Economic and Environmental Modeling: Overview

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Workshop on

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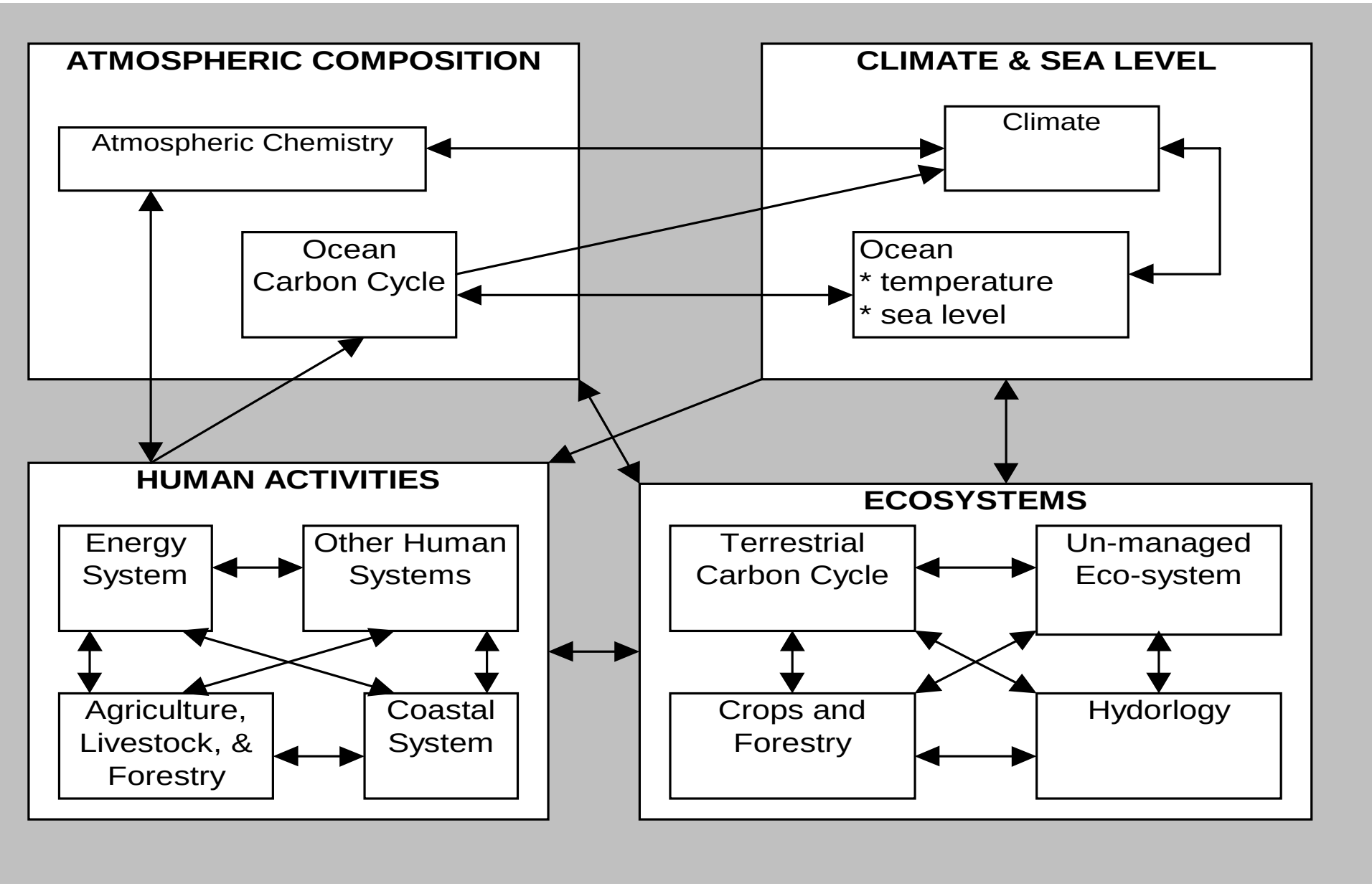
Overview

- Contributions of Modeling
- Elements of Integrated Assessment
- Two Types of Integrated Assessment Models
  - Policy Optimization
  - Policy Evaluation
- Uses of Integrated Assessment Models
- Cost Analyses
- Benefit Analyses
- Integrating Costs and Benefits
- Uncertainty Analyses
- State of the Art Critique

Contributions of Modeling

- Insights
- Rough Numbers
- Identify Ambiguities
- Quantify Sensitivities
  - Direction
  - Order of Magnitude
- Identify/Quantify Inefficiencies
- Help Explore Alternative Policy Architectures
- Identify Data Requirements
- Identify Areas for Model Development

Key Components of Integrated Assessment Models



Two Kinds of Integrated Assessment Models

- Policy Optimization Models
  - Focused on Finding Optimal Level of Emissions
  - Usually Include Impacts at the Aggregate Level
- Policy Evaluation Models
  - Focused on Simulating Effects of Policies
  - Usually More Detailed Impacts
  - Can be Run Backwards - Tolerable Windows Approach

Types of Integrated Assessment Models

Deterministic Models

Deterministic Policy Optimization Models	Deterministic Policy Evaluation Models

Decision Making Under Uncertainty Models

Stochastic Policy Optimization Models	Stochastic Policy Evaluation Models

Uses Of Integrated Assessment Models

Deterministic Models

Deterministic Policy Optimization Models

- Compute Optimal Carbon Taxes, Control Rates, etc.
- Calculate Costs of Meeting Emission/ Concentration/Climate/Impact Targets

Deterministic Policy Evaluation Models

- Project Wide Range of Impacts
- Insure Consistency in Assumptions
- Assess Interactions and Feedbacks
- Identify Critical Gaps in Research

Decision Making Under Uncertainty Models

Stochastic Policy Optimization Models

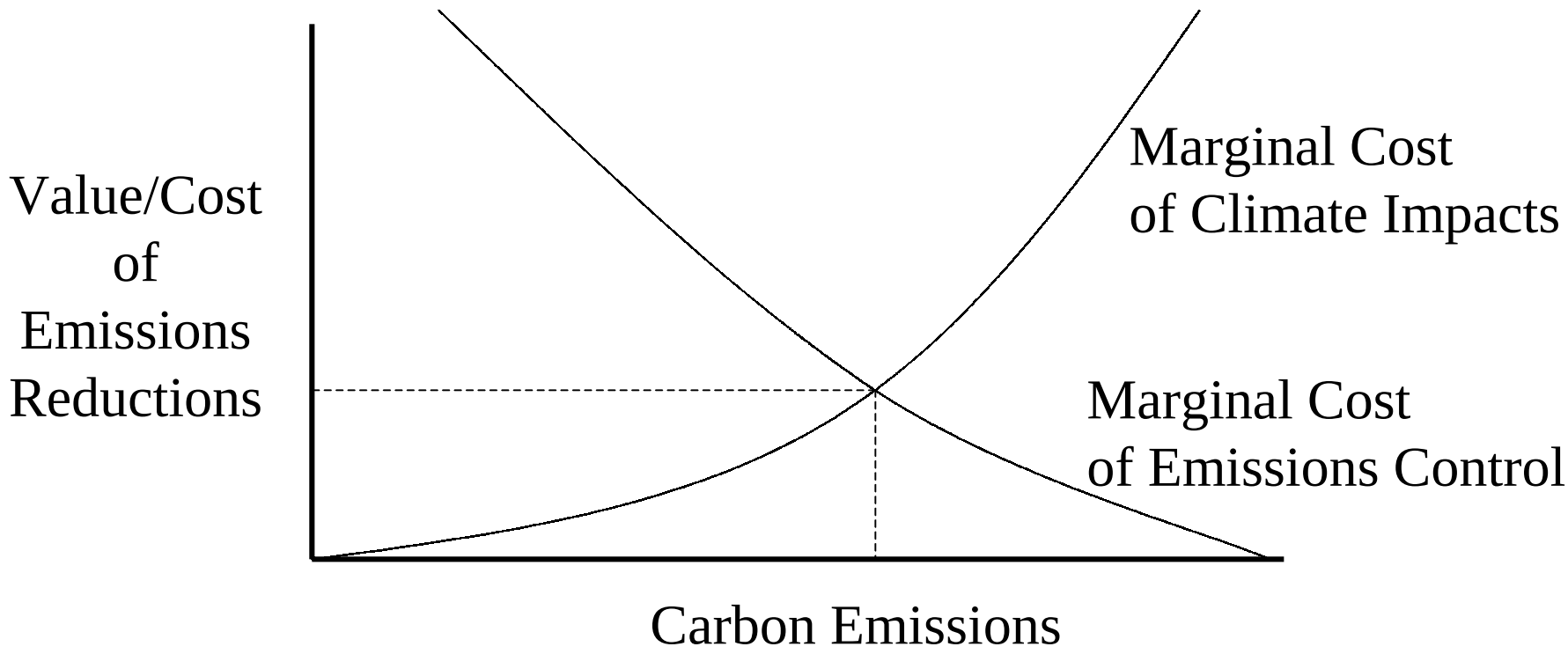
- Assess Optimal Policies Under Uncertainty
- Compute Value of Information/Research

Stochastic Policy Evaluation Models

- Compute Probabilities of Cost/Benefits of Climate Policies
- Compute Probabilities of Meeting Targets

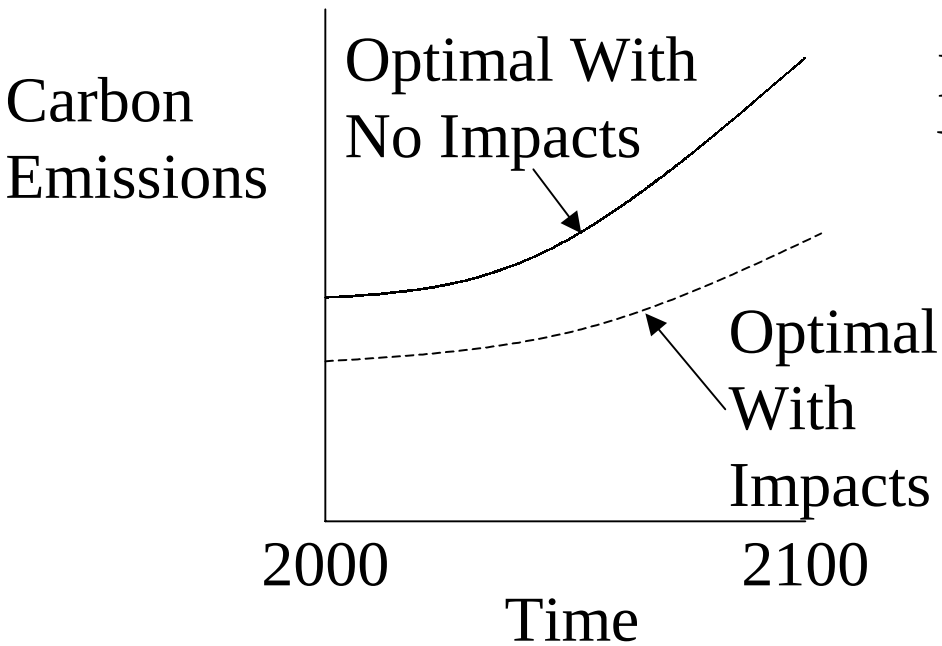
Cost/Benefit Modeling Approach:

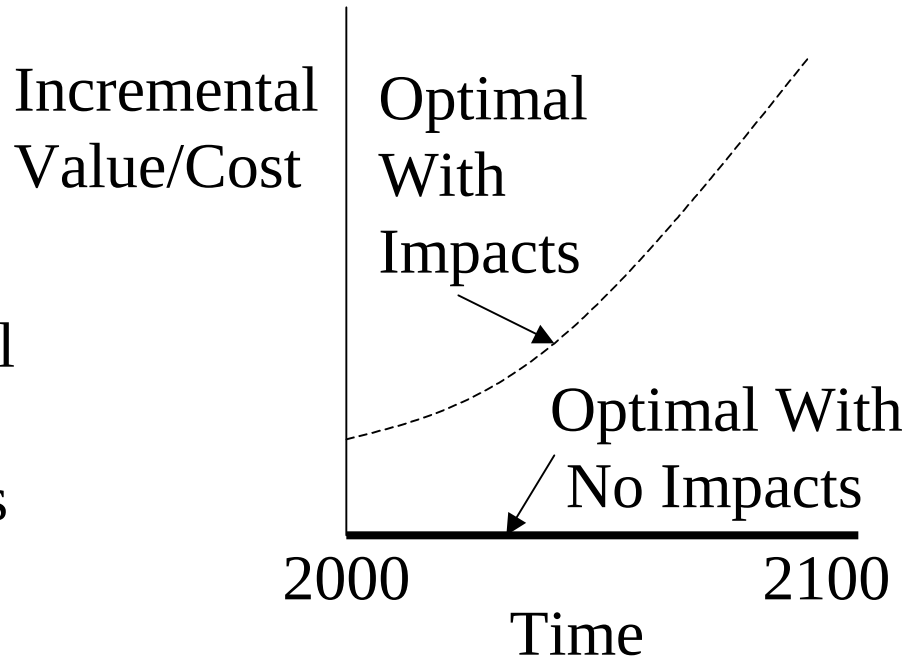
Balancing the Costs of Controlling Carbon Emissions Against the Costs of the Climate Ipacts They Cause



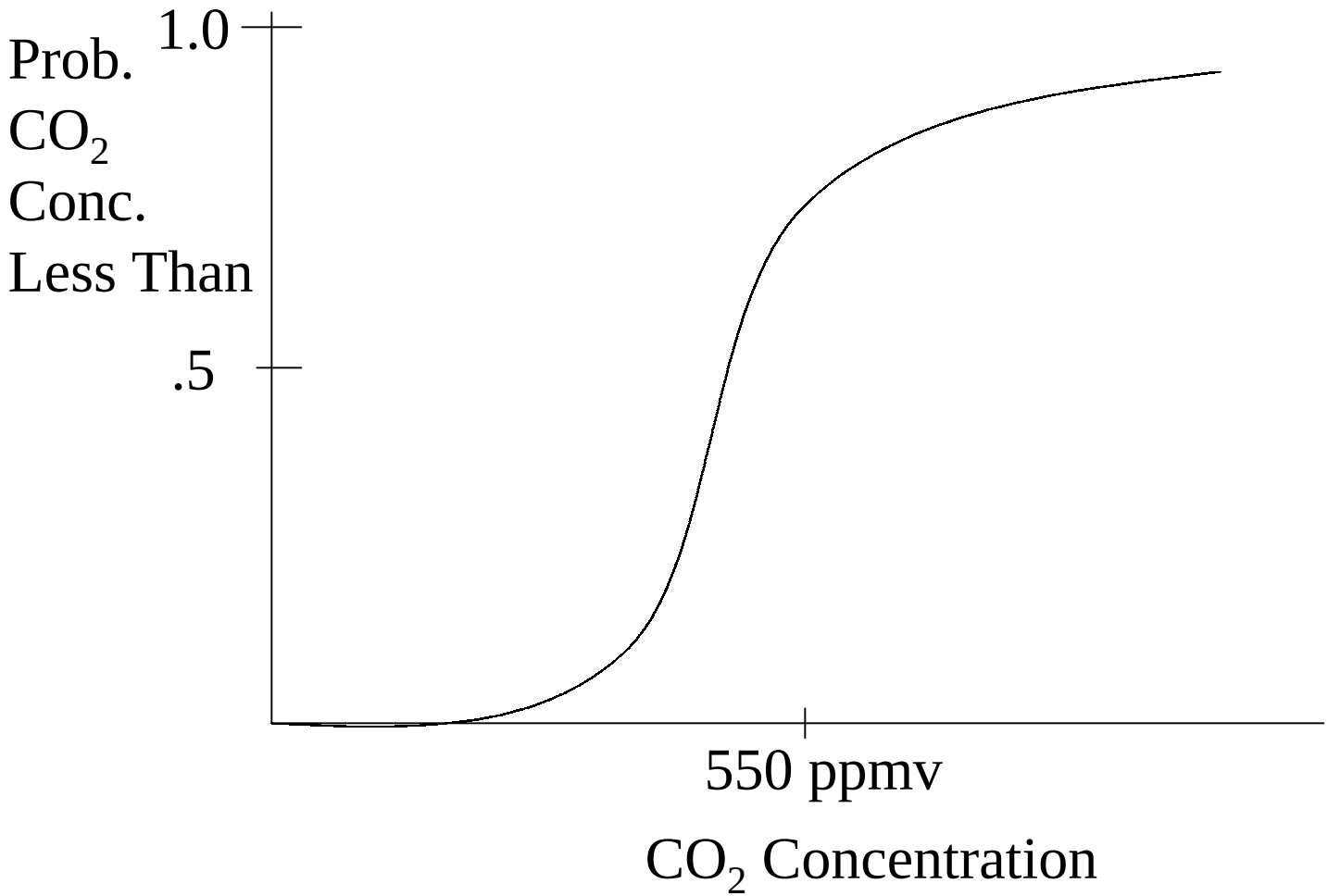
Deterministic Policy Optimization Models:

Balancing the Costs of Controlling Carbon Emissions Against the Costs of Climate Impacts Over Time

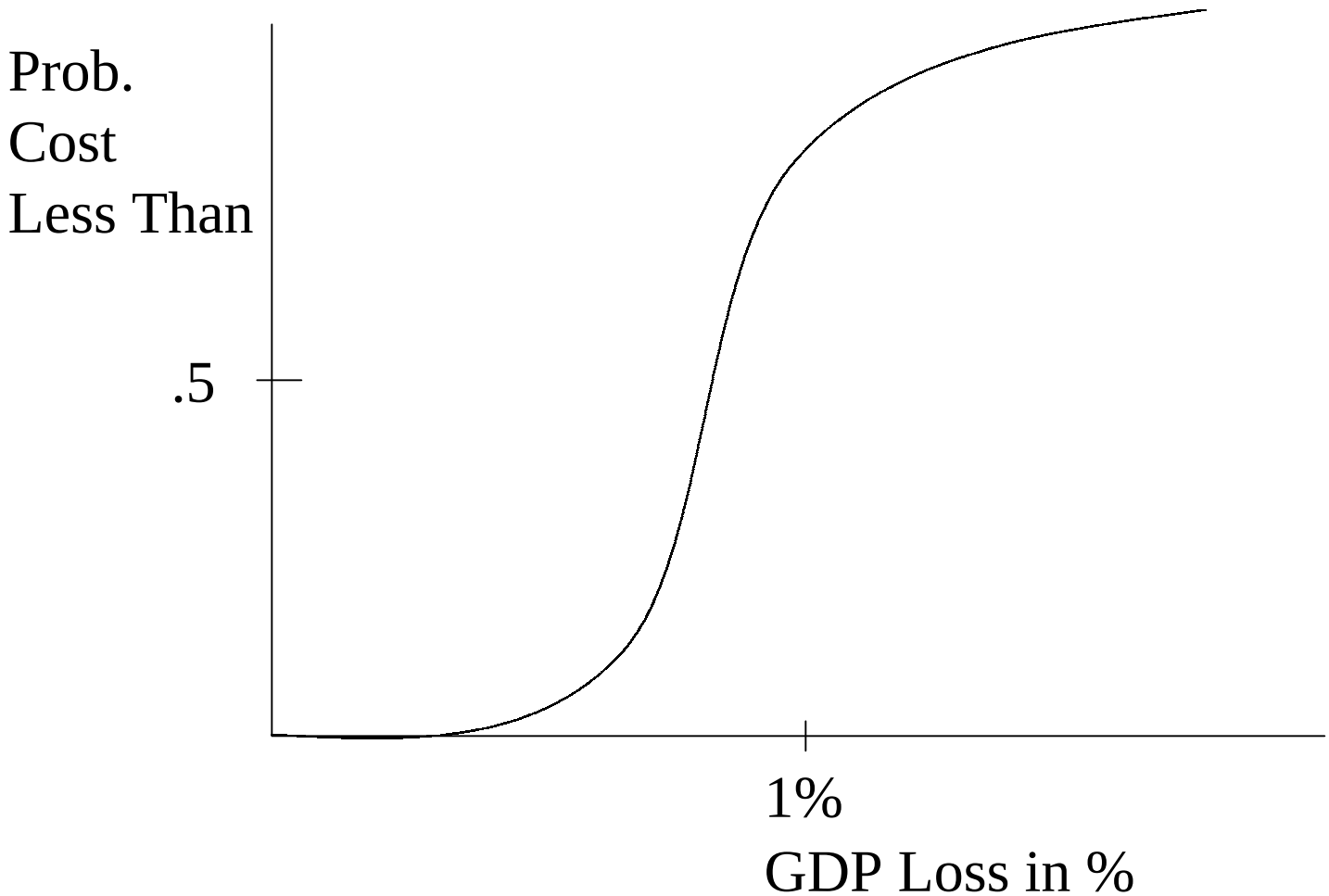




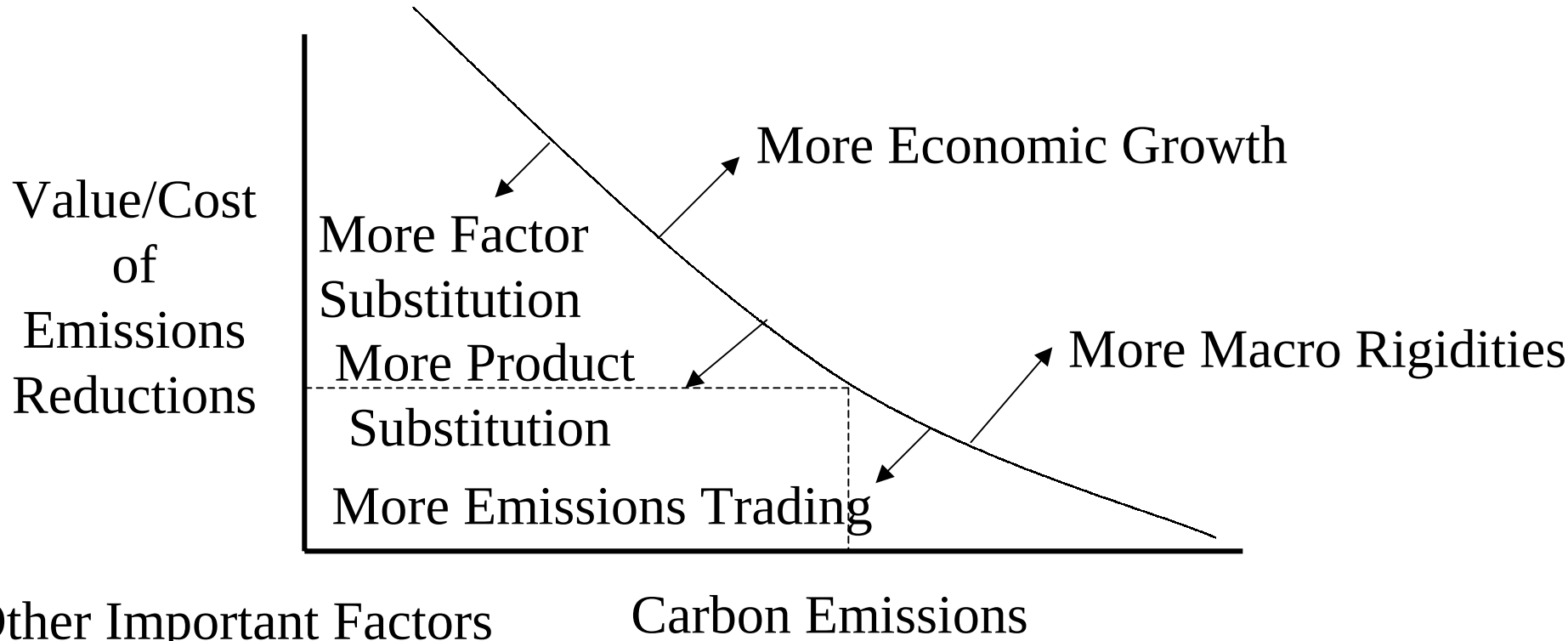
Probability of CO_2 Concentration Below Level



Probability of Cost of Meeting 550 ppmv CO_2 Concentration Target



Important Determinants of the Costs of Controlling Carbon Emissions



<u>Other Important Factors</u>

Market Barriers

Technological Change

Revenue Recycling

Trade Effects

Ancillary/Co-Benefits

Types of Costing Models

- Process Engineering
  - Individual Technologies Represented
  - Can Help Identify Possible Market Failures
  - Need to Add in Market and Economy Wide Effects
- Energy Market Models
  - Bring in Energy Market Feedbacks
  - Can Help Verify Possible Market Failures
  - Weaker on Technology
- General Equilibrium Models
  - Bring in Economy-Wide Feedbacks
  - Can Consider Multiple Economic Sectors
  - Weaker on Energy Markets and Technology

Key Determinants of Mitigation Cost Projections

- Factors Largely External to the Models
  - Baseline Emission Projections
  - Policy Regime
  - Discount Rate
- Factors Internal to the Models
  - Factor/Product Substitution
  - Technology and Technological Change
  - Foresight by Producers/Consumers and Governments

Areas Where Climate Change Impacts Are Anticipated

MARKET

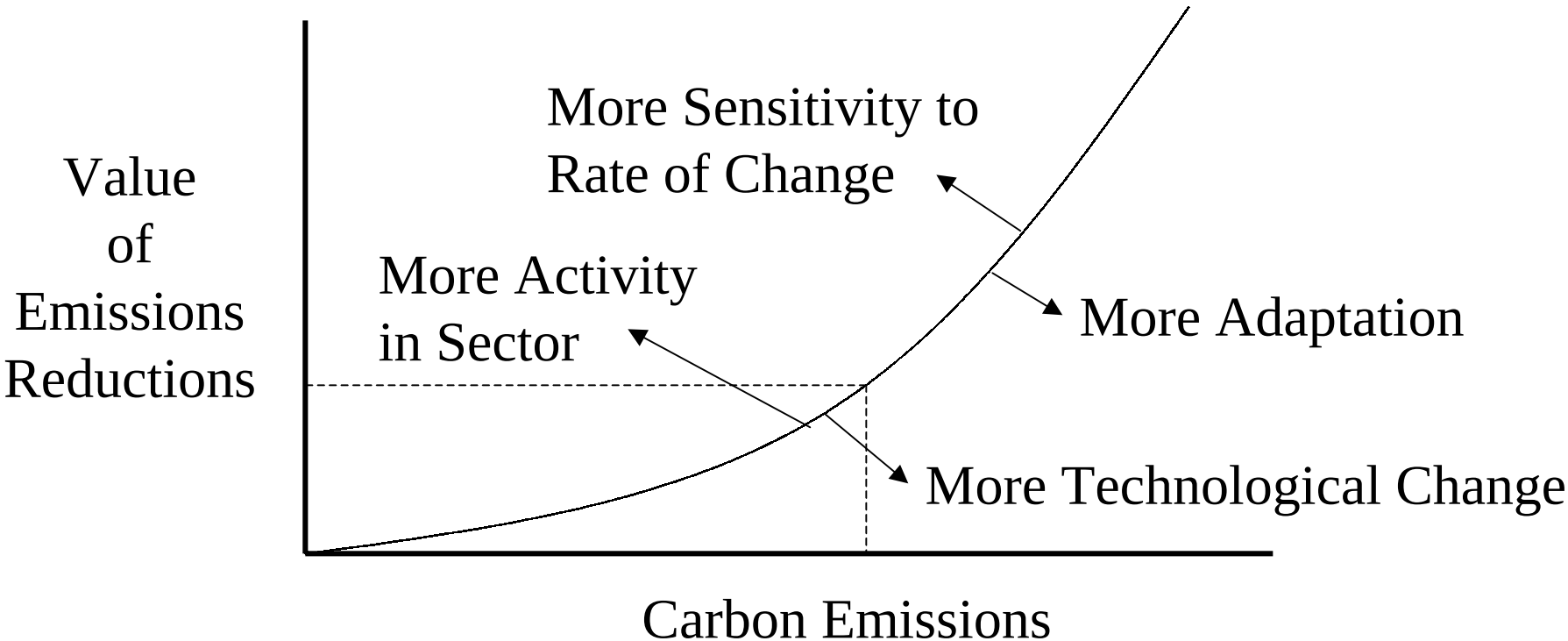
- **Agriculture**
- **Forestry**
- **Sea Level Rise**
- **Water Supply**
- **Energy Consumption**
- **Fisheries**
- **Extreme Events/Insurance**

*Some Market Components

NON-MARKET

- **Unmanaged Eco-Systems**
  - **Terrestrial**
  - **Marine**
- **Human Health***
- **Bio-Diversity***
- **Wildlife**
- **Recreation***
- **Amenities**

Key Determinants of the Costs of Climate Impacts



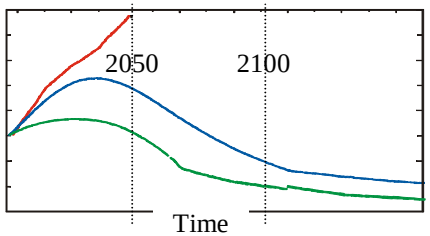
<u>Other Important Factors</u>
Vulnerability to Variability

Approaches to Valuing Climate Change Impacts

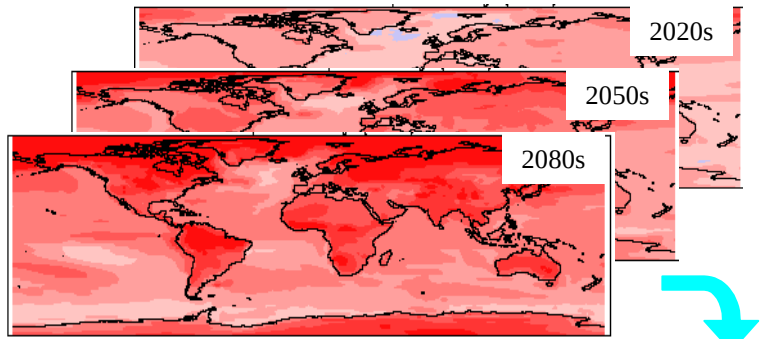
- Structural Models
  - Output = fcn.(Inputs)
- Aggregate Statistical Models
  - Use Variation Across Regions
- Travel Cost Models
  - Value of Recreation > Cost of Doing It
- Contingent Valuation Surveys
  - Use of Questionnaires to Assess Values

OVERVIEW OF CRA PROCESS FOR CLIMATE CHANGE

Greenhouse gas emissions scenarios

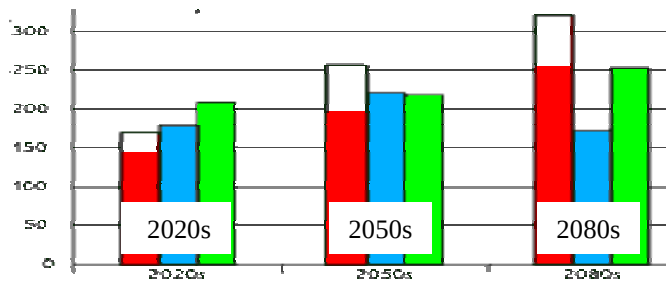


Global climate modelling:



Health impact model

Generates comparative estimates of the regional impact of each climate scenario on the relative risk of specific health outcomes



Conversion to GBD endpoints (DALYs)

Level	Age group (years) 0-4	5-14	15-29	30-44	45-59	60-69	70+
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
3	1.7	1.7	1.7	1.7	1.7	1.7	1.7
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
3	1.7	1.7	1.7	1.7	1.7	1.7	1.7
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
3	1.7	1.7	1.7	1.7	1.7	1.7	1.7
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
3	1.7	1.7	1.7	1.7	1.7	1.7	1.7
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
3	1.7	1.7	1.7	1.7	1.7	1.7	1.7

HEALTH OUTCOMES INCLUDED

	GBD code
Direct impacts of heat and cold:	
Incidence of deaths due to Cardiovascular disease	(G089)
Food and water-borne disease:	
Incidence of episodes of Diarrhoea	(G009)
Vector-borne disease:	
Incidence of cases of Malaria	(G018)
Dengue	(G027)
Natural disasters:	
Incidence of deaths attributable to coastal flooding	(G131)
Incidence of injuries attributable to coastal flooding	(G131)
Incidence of deaths attributable to inland flooding	(G131)
Incidence of injuries attributable to inland flooding	(G131)
Risk of malnutrition	
Prevalence of shortfall in energy intake	(G048)

HEALTH OUTCOMES NOT INITIALLY BEING CONSIDERED

Relatively small health burden:

Ciguaterra poisoning (temperature-stressed marine ecosystems)

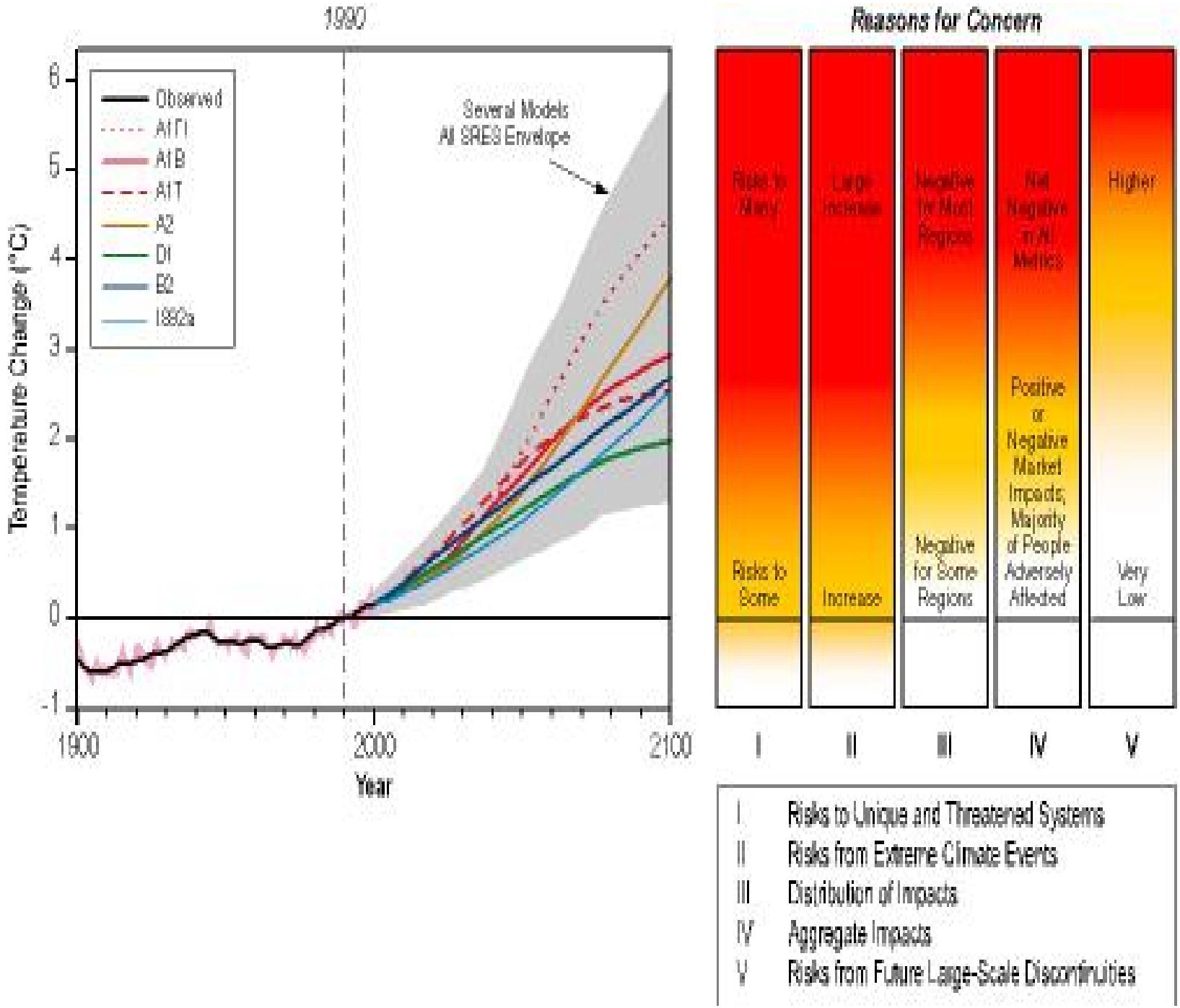
- **Tick-borne encephalitis**

Lack of global quantitative models:

- **Other infectious diseases (esp. other vector-borne diseases)**
- **Drought and famine** (lack of safe drinking water, crop failure)
- **Population displacement due to natural disasters**
- **Destruction of health infrastructure in natural disasters**
- **Increased pollution and aeroallergen levels**
- **Indirect effects of plant pests and diseases on food production**
- **Conflict caused by climate change and its environmental sequelae** (e.g., conflicts over access to water in newly drought-affected areas)

IPCC Synthesis into Causes for Concern

- Risks to Unique and Threatened Systems
- Risks from Extreme Climate Events
- Distribution of Impacts
- Aggregate Impacts
- Risks from Future Large-Scale Discontinuities


1990
Observed
A1FI
A1B
A1T
A2
B1
B2
IS92a
Several Models
All SRES Envelope
Temperature Change (°C)
6
5
4
3
2
1
0
-1
1900
2000
2100
Year
Reasons for Concern
Risks to Many
Risks to Some
Large Increase
Increase
Negative for Most Regions
Negative for Some Regions
Net Negative in All Metrics
Positive or Negative Market Impacts; Majority of People Adversely Affected
Higher
Very Low
I
II
III
IV
V
I Risks to Unique and Threatened Systems
II Risks from Extreme Climate Events
III Distribution of Impacts
IV Aggregate Impacts
V Risks from Future Large-Scale Discontinuities

Approaches to Integration of Costs & Benefits

- Do Informally Through Careful Choice of Target and Then Minimize Costs to Achieve
- Iterate Between Tolerable Windows and Optimization Approaches
- Formal Cost/Benefit Analysis

Some Key Challenges for Integrated Assessment

- Dealing With Uncertainty
- Comparing Impacts Across Space and Time
- Sustainable Development and Climate Change
- Measuring/Evaluating Impacts
- Integrating Climate Impacts With Impacts of Policies Designed to Ameliorate Them
- Representing Technology/Technological Change and Linking to Policy Options

Dealing With Uncertainty in Integrated Assessment

Sequential Decision Making under Uncertainty

Infinite-horizon Stochastic Optimization

$$\max_{\vec{C}_t} \sum_{t=0}^{\infty} \rho^t E(u(\vec{P}_t, \vec{I}_t, \vec{C}_t))$$

Optimization Models

Finite-horizon Stochastic Optimization

$$\max_{\vec{C}_{jt}} \sum_{j=1}^{J} E\left(\sum_{t=t_j}^{t_{j+1}-1} \rho^t u(\vec{P}_t, \vec{I}_{t_j}, \vec{C}_t) \right)$$

where t_j corresponds to times where the state of information is updated

Policy Evaluation Models

Multi-period Decision Analysis

$$\max_{\{\vec{C}^i_j \in \{\vec{C}_j^1 \ldots \vec{C}_j^{N_j}\}, j=1 \ldots J\}} \sum_{j=1}^{J} E\left(\sum_{t=t_j}^{t_{j+1}-1} \rho^t u(\vec{P}_t, \vec{I}_{t_j}, \vec{C}^i_t) \right)$$

where Nj corresponds to the number of discrete decision alternatives available at decision point j

Uncertainty Propagation

Optimization with Resolved Uncertainty

$$E\left(\max_{\vec{C}_t} \sum_{t=0}^{T} \rho^t u(\vec{P}_t, \vec{C}_t) \right)$$

Single-Period Decision Analysis

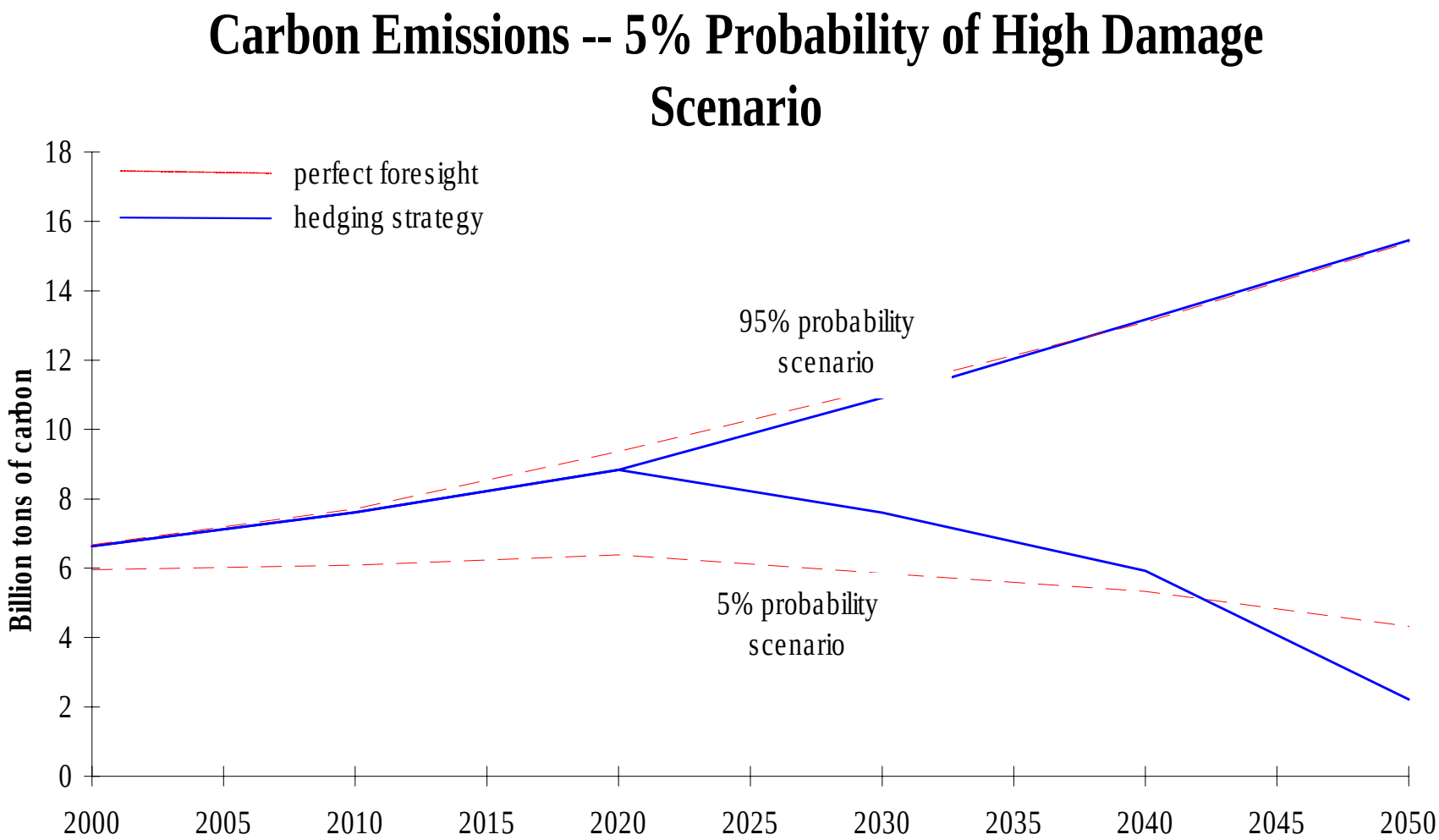
$$\max_{\vec{C}^i \in \{\vec{C}^1 \ldots \vec{C}^N\}} E\left(\sum_{t=0}^{T} \rho^t u(\vec{P}_t, \vec{C}^i_t) \right)$$

Single-Policy Uncertainty Evaluation

$$E\left(\sum_{t=0}^{T} \rho^t u(\vec{P}_t, \vec{C}_t) \right)$$

$\vec{P}_t$ = Physical state, $\vec{I}_t$ = Information state, $\vec{C}_t$ = Control variable, ρ = Discount rate, E = Expectation operator, u = Utility function

Dealing With Uncertainty in Integrated Assessment



World Views on Climate Change Policy Analyses

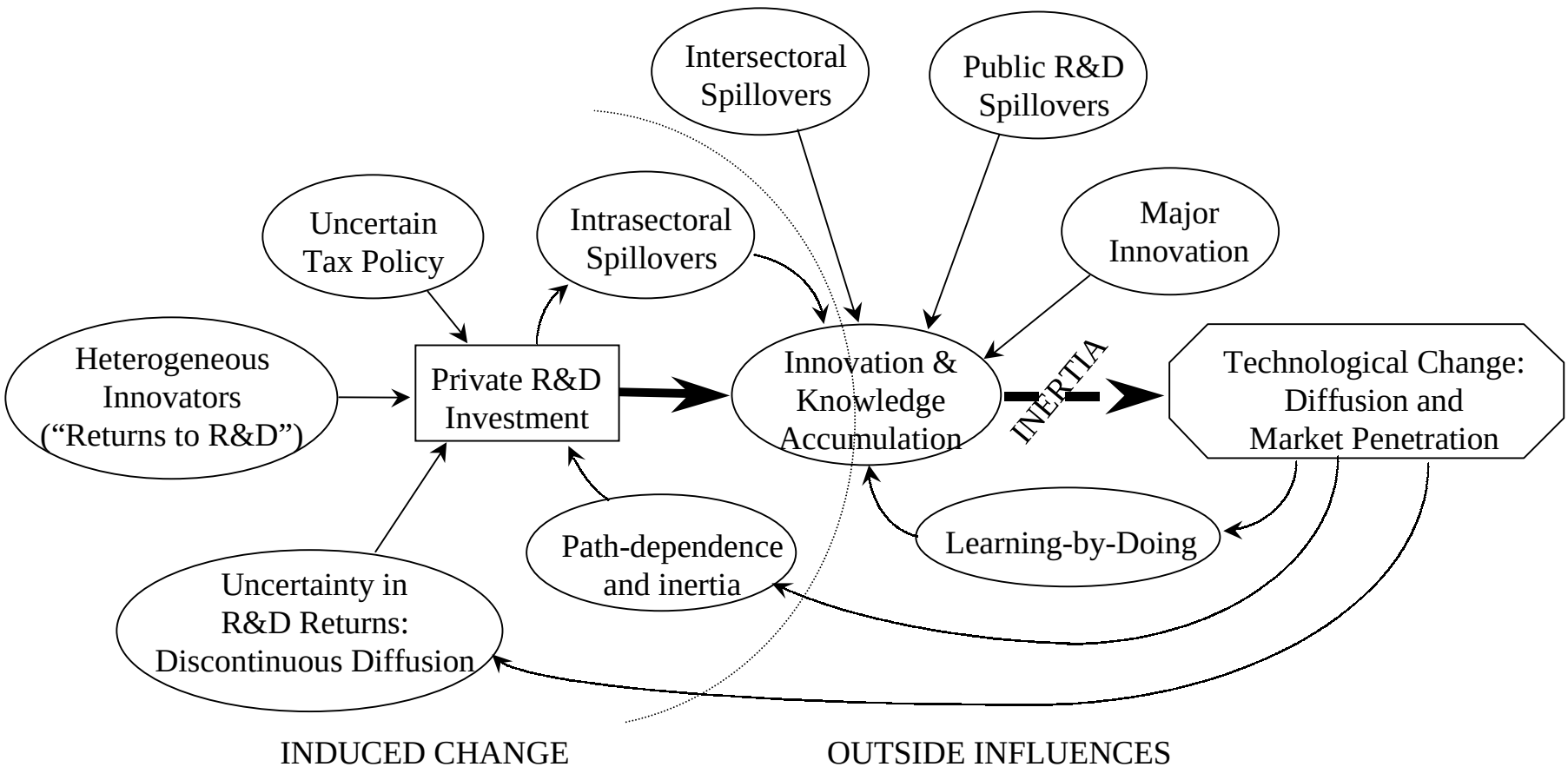
Class of World Citizen	Typical OECD (AEA Member?) Analysis	ROW Analysis
2 Billion People Without Markets	What 2 Billion People?	High Priority: Reduce Their Vulnerability
2 Billion In or Near Poverty with Fragile Markets	They Don't Count for Much!	High Priority: Reduce Their Vulnerability
2 Billion Potential Decaf Latté Drinkers	Half Are Stuck In Transition, But the Rest We Can Help	They Can Take Care of Themselves

General Approaches to Modeling Technological Change

- Exogenous Assumptions
  (e.g., AEEI, Changing Menu of Technologies)
- Price Induced Technological Change
  - Learning by Doing
  - R&D and Knowledge Capital
- Learning Curves
  - With Respect to Cumulative Experience
  - With Respect to Cumulative R&D Expenditures
- Other Modifications to Model Parameters With Respect to Time or Policies

Limitations and Possible Extensions to Current Methods for Modeling ITS

Current approaches omit important dynamics of technological change. A broader framework for analyzing ITC is needed.



Common Pitfalls in Integrated Assessment

- Lack of Focus
  - Pick a basic model structure without a set of applications firmly in mind
  - Not modifying model in response to new problems
- Mistaking the Model for Reality
  - If its not in the model it probably doesn’t exist
  - Test alternative assumptions only against the model
  - Methodological limitations imply real world restrictions
- Poor Communication of Results
  - Overstating strength of results
  - Omitting key relevant assumptions/qualifications