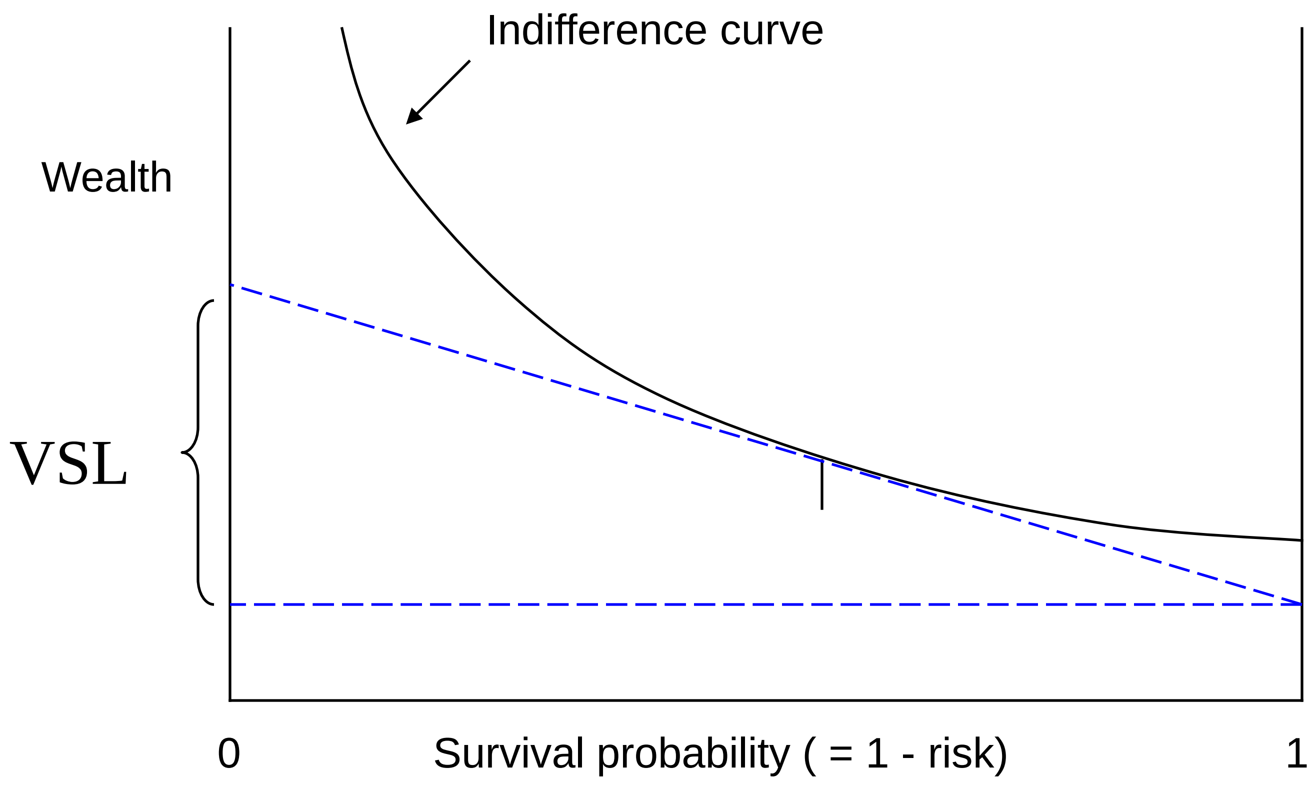
$$VSL \approx \frac{WTP}{\Delta p}$$



$$VSL \approx \frac{WTP}{\Delta p} \approx \frac{WTA}{\Delta p}$$



VSL = slope (local approximation)



Value per Statistical Life

- Is NOT a measure of the intrinsic worth of an individual
- Does NOT measure what an individual would pay to avoid certain death (or accept as compensation for certain death)
- Depends on
  - (total) baseline risk
  - income and wealth
- May depend on other characteristics of risk
  - e.g., acute trauma or chronic disease
  - "Voluntary," "controllable," "dread"

Quality Adjusted Life Years

- "Health profile" = a time path through various "health states"
- Utility of a health profile
  - = time spent in each health state weighted by quality of stated
    - Perfect health: q = 1
    - As bad as dead: q = 0

QALYs Impose Strong Constraints on Preferences

Utility (quality) of a health state is

- Independent of its duration
- Independent of previous (and subsequent) health states

Improvement in health for rest of life is worth the same fraction of remaining life expectancy

Risk neutral over gambles on length of life

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Expected Values

Humans dislike risk & ambiguity

Should we take greater precaution when probabilities are uncertain?

Perils of Prudence

(Nichols & Zeckhauser 1986)

Conservative assumptions, worst-case analysis, risk & ambiguity aversion can increase risk

Technology	Deaths	Probability	Expected deaths
Ambiguous	1	0.99	
	1,000	0.01	11
Certain	101	1.0	101

Using upper-bound risk estimates, Certain would be preferred to Ambiguous

Perils of Prudence

If decision is repeated for 10 pairs of technologies (and risks are independent)

Technology	Deaths	Probability
Ambiguous	10	0.904
	< 1,010	0.996
Certain	1, 010	1.0

Policy of choosing Certain (with smaller upper-bound risk) is almost sure to kill more people

Value of Information

For each of 10 technologies, learn true number of deaths for ambiguous type

- Choose ambiguous if it causes 1 death
- Choose certain otherwise

Choice	Expected deaths
Ambiguous (always)	110
Certain (always)	1,010
Perfect information	20
Expected value of information	90 lives saved

Quantifying Uncertainty: Probability

Probabilities of health risks are "subjective"

- Often extrapolated from animal experiments or observational human data
- Quantitative measure of degree of belief
- Individuals can hold different probabilities for same event

There is no "true" probability

All probabilities are subjective

- "Objective randomness" is not random but chaos (e.g., coin toss, roulette wheel)
  - Deterministic process
  - Sensitively dependent on initial conditions (butterfly flapping wings in China may cause hurricane in Atlantic)
- Insufficient information about initial conditions

Disagreement Among Experts

- Individuals can hold different probabilities
  - Inadequate evidence to choose among them
- As evidence accumulates
  - Experts should update their probabilities
    - "When somebody persuades me that I am wrong, I change my mind. What do you do?" - John Maynard Keynes
  - Ultimately, probabilities should converge
    - Coin toss, roulette wheel
    - "In the long run we are all dead."- John Maynard Keynes

Value(s) of Better Information

- Increase chance of choosing decision that is best (or not bad) for actual conditions
  - "Expected value of information" in decision theory
- Overcome burden of proof needed to depart from status quo policy or default assumption
  - Compensate for decision rule that does not maximize expected value of outcome
- Reassure decision makers and affected public that decision is appropriate
  - Enhance compliance, minimize opposition & legal challenges
  - Incorporate compliance and challenges as factors in analysis?

Expected Value of Information
(Decision theory)

Decision making under uncertainty: "act then learn"

- For some realizations, best ex ante act A* is not best ex post
- (good decision v. good outcome)

With better information: "learn then act"

- Choose the act A_c that is best for the realization c

Expected value of information = expected improvement in consequences (e.g., net benefits)

- Improvement in outcome by choosing act A_c that is best for realization c rather than the act A*,
- weighted by the probability of realization c
- Summed over all possible realizations of uncertainty

Ex ante, collecting information that cannot lead to change of decision has no value

- If A* will be chosen for all realizations, no value of information

Value of Information Heuristics
(Hammitt & Cave 1991)

Expected value of information about a parameter is likely to be greater when

Uncertainty about the parameter is greater

Research is more *informative*

- Reduces uncertainty more

Alternative decisions are more *promising*

- Better than A* for probable realizations

Value of the parameter is more *relevant* to decision

- Best decision is sensitive to parameter value
- When risk is product (e.g., emissions x exposure x toxicity) all factors are equally relevant

Note: heuristics work best when net benefits of each decision are linear functions of uncertain parameters

Value of Information Limitations

- Expected value of information is highly sensitive to the decision problem
  - Set of decision options (acts)
  - Consequences (e.g., population affected, time horizon)
- VOI may increase or decrease with
  - Uncertainty
  - Adding or removing decision options
- Often hard to foresee decision problems to which information may contribute
  - How many regulations or locations may be affected?
  - Basic research

Conclusion: Benefits of BCA & CEA

Cognitive aid to decision making

- Framework for comprehensive accounting of all important consequences, not only salient ones

Transparent accounting framework

- Significant consequences, magnitudes, probabilities, valuation must be specified, open to review
- Limits of knowledge are (should be) explicit

Populist basis

- Principled method to account for everyone's preferences
- Values (of health, environmental quality, etc.) based on individuals' preferences