Risk Assessment & Risk Management

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Main Messages

Risk management requires tradeoffs among multiple (uncertain) consequences

- Need risk assessment and impact assessment (e.g., economic evaluation) to help structure and illuminate complicated choices
- Analysis must address policy options – purpose of analysis is to quantify tradeoffs among them

Risk management and risk communication must confront tradeoffs, not ignore them by oversimplification

Overview

Regulatory decisions have multiple (uncertain) consequences

- Need principled method to account for multiple factors

Economic evaluation (benefit-cost analysis)

- Comparison with alternatives
- Principles & themes
- Description or prescription?

Quantifying uncertainty with probability

Precautionary regulation

- EU – US comparison

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
- Distribution across population
  - When is it permissible to impose harms (or forgone gains) on some to benefit others?

Economic Evaluation: Benefit-Cost Analysis

Objective: determine if a population is better off with the project (and its costs) or without

Compare:

- Monetary value of benefits to "winners"
- Monetary value of harm to "losers"

If B > C, then in principle costs can be allocated so everyone is better off with the project than without it

- "Better off" is defined by the affected individuals' own preferences

Focus on size of pie, not its distribution

- Larger pie → everyone can have a bigger piece
- Smaller pie → someone must have a smaller piece

Alternatives to BCA: "Policy Heuristics"

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

Benefits & Costs of BCA

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 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 individuals

Monetary values of health, environmental quality, other non-market goods explicitly based on individual preferences

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 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

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
  - Ambiguity 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

Ambiguity Aversion

Humans dislike ambiguous (uncertain) probabilities

- Risk of bad outcome
- Risk of bad probability

Should we take greater precaution when probabilities are uncertain?

Perils of Prudence

(Nichols & Zeckhauser 1986)

Conservative assumptions, worst-case analysis, and 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

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

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 models incorporate many assumptions

- Structural
- Parametric

Choices usually made by modelers, informed by scientific literature

Alternative: expert elicitation

Expert Elicitation

Experts provide subjective probability distributions for key parameters

Can go beyond data

- E.g., probability that animal carcinogen causes cancer in humans

Rigorous, replicable process

- Selection of experts (e.g., peer nomination)
- Preparation
  - Training in subjective probability, common errors and biases
  - Discussion of key scientific literature, models
- Interview (team including elicitor & domain expert to challenge judgments)

Less credible than computer model?

- Process is too transparent?
- Computer-model assumptions are hidden

Precautionary Regulation: EU – US Comparison

Data

- Selection of risks
- Scoring

Results

- Relative precaution
- Trends

(with Jonathan Wiener, Brendon Swedlow, Denise Kall, Zheng Zhou)

Definition and Selection of Cases

Unit of analysis – "a risk that may be regulated"

- No comprehensive list

Risk matrix

- Constructed by pooling 403 lists from 252 sources (articles and reports)
- Condensed ~11,000 "verbatim" risks to 2,878 "unique" risks
- Classified unique risks by
  - Type (18 categories)
  - Endpoint (ecological, health, safety)

Simple random sample of 100 risks

- Cover 17 categories (sample missed construction risks)

Scoring of Relative Precaution

Collected information on regulations

- EU, US federal, selected EU & US member-states
- Evaluated most stringent regulations

Rated relative stringency of regulations for each risk in each year (1970-2004)

Score = sum of annual ratings

- Europe: +1, Tie: 0, US: -1
- Weighted rating by confidence level (0, 1/3, 2/3, 1)
- Weighted & unweighted scores range from –35 to +35

Relative Precaution (1970 – 2004)

Relative precaution	Weighted		Unweighted		Examples
	Risks (of 100)	Types (of 18)	Risks (of 100)	Types (of 18)	
US more precautionary	29	5	38	6	Alcohol, tobacco, drugs Environmental pollution
Equal	3	2	6	3	Financial Consumer product
EU more precautionary	68	10	56	8	War, security, terrorism Global Transportation Toxic substances

Figure 1. Trends in Relative Precaution
(all risks)

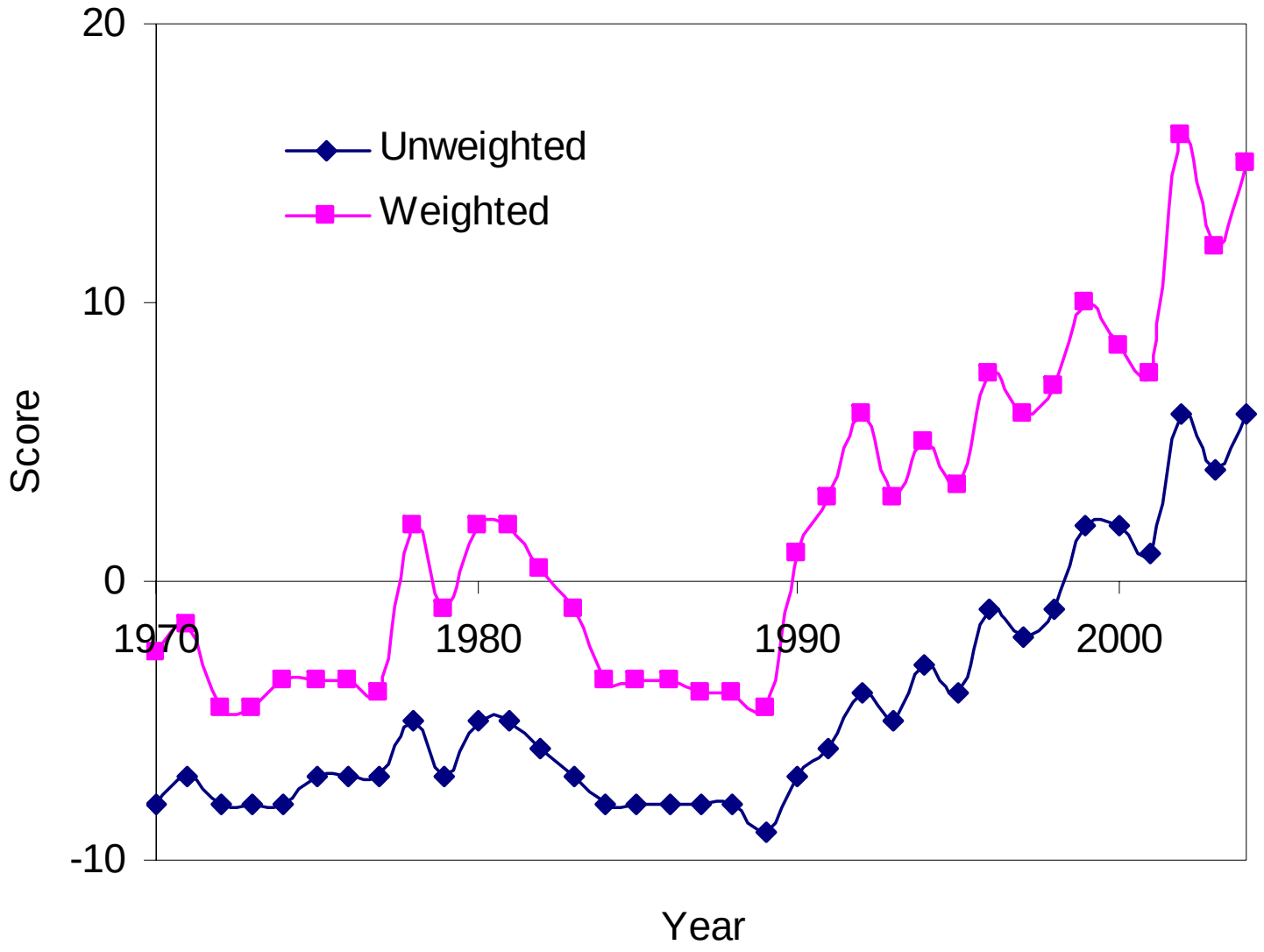
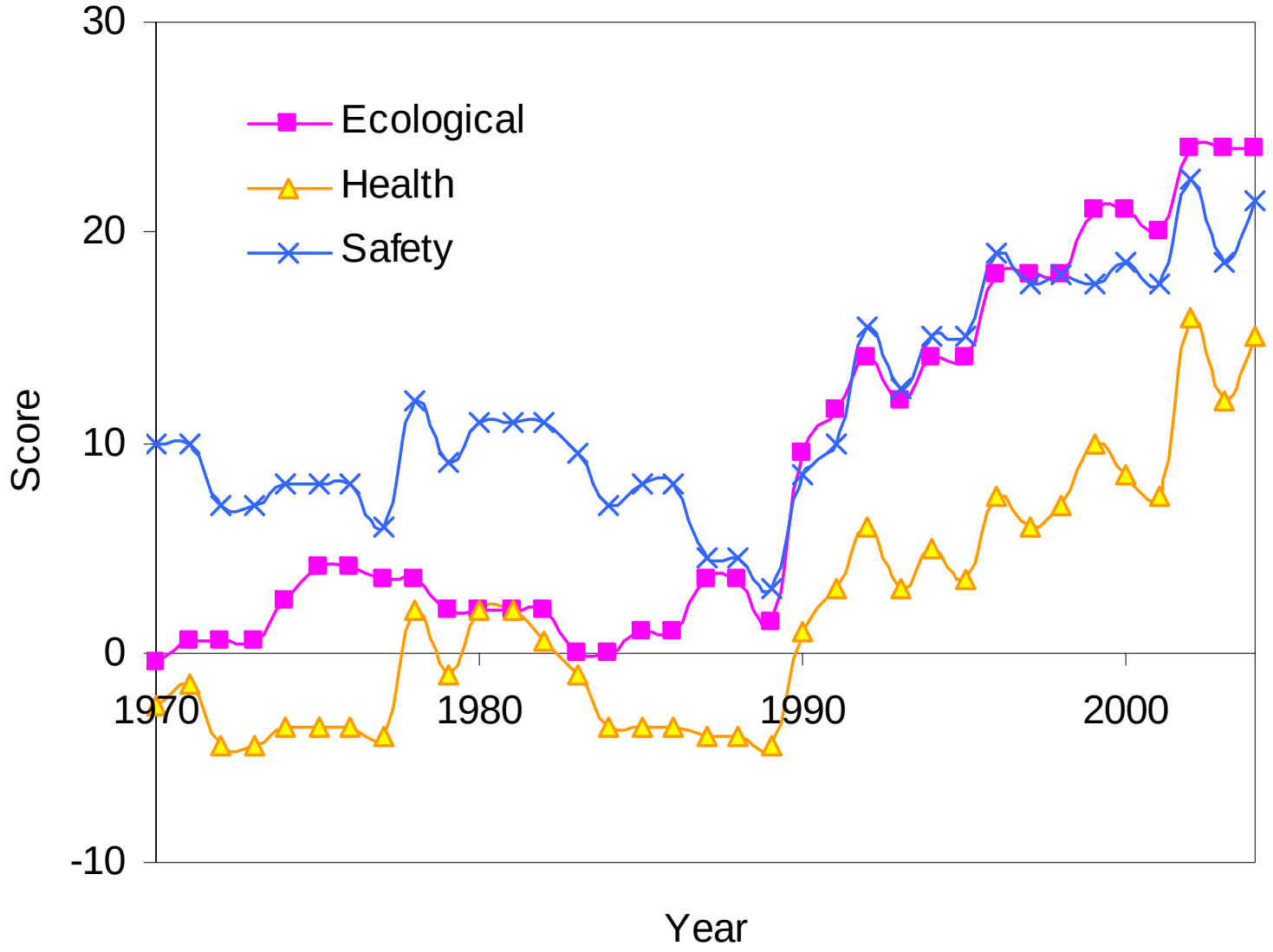


Figure 3. Trends by Endpoint Category (weighted scores)



Summary

Trends consistent with "flip-flop"

- No trend 1970 – 1989
- Shift toward relatively more precaution in EU 1990 – 2004

Diversity across risks

- Shift toward greater EU precaution: 21 risks
- Shift toward greater US precaution: 14 risks
- EU always more precautionary: 11 risks
- US always more precautionary: 9 risks