Valuing Consequences – Probabilities & Preferences

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Decision Analysis & Climate Change

Balance

- Benefits of action
  - avoided damages
- Costs of action
  - opportunity cost = forgone benefits

Uncertainty

- Weigh benefits and costs by probability of occurrence

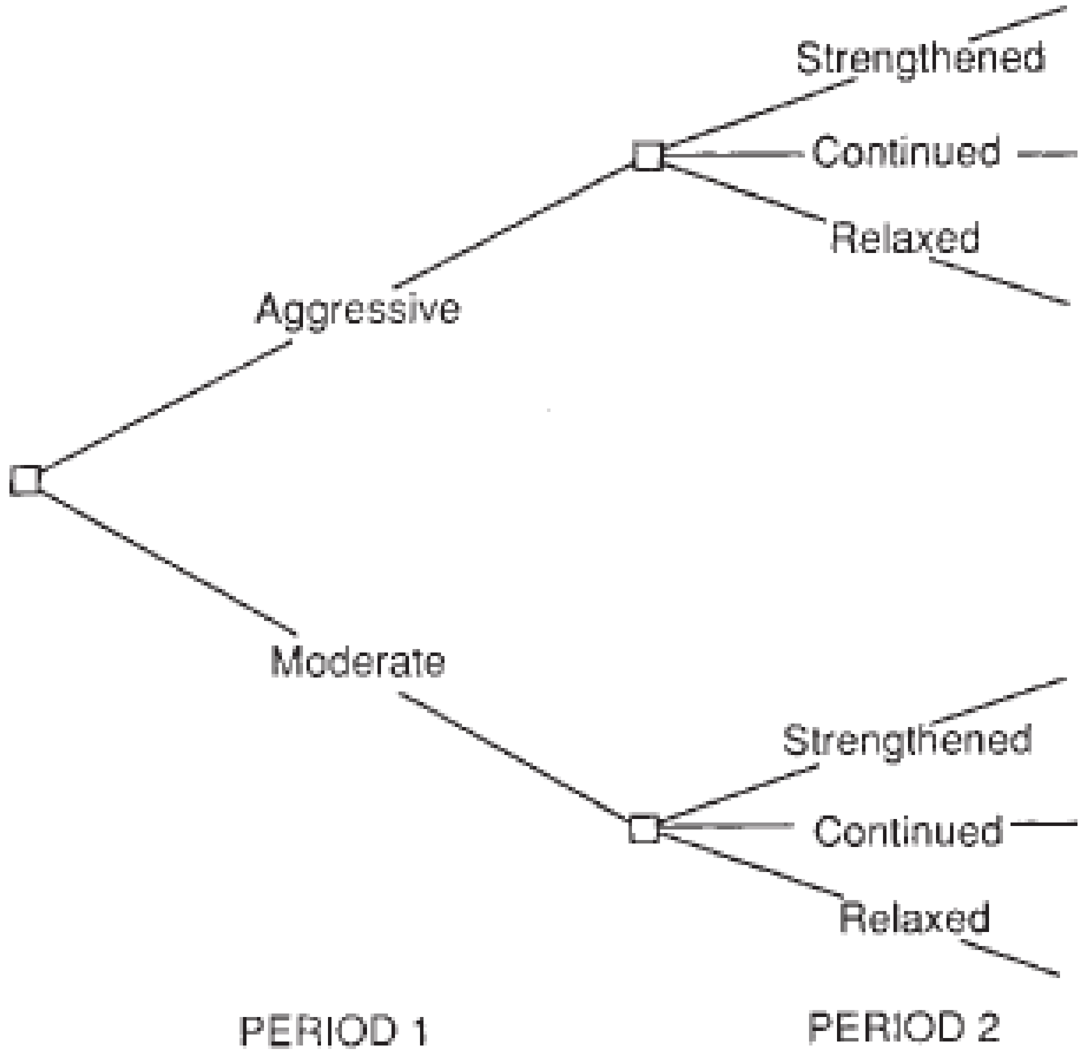
Dynamic Problem

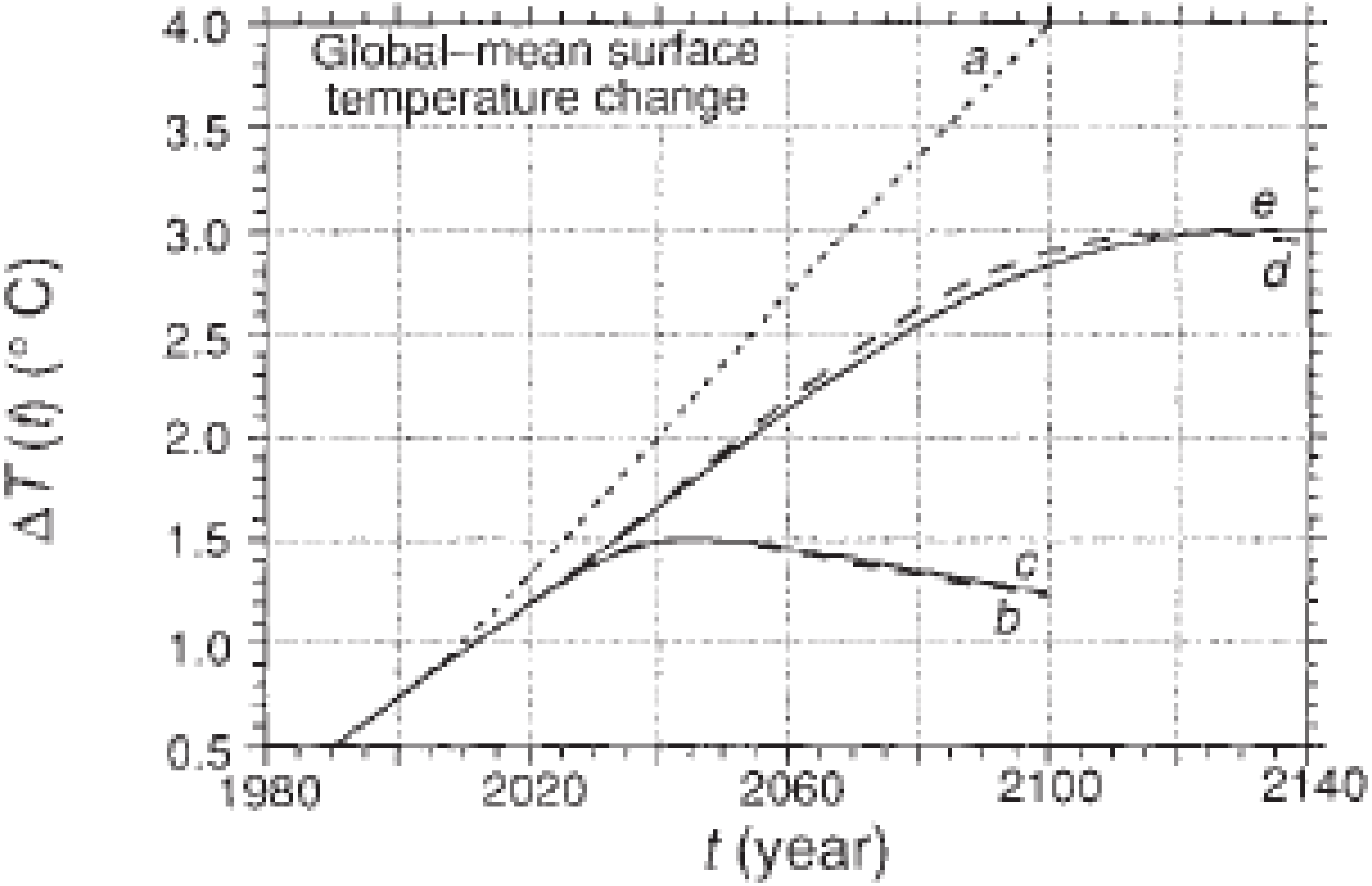
Learn, update policy over time

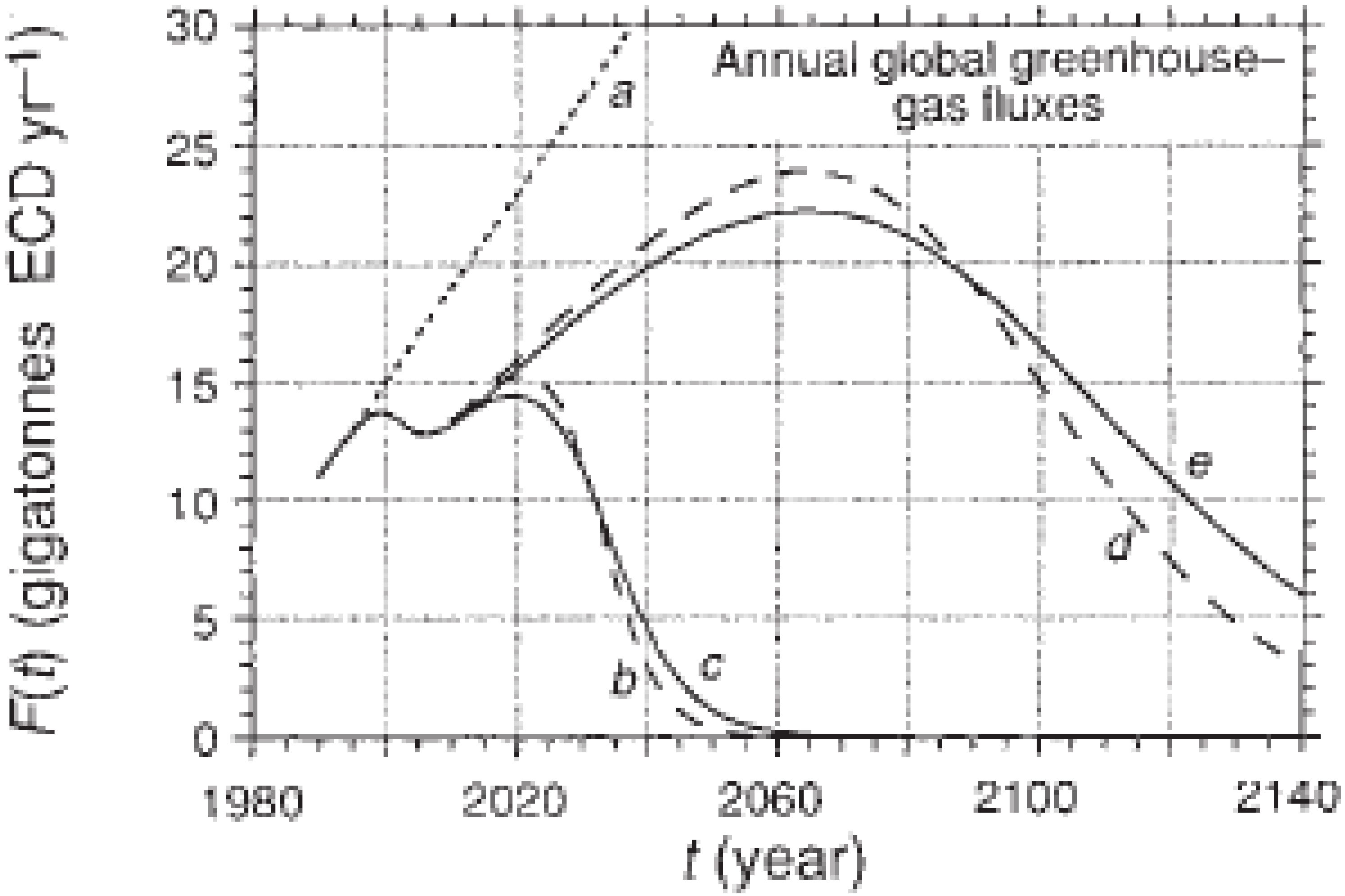
- Better-target stringency and nature of policy
- Apply new, lower-cost technologies

Persistent effects of current actions

- Low-cost actions that are forgone may require higher cost actions later
- Warming commitment


Strengthened
Continued
Relaxed
Aggressive
Moderate
Strengthened
Continued
Relaxed
PERIOD 1
PERIOD 2


Global–mean surface
temperature change
a
b
c
d
e
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ΔT (t) (° C)
1980
2020
2060
2100
2140
t (year)



Annual global greenhouse–
gas fluxes
F(t) (gigatonnes ECD yr⁻¹)
t (year)
a
b
c
d
e
0
5
10
15
20
25
30
1980
2020
2060
2100
2140

Themes in Decision Analysis (for Public Policy)

1. Preferences for consequences
   - Whose preferences?
2. Probabilities of consequences
   - Whose probabilities?
3. Aggregation and tradeoffs

1. Preferences for Consequences

Consequences of policies depend on policy and on (uncertain) characteristics of the world

- Science can improve predictions about consequences, by improving information about the "state of nature"

Consequences are not inherently good or bad; desirability is defined by & depends on human preferences and values

- Science cannot determine preferences
- It can measure them

“Good Science” is Not Sufficient

Suppose we knew exactly the consequences of abating and not abating greenhouse gas emissions

- Future time path of climate (with regional & seasonal detail)
- Future time paths of impacts on
  - Agriculture
  - Sea level
  - Wildlife habitat and ecosystem function
  - Storm frequency and severity
  - Human health
  - Everything else that might be affected
- Costs and consequences of abatement

Would we agree on how much to abate emissions?

Value Questions Remain

Tradeoffs among valued goods

- How much of other good things are we (should we be) willing to give up to avoid impacts of climate change?
  - Abatement costs (e.g., smaller cars, car pooling, more expensive electricity?
  - Opportunity cost (address other problems)
    - Copenhagen Consensus: malaria, malnutrition, SIDA, etc.

Distribution among people

- Which people should sacrifice for the benefit of others?
- How much should current generations give up to benefit future generations?
  - (that may be better off than current generations)

2. Probabilities of Consequences

Need to consider both probability and severity of consequences

- Low-probability risks are worth evading, if the cost is small enough
- High-consequence risks are worth running, if the probability is small enough

"Zero – infinity" risks

- Small probability of catastrophic consequence

Probabilities Alone are Inadequate

"Negligible" or "acceptable" risk

Probability of a serious automobile accident is very small (1 per 1 million trips)

- Almost every time we buckle a seatbelt, we are wasting our time

Consequences Alone are Inadequate

"Worst-case analysis"

- Limited only by our imagination
- For want of a nail, a horseshow 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.

Ambiguity Aversion

Humans dislike ambiguous (uncertain) probabilities

- Risk of bad outcome
- Risk of bad probability

Should we take greater precaution when probabilities are uncertain?

- Conservative assumptions
- Worst-case analysis

Perils of Prudence

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

Technology	Deaths	Probability	Expected deaths
A	1	0.99	
	1,000	0.01	11
B	101	1.0	101

Using upper-bound risk estimates, B would be preferred to A

Perils of Prudence

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

Chemical	Deaths	Probability
A	10	0.904
	< 1,010	0.996
B	1,010	1.0

Policy of choosing B (with smaller upper-bound risk) is <u>almost</u> certain to kill more people

"Dangerous Anthropogenic Interference with the Climate System"

Great uncertainty about

- Magnitude of climate change
- Severity (and sign?) of impacts

Zero anthropogenic interference is impossible (too late)

Definition of "dangerous anthropogenic interference" must incorporate both probability and severity of consequences

Bright-line criteria (stabilization targets, tolerable windows) are simplistic

- Imply no benefit to surpassing goal, that would reduce impacts or create greater margin of safety

3. Aggregation & Tradeoffs

Across attributes

- Environmental quality
- Human health
- Opportunity cost

Across people

- Within generations
- Between generations

Quantifying Probability

Probability of climate change and impacts is "subjective"

- Quantitative measure of degree of belief
- Individuals can hold different probabilities for same event

All probabilities are subjective

- "Randomness" is really chaos (e.g., coin toss, roulette wheel)
  - Deterministic process
  - Sensitively dependent on initial conditions
  - 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

Models used to estimate consequences incorporate many assumptions

- Structure (causal relationships, feedback loops, functional forms)
- Parametric (values of parameters, e.g., chemical-rate constants, dose-response functions)

Choices are 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 particulate air pollution causes death

Rigorous, repeatable 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

Quantifying Preferences

Health

Environment

Human Health Benefits

Typically small change in risk to many individuals

Willingness to pay (to reduce risk) / willingness to accept compensation (for risk increase)

- Value per Statistical Life (VSL)
  - Individual WTP to reduce risk of death (or illness)
  - Includes personal financial consequences plus pain & suffering
- Other resource costs
  - Medical expenses, lost productivity

Quality-adjusted life years (QALYs), disability-adjusted life years (DALYs)

- Mortality: life years lost
- Morbidity: duration weighted by severity

Environmental Benefits

Use value

- Factor input (industry, agriculture)
- Ecosystem services (flood mitigation, waste treatment)
- Recreation, visitation, aesthetic enjoyment
- Vicarious use (viewing pictures)

Option value

- Possible future use (by self or others)

Existence value

- Knowledge that wilderness exists

Existence Value

"There are many persons who obtain satisfaction from mere knowledge that part of wilderness North America remains even though they would be appalled by the prospect of being exposed to it."

- John Krutilla, Conservation Reconsidered, 1967

Concerns

What determines "quality" of an ecosystem?

- Public (and experts) do not know all the services ecosystems provide
  - Discovery of new drugs in rain forest?

Value of ecosystems should not depend on human preferences

- "Should Trees Have Standing?" – Christopher Stone
- "How Not To Think About Plastic Trees" – Laurence Tribe

Bias toward the cuddly: "charismatic megafauna"

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Methods for Estimating Preferences

Revealed preference

Stated preference / contingent valuation

Revealed Preference

People assumed to prefer the choice they make to available alternatives

- Attributes of alternatives are known
- People are free to choose among them

Choices are observed, but alternatives (and their costs) must be inferred

Applicable only where choices are observed – preferences leave “behavioral trace”

- Wages and occupational risk
- Housing prices and local environmental quality
- Choice among food types (e.g., organic or conventional; GM or non-GM)

Stated Preference, Contingent Valuation (CV)

Survey respondents about their choice in hypothetical situation

Extremely flexible

- Ask about intervention of interest, even if future, hypothetical
- Survey relevant population

Intuitive

Quality is controversial

- Hypothetical choice – limited incentive to choose carefully, report truthfully
- Framing – response can be sensitive to how the question is asked

Timing of Benefits & Costs: Discounting

If benefits and costs measured as monetary values, discount future consequences at same discount rate

- Discounting physical units at same rate implies value per unit does change over time – increasing value of wilderness or health offsets discounting

1€ today can be invested to yield $(1 + r)^T$ € T years in the future

1€ T years in future is worth $1 / (1 + r)^T$ € today

Choose between (PV now) and (FV in T yrs)

- $FV = PV (1 + r)^T$
- $PV = FV / (1 + r)^T$

Discounting the Future?

Common claim that discounting "devalues" the future is cognitive illusion

For large T and non-zero r

- $1 / (1 + r)^T$ is a very small number
- $(1 + r)^T$ is a very big number

Key question: what rate of return r can be achieved over long term?

- Compound growth is highly sensitive to rate

Discounting the Future?

T	r	PV of 1 in future	FV of 1 now
100 yrs	2%	0.1	7
100 yrs	7%	0.001	900
200 yrs	2%	0.02	50
200 yrs	7%	0.000001	800 000

Decision Making about Climate Change

Decision making under uncertainty must balance possible outcomes

- Uncertainty about consequences – probability
- Significance / severity of consequences – preferences

Neither factor can be neglected

Both should be described & quantified

- Requires comprehensive recognition of uncertainty and of imprecision of estimates

No easy answers !!!