Structural Modeling of the Economic Impacts of Climate Change
A Peek Under the Hood

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Geophysical impacts:
- Categorization
- Timing
- Location
- Sectoral incidence
- Sign/magnitude
- Monetization

Human system impacts:
- Categorization
- Timing
- Location
- Sectoral incidence
- Sign/magnitude
- Monetization

Climate Damages

Models
- Integrated Assessment Models
- Earth System and General Circulation Models

Data
- Drivers: GDP, Population, Technology...
- Emissions: \( \text{CO}_2, \text{CH}_4, \text{N}_2\text{O}, \text{HFCs}, \) aerosols, land use patterns
- Concentrations: \( \text{CO}_2, \text{CH}_4, \text{N}_2\text{O}, \) ozone, and aerosol loadings.
- Climate Projections (including: radiative forcing, temperatures, precipitation, snow cover, sea ice, sea level, etc.)

Effect
- Geophysical impacts (including: river runoff, coastal erosion, vegetation shifts, wildfire modeling, etc.)
- Species-level and Human impacts (including: infectious diseases, heat stress, species distributions, insurance losses, etc.)
Co-Evolution of economy, climate, damage, feedbacks on human systems/well-being

Potential mitigation-adaptation synergies and/or tradeoffs

Drivers: GDP, Population, Technology...
Emissions: CO₂, CH₄, N₂O, HFCs, aerosols, land-use patterns
Concentrations: CO₂, CH₄, N₂O, HFCs, ozone, and aerosol loadings.
Climate Projections (incl. radiative forcing, temperatures, precipitation, snow cover, sea ice, sea level, etc.)
Geophysical impacts (incl. river run-off, coastal erosion, ecosystem shifts, wildfire modelling, etc.)
Species-level and Human impacts (incl. infectious diseases, heat stress, species distributions, insurance losses, etc.)
Tightly Coupled Co-Evolution: Early Integrated Assessment Models

Aggregate Global/Regional Economy
- Population
- Production
- Consumption
- Energy use
- Well-being

Simplified Carbon Cycle/Climate Model

Δ Global mean temperature
Δ Global GHG emissions
Δ GDP due to climate damage

Model steps through time to simulate the future
Tightly Coupled Co-Evolution: Early Integrated Assessment Models

Aggregate Global/Regional Economy
- Population
- Production
- Consumption
- Energy use
- Well-being

RICE, WITCH models: regionalization
- Global GHG emissions

Simplified Carbon Cycle/Climate Model
- Global mean temperature
- GDP due to climate damage

Challenges
- Computational expense of simulating the evolution of the climate and geophysical drivers of impacts at the spatial/temporal scales at which damages are felt
- Empirical provenance of aggregate damage functions
- Moving beyond GDP to elaborate effects of impacts on the economy’s functioning, emergent behavior, and endogenous capacity to adapt
- Complexity of system integration grows with improvements to the fidelity of individual components
- Modeling the system via forward-looking behavior is computationally intractable
Current Generation IAMs:
Global Change Intersectoral Modeling System (GCIMS)
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CLIMATE EMULATORS
- Gridded temperature, precipitation series

IMPACT EMULATORS
- Xanthos
- Persephone
- Wildfires
- Forest Productivity

GCAM
- Core Partial Equilibrium Economic Model
- 32 Energy Economy Regions
- 235 Water Basins
- 384 Land Regions

DISAGGREGATION
- Tethys
- Demeter

Damage Estimation Modules
- Downscaled economic activity exposed to damage

Δ Global mean temperature
Δ Global GHG emissions

https://gcims.pnnl.gov/modeling
Current Generation IAMs: Global Change Intersectoral Modeling System (GCIMS)

- Global Change Intersectoral Modeling System (GCIMS)
  - [https://gcims.pnnl.gov/modeling](https://gcims.pnnl.gov/modeling)

- Pattern Scaling
  - Fldgen
  - Xanthos

- Carbon Cycle/Climate Model
  - Hector
  - Forest Productivity

- Damage Estimation Modules
  - Persephone
  - Wildfires

- Gridded temperature, precipitation series

- Recursive dynamic simulation myopically stepping through time

- Δ Global mean temperature
  - Gridded temperature, precipitation series

- Δ Global GHG emissions

- Δ Global mean

- Δ Global GHG emissions

- Multiple effects on different sectors

- Core Partial Equilibrium Economic Model
  - GCAM
  - Moirai
  - GCAM Data System

- Disaggregation
  - Demeter
  - Pathys

- Initializing
  - 32 Energy Economy Regions
  - 235 Water Basins
  - 384 Land Regions

- CASSANDRA
The Shared Socioeconomic Pathway (SSP) Scenarios: A Coordination Device for Division of Modeling Effort

Integrated Assessment/Economic Models
- dynamics of economy, energy, GHG emissions, mitigation

Global Climate Models
- standalone computationally expensive machinery
- consistent, spatially resolved changes in geophysical variables
- archive outputs and use as input data to impact calculations


Impacts/Adaptation

Weather Observations
• Temperature
• Precipitation
• Humidity
• Windspeed

Global Climate Model Projections
[ GCM x (Current climate + Future climate x SSP scenario) ]
• Meteorological variables

Dedicated Mechanistic Process Simulations
• Computationally expensive compared to statistical emulators
• Structural system of numerically parameterized equations representing relationships among natural/human variables
• Can be challenging to assess theoretical basis, empirical provenance of human/natural linkages, drivers of complex emergent behavior

Impact Observations
[ endpoint x sector x place x period: can be physical or monetary units ]
• Data coverage: global-scale datasets are the exception not the norm
• More common: patchwork of location-/context-specific studies

Empirical Impact Responses
• Rigorous, causally-valid estimates
• Uncertainty ⇒ transfer f’n CIs

Impact Shocks/Adaptation Responses
[ endpoint x sector x place x period ]

Translation/Aggregation
• e.g., temporal/spatial averaging, binning

Economic Models
Economic Modeling of Impacts/Adaptation (1)

• Limited coverage of empirical studies ⇒ unavoidable extrapolation of impact responses derived for areas where impact observations are available to areas where they are not

• Much of the action is in the “buffer” through which impacts must be translated to affect the core of an economic model
  • Translators need to specify, for a particular category of impact, what kinds of activities, within what sectors of the economy, are affected, and in what ways

• Geographic/sectoral mismatch
  • For computational tractability, economic behavior in IAMs/CGE models typically aggregated to countries/multi-country regions, coarse sectoral categories
  • Necessitates spatial downscaling of activity, aggregation of fine-scale impacts
  • Sparse documentation of the details of downscaling/aggregation procedures ⇒ challenging to assess the extent to which different choices matter for aggregate estimates of damages
Economic Modeling of Impacts/Adaptation (2)

- Challenges in accounting for, and representing, adaptation
  - Empirical studies: adaptation either modeled directly or controlled for statistically
  - Process simulation studies: may or may not include different adaptation mechanisms
  - Economic models simulate input substitution, price/quantity adjustments using stylized firm production/cost and household utility/expenditure functions
  - Potential for double counting adaptations’ moderating effects!

- One-way coupling ⇒ sacrifices the co-evolution captured by early IAMs (albeit in a highly stylized manner)
  - Climate change “shocks” constructed by bottom-up/empirical studies serve purely as inputs to top-down economic models
  - Economic model outputs rarely feed back on processes generating impact shocks
  - Challenging to foresee unintended consequences (e.g., the mitigation-adaptation tradeoff due to electricity consumption amplification driven by residential AC adoption as households attempt to shield themselves from worsening heat)
• Economic models’ equilibrium solution paradigm threatens to gloss over disequilibrium impacts with potentially large attendant costs
  • Particularly important for singular extreme events: chaotic post-disaster aftermath ⇒ transitory breakdown of market functioning
• Related issue: nonmarket impacts not readily associated with categories of (market) activities captured by economic accounts, represented in production/consumption activities in models
• Lots of potential for progress characterizing mechanisms of underlying impacts, WTP
• How to aggregate these outcomes, incorporate them into economic models is at the cutting edge of research
• Whither equity: vulnerable populations at the margins of the formal economy
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