Benefit-cost-risk analysis for evaluating social responsibility

James K. Hammitt

Harvard University (Center for Risk Analysis)

Toulouse School of Economics (LERNA-INRA)

Socially Responsible Investment

- (Some) investors wish to align corporate behavior with (their view of) social values
- (Partial) substitute for government laws & regulations
  - More responsive to new information
    - Consumer boycott of CFC aerosol sprays
    - Contaminated food incidents
  - Different allocation of influence
    - Investors vs. voters, political parties, etc.
- What are social values?
  - In a particular instance?
  - *Tradeoffs are everywhere – how to determine net effect?*

Outline

Example: alternative bus fuels

Economic evaluation: BCA, CEA, & alternatives

Uncertainty & value of information

Social costs

Misconceptions

Diesel v. CNG

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?

Are firms that produce or operate conventional diesel buses socially responsible?

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							
ECD							
CNG							

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 Costs (vs. CD)

($ per bus per year)

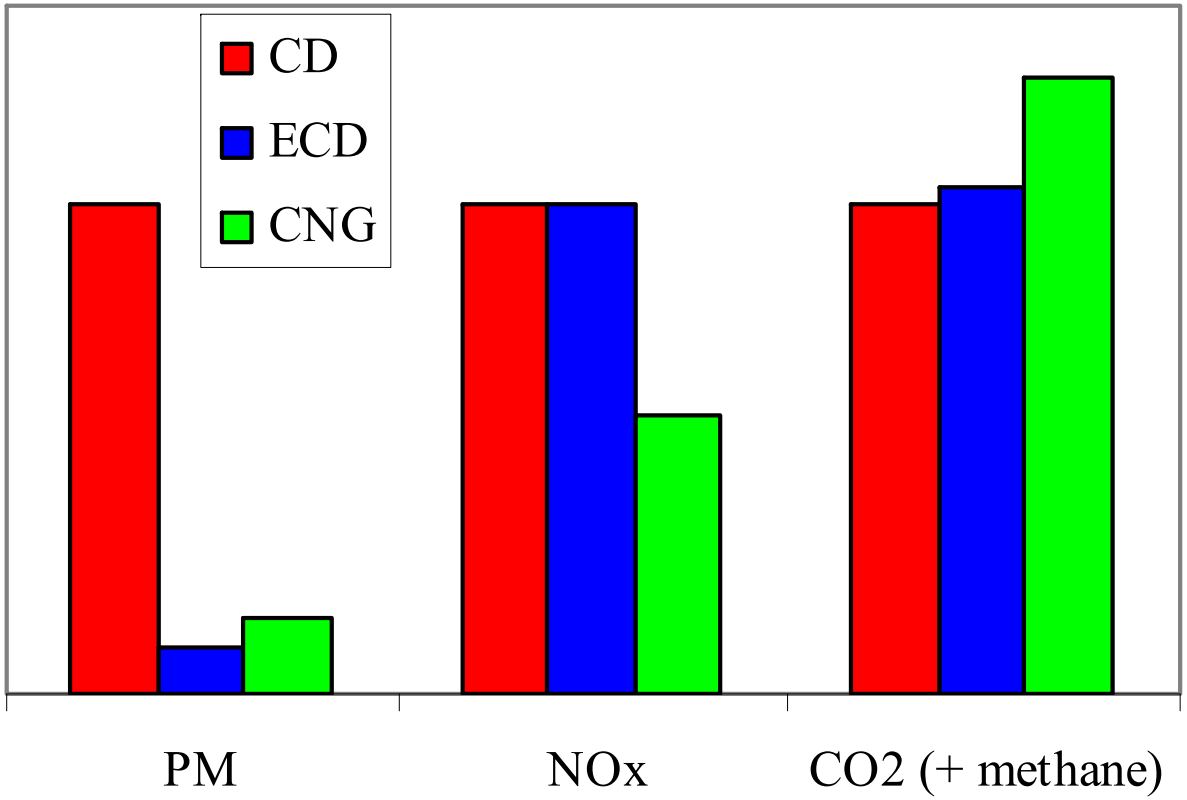
Cost component	ECD	CNG
Bus	750	2,800
Fuel	800	3,200
Fueling station	0	3,600
Maintenance		
Bus	130	6,000
Fueling station	0	2,300
Total	1,700	18,000

Health Effects

Expected cases = function of

- Emissions of pollutants
- Effect on atmospheric concentrations and human exposure
- Exposure-response function

Emissions (in-use plus fuel-cycle)



Health Effects

(per 1,000 buses per year)

Health effect	CD	ECD	CNG
PM			
Mortality	0.91	0.34	0.32
Cancer	0.07	0.03	0
NOx			
PM mortality	0.33	0.33	0.21
O_3 mortality	0.20	0.20	0.12
Expected deaths	1.51	0.90	0.65
Range	0.06 – 1.64	0.05 – 0.95	0.03 – 0.75
Asthma cases	1.2	1.2	0.8

Value of Health Effects

To compare with costs of control

- Willingness to pay (WTP) per statistical case
  - Value per statistical life (VSL)
- QALYs lost per case
  - Quality-adjusted life years

Monetary Value of Health Effects

(per 1,000 buses per year)

	CD	ECD	CNG
Deaths	1.51	0.90	0.65
x VSL ($6 million)	9.1 M	5.4 M	3.9 M
Asthma cases	1.2	1.2	0.8
x Value per case ($25k)	30k	30k	20k
Total ($)	9.1 M	5.4 M	3.9 M

Incremental Benefits & Costs v. CD
($ thousands 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

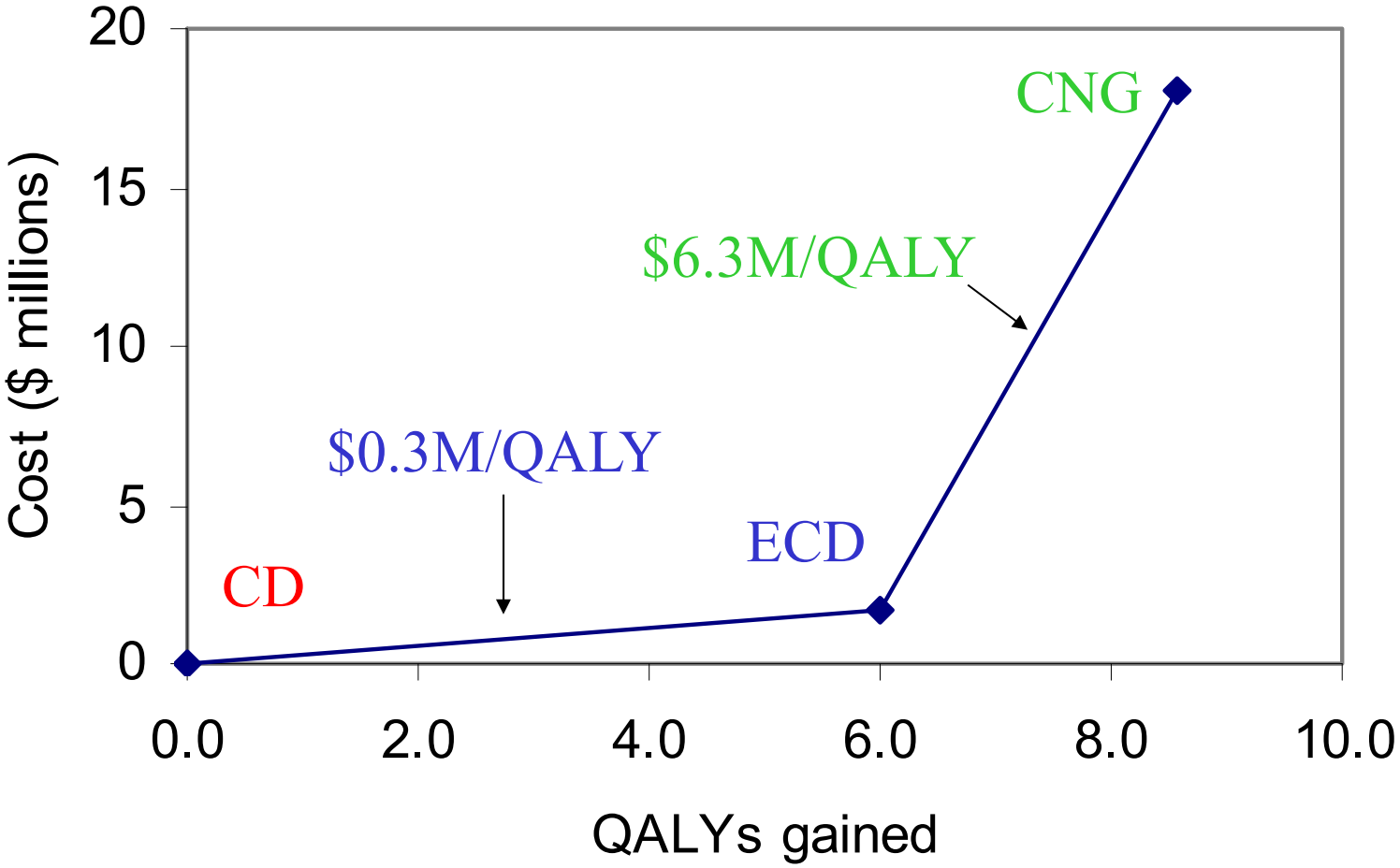
Uncertainty: magnitudes, other effects?

QALY Value of Health Effects

(per 1,000 buses per year)

	CD	ECD	CNG
Deaths	1.51	0.90	0.65
x 10 QALYs / death	15.1	9.0	6.5
Asthma cases	1.2	1.2	0.8
x 0.25 QALYs / case	0.3	0.3	0.2
Total	15.4	9.3	6.7

Cost Effectiveness



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 best for actual conditions
- Distribution across population

Distribution: Tradeoffs Among People

Fundamental question of social policy:

When is it permissible to inflict harm 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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Types of Analysis

Economic evaluation
- Benefit-cost analysis
- Cost-effectiveness analysis

Risk analysis
- Risk assessment, management, perception & communication
- Comparative risk analysis
- Risk tradeoff analysis

Others
- Life-cycle analysis
- Health-health analysis
- Multi-criteria analysis

Public or private perspective

Benefit-Cost Analysis (BCA)

Benefits and costs measured in a common unit, typically monetary

Allows identification of the “optimal” level of control

Some benefits & costs may be difficult to measure in monetary units

Non-quantifiable factors may receive inadequate attention

Cost-Effectiveness Analysis (CEA)

- Benefits measured in “natural” (non-monetary) units
  - Health effect (e.g., "lives saved," asthma cases averted)
    - QALYs, DALYs
  - Exposure (e.g., peak ozone concentration)
  - Emissions (e.g., tons of CO_2)
- 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

Consistency

- 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 change
  - Diesel, gasoline, CNG motor vehicles – fine particulates, ozone, climate

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 risk, *de minimis* risk
    - 1 in a million (per lifetime)
    - Exposure below limits of detection
- Consequence
  - Worst-case analysis
  - Knee-of-the-curve 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

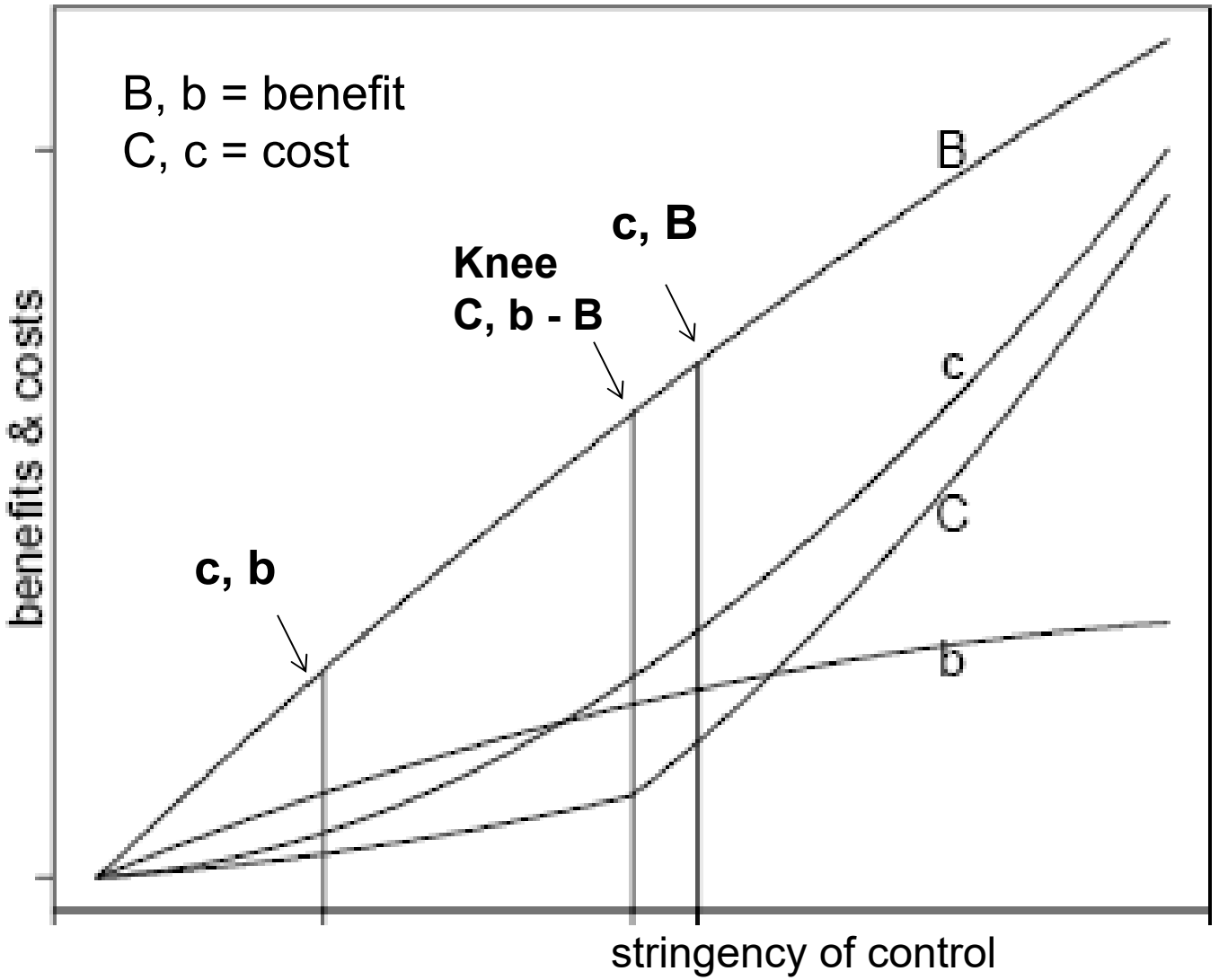
"Worst-case analysis is limited only by our imagination" – Lester Lave

- 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

Knee-of-the-Curve Analysis



Benefits & Costs of BCA & CEA

Benefits

- Cognitive aid to decision making
- Transparent accounting framework
- Populist basis

Costs

- Transparent accounting framework

Cognitive Aid to Decision Making

Framework for comprehensive accounting of all the important consequences

- Target risk, ancillary benefits, countervailing risks, opportunity costs
- Includes both probability and magnitude of effects

Alternative, holistic judgments often influenced by small number of salient factors

- Carcinogenicity of diesel exhaust (increases estimated deaths from particulate matter < 5%)

Transparent Accounting Framework

- Significant consequences, magnitudes, probabilities, valuation must all be specified
  - Assumptions & inferences are explicit, open to review, challenge, & revision
  - Decision makers cannot disguise policy choice as scientific conclusion
- Extent & limits of scientific knowledge are (should be) explicit
  - Counteract overconfidence bias

Populist Basis

- Principled method to account for everyone's preferences
  - Not just those who are politically influential
  - Not just those in the majority
- Net benefits are defined as sum over affected population
- Monetary values of health, environmental quality, other consequences explicitly based on preferences of affected individuals

Costs of Transparency?

Rationale is explicit

Cannot disguise policy judgment as scientific result

- Scientific evidence that
  - Burning fossil fuels causes global warming
  - Diesel exhaust causes lung cancer
  - Mobile phone use while driving causes traffic accidents

  does not tell us whether or how much to restrict them
- Decision requires consideration of the values of health risks, costs, other consequences

Costs of Transparency? Ford Pinto

- Small, inexpensive car sold in 1970s
- Gasoline tank in rear, susceptible to fire when hit from behind
- Ford estimates (documented in memorandum)
  - Costs of safer design = $120 million
    - $11/car x 11 million cars
  - Expected liability costs = $50 million
    - 180 burn deaths x $200,000 = $36 million
    - 180 serious burn injuries x $67,000 = $12 million
- Jury awarded $1.2 billion in punitive damages
  - No punitive damages if Ford had not considered (evaluated?) alternative design?
  - Errors of commission more reprehensible than errors of omission?
  - Survey evidence suggests public is more accepting of a decision supported by BCA (Baron & Gurmankin, 2003)

Ford Pinto - Observations

$11 cost per vehicle is to Pinto buyers

Would they view safety benefit as more valuable?

- Would they recognize safety when choosing Pinto vs. Chevy Vega?

Yes: using their values of health, benefit = $800M > cost = $120M

- 180 burn deaths x $3M = $540M
- 180 serious burn injuries x $1.5M = $270M

Note: risk of death or serious burn injury < 2 per million per year

- Acceptable risk?

Risk tradeoffs: would alternative design have increased/decreased risks in other accidents?

- Hard to make salient at trial

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?
- Examples
  - Information disclosures
  - Uncertainty aversion

Information Disclosure

Provision of accurate information generally viewed as

- Not harmful
- Possibly beneficial

Individuals may be misled

- Over-emphasize salient attributes (e.g., possibility of carcinogenesis, neglect of probability)
- Aversion to irrelevant(?) attributes (e.g., synthetic v. natural chemicals, GMOs)

Prohibiting (accurate) information disclosure may be appropriate

- Probative v. prejudicial value of evidence

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Aversion to Risk, Uncertainty, Ambiguity, & Ignorance

Humans dislike not knowing

- Risk: "objective" probabilities
- Uncertainty: subjective probabilities
- Ambiguity: unknown probabilities
- Ignorance: unknown possible outcomes

Should we take greater precaution when risks are more uncertain?

Perils of Prudence

(Nichols & Zeckhauser 1986)

Conservative assumptions, worst-case analysis, uncertainty aversion can increase risk

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

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

Perils of Prudence

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

Technology	Deaths	Probability
Uncertain	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 uncertain type

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

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

Value(s) of Information

- Increase chance of choosing decision that is best 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?

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

Expert Judgment

Risk assessment & economic models incorporate many assumptions

- Choices usually made by modelers, informed by scientific literature
- Meta-analysis can be used when literature is rich

Alternative (or complement): expert elicitation

- Experts provide probability distributions for key parameters
- Rigorous, replicable process
  - Selection of experts
  - Preparation
  - Interview

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Social 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)

Cost of Burning Gasoline
(US, 2000)

Retail price	$1.48
Crude oil (extraction, scarcity rent)	$0.68
State and federal taxes	$0.41
Refining and profit	$0.21
Distribution & marketing	$0.18
Other costs	
– Air pollution (consumption, refining)	$0.40?
– Oil spills	?
– Others?	?

Note: Data for 2000, EIA. Air pollution cost from Levy 1999, Toy 2002

Financial Cost of Environmental Risk
(Garber & Hammitt 1998)

- Superfund program holds firms liable for cleanup of hazardous-waste sites
  - Magnitude of liability resolved over many years
  - Imposes financial risk on equity holders
- Cost of capital to large chemical firms increased ~0.5-1.5% / yr (in 1980s)
- Social cost of bearing financial risk
  - ≈ $700-800 million / yr
  - Cleanup expenditures ≈ $1 billion / yr

Are Costs Overestimated? Ex Ante v. Ex Post

Putnam, Hayes, and Bartlett (1980)

- Costs overestimated by 26-156%

OTA (1995)

- emphasis on conventional rather than new technology
- "actual cost considerably less than OSHA estimates"

Goodstein and Hodges (1997)

- "reducing pollution at the source almost certain to be less costly than estimated beforehand"

Ex Ante vs. Ex Post Estimates
Harrington, Morgenstern, Nelson (2001)

Surveyed 24 case studies of individual regulations

Examined 3 outcomes

- Total cost
- Cost per unit
- Quantity reduction

Include only estimates by government agencies

Ex Ante vs. Ex Post Estimates

Harrington, Morgenstern, Nelson (2001)

Classification of Case Studies				
	Over-estimate	Accurate	Under-estimate	Unable to determine
Command & control				
Total cost	8	3	2	3
Economic incentives				
Total cost	4	2	0	2

Ex Ante vs. Ex Post Estimates

Harrington, Morgenstern, Nelson (2001)

Classification of Case Studies				
	Over-estimate	Accurate	Under-estimate	Unable to determine
Command & control				
Total cost	8	3	2	3
Quantity reduction	8	6	0	2
Per-unit cost	5	6	5	0
Economic incentives				
Total cost	4	2	0	2
Quantity reduction	1	3	4	0
Per-unit cost	7	1	0	0

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GDP measures welfare

Jobs are a benefit

GDP Does Not Measure Welfare

- GDP (Gross Domestic Product) measures total value (price x quantity) of market transactions, including
  - Environmental cleanup costs, medical treatment
  - Pollution control expenditures
- GDP does not include benefits that are not exchanged in markets
  - Improved environmental quality
  - Improved health
  - Household production
- GDP does not recognize changes in assets (stocks)
  - Depletion of natural resources
- "Green GDP" attempts to incorporate these factors

Jobs Are a Cost, Not a Benefit

Labor costs are resource costs

- Assumes workers could be producing something else

Long-run perspective

- Costs of increasing or decreasing jobs in region, economic sector, etc., viewed as transitional
- Overall employment level determined by macroeconomic conditions, not regulatory decisions

If jobs are a benefit, shouldn't we outlaw bulldozers?

Conclusion: Benefits of BCA & CEA

Systematic method to help identify social improvements

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 consequences are those of affected individuals