Modeling Exposure, Vulnerability, and Response

BEE 6940 Lecture 14

May 1, 2023

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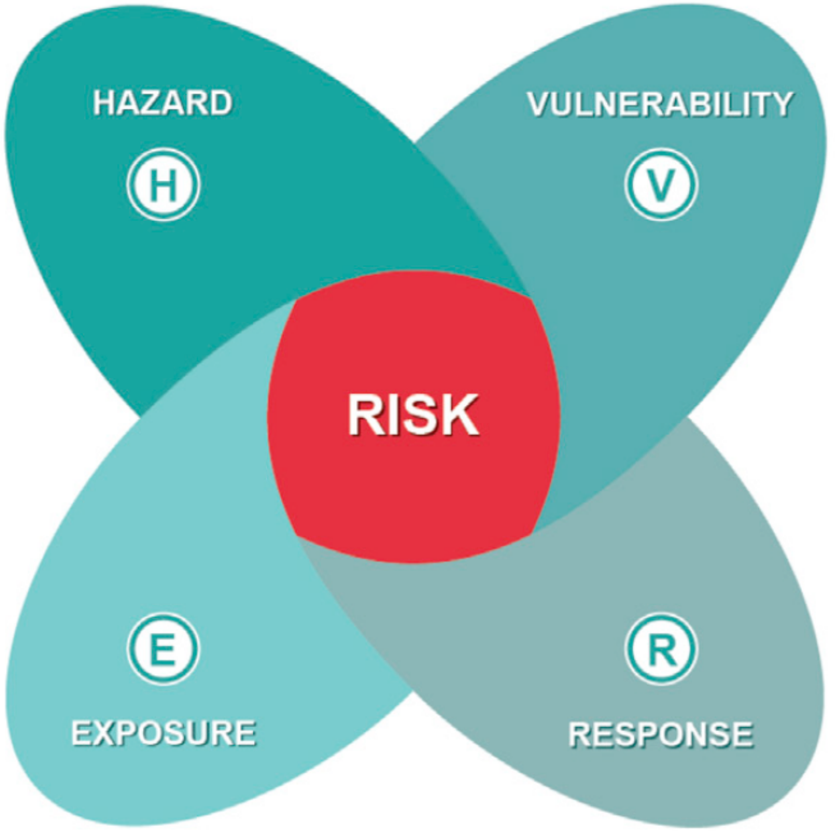
Review of Risk

Risk Decomposition

Common framework:

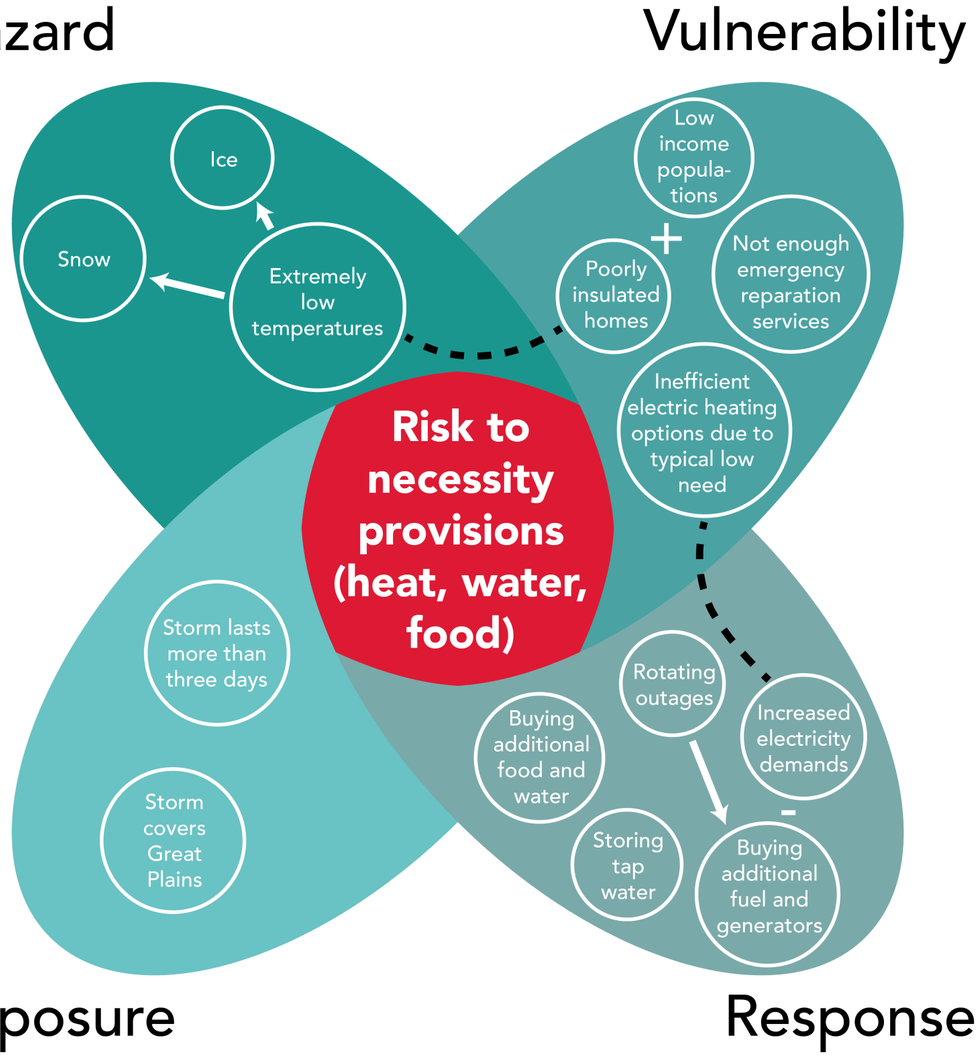
Risk as a combination of

- *Hazard*
- Exposure
- Vulnerability
- Response



Source: Simpson et al (2021)

Example: Winter Storm Uri

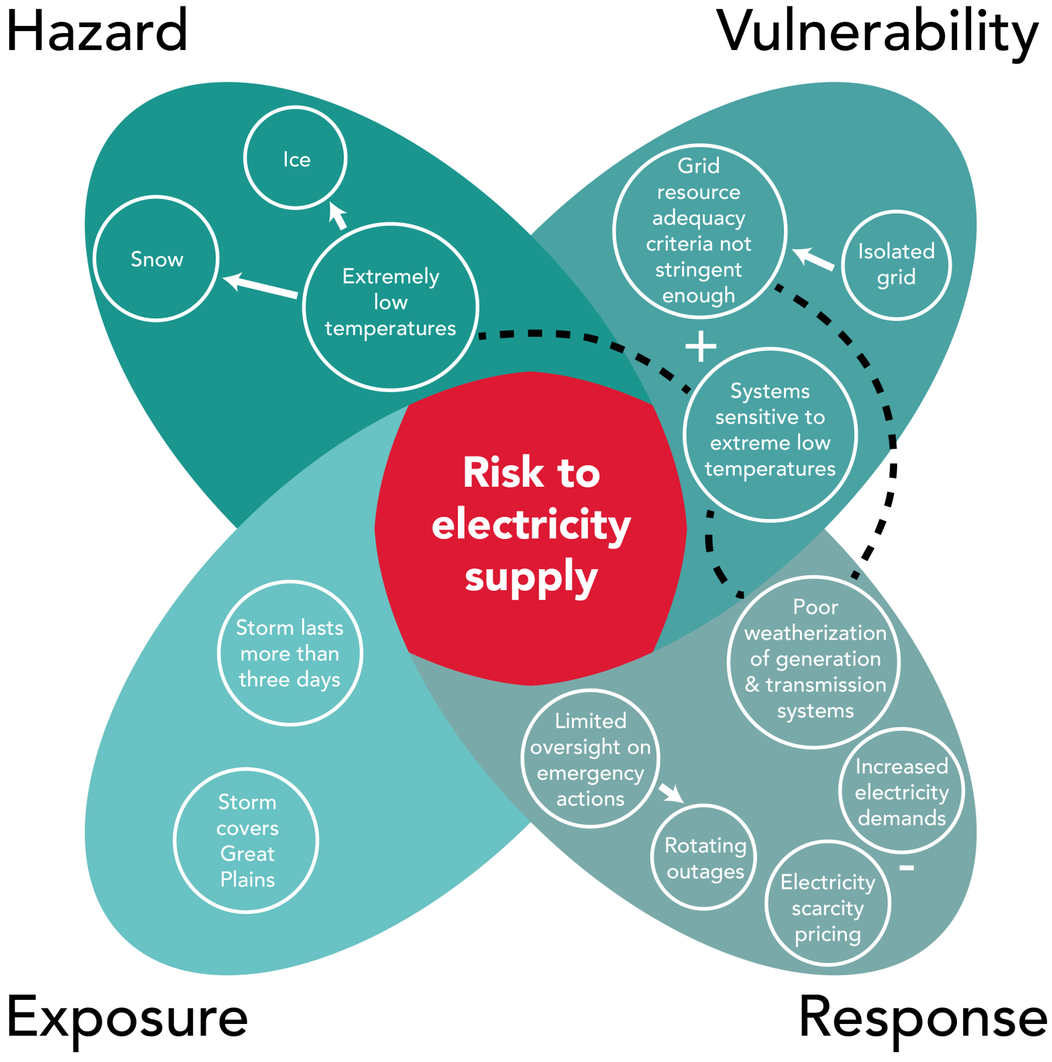


Severity of impacts to electricity-dependent services came from:

- poor winter-proofing of homes;
- worries about provisioning.

Source: Reed et al (2022)

Example: Winter Storm Uri

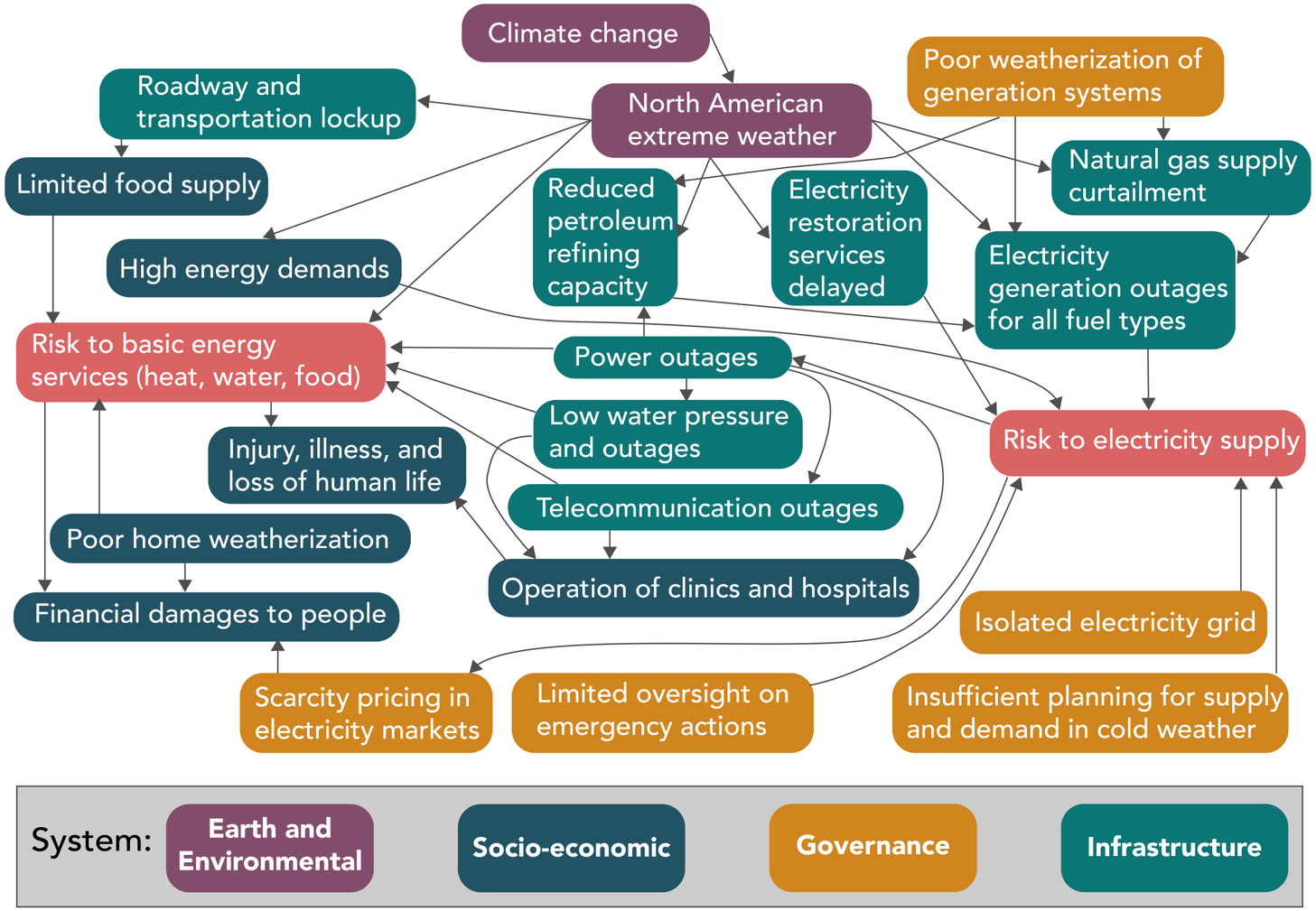


Severity of impacts to electricity supply came from:

- fragility of (isolated) grid to low temperatures;
- increased electricity demand.

Source: Reed et al (2022)

These Determinants Can Be Complex



Contributors to failures span systems, sectors, and scales.

Source: Reed et al (2022)

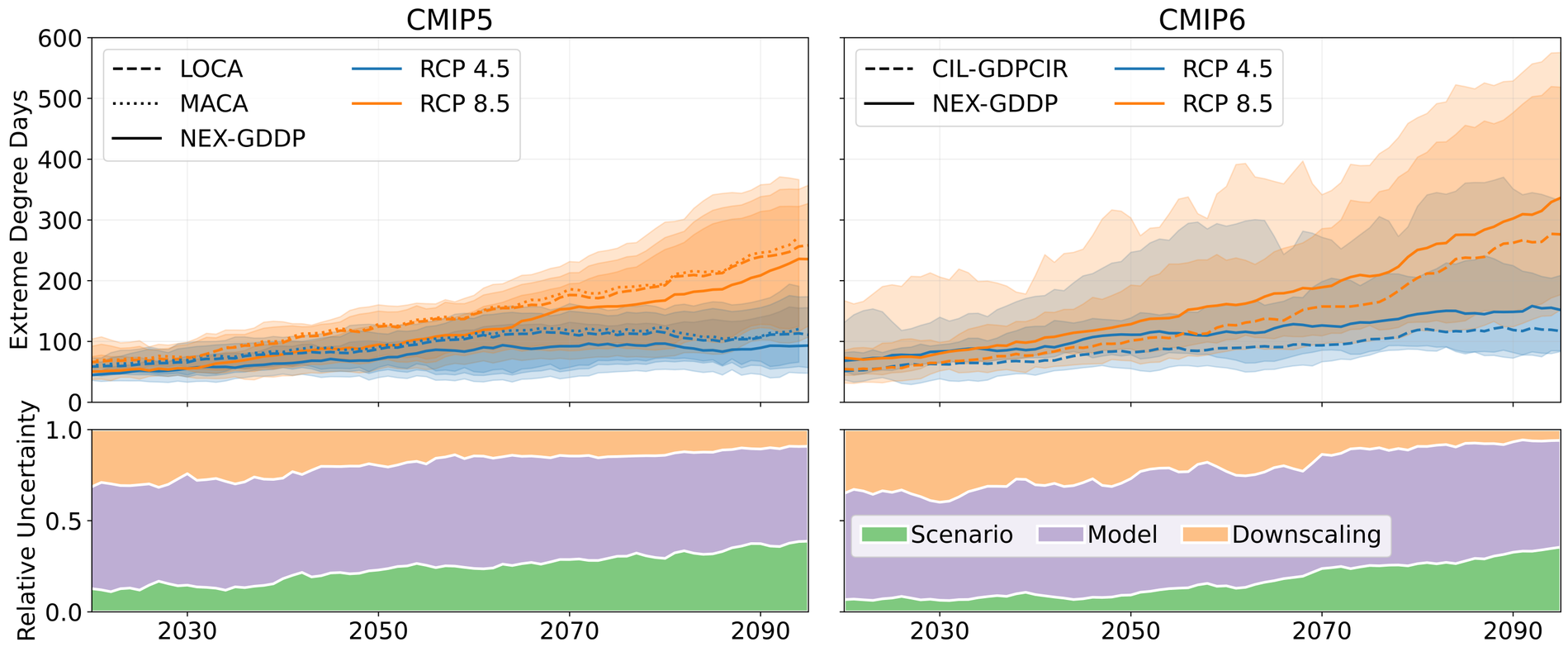
Challenges and Appraoches: Modeling Exposure, Vulnerability, and Response

Overarching Challenges

Several categories of challenges for modeling exposure, vulnerability, and response:

- Downscaling uncertainties;
- Data collection/availability at appropriate scales;
- Dynamic changes due to endogenous dynamics.

Downscaling Uncertainty



Source: Lafferty & Sriver, Uncertainty in the Representation of Climate Extremes Across Downscaled and Bias-corrected CMIP Model Ensembles (In Prep.)

Data Availability at Appropriate Scales

What kind of data do we need to assess exposure, vulnerability, and response?

- Database of population/assets that might be exposued;
- How much damage could ensue from different events;
- Adaptation measures which have already been implemented;
- Extent to which further adaptation measures or responses might be triggered.

These are all high-resolution pieces of information which can be difficult to gather!

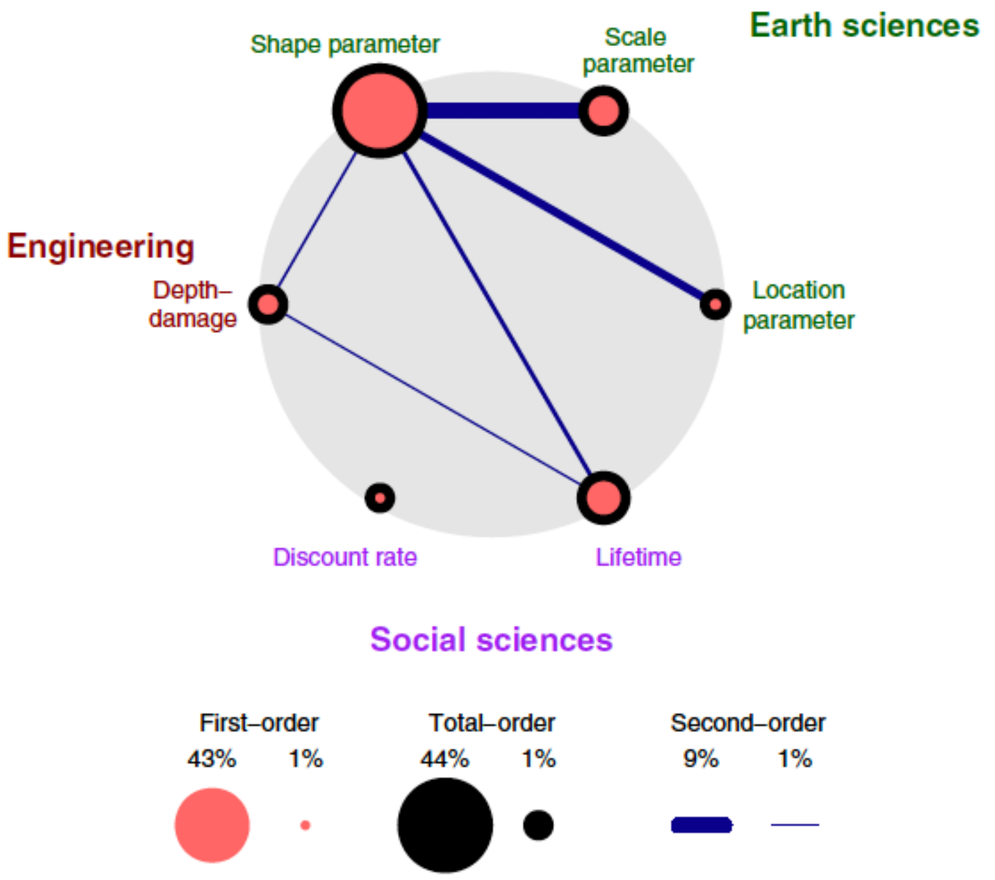
Data Availability at Appropriate Scales

For flood risk:

- Structure inventory in floodplain;
- Reasonable depth-damage curves (including already-undertaken adaptations);
- Socioeconomic/settlement data;
- Information about how people would respond to new policies/programs or dynamic hazards.

Uncertainty in Damage Estimates

How much does the estimate of potential damages affect risk?



Source: Zarekarizi et al (2020)

Structural Uncertainty and Damages

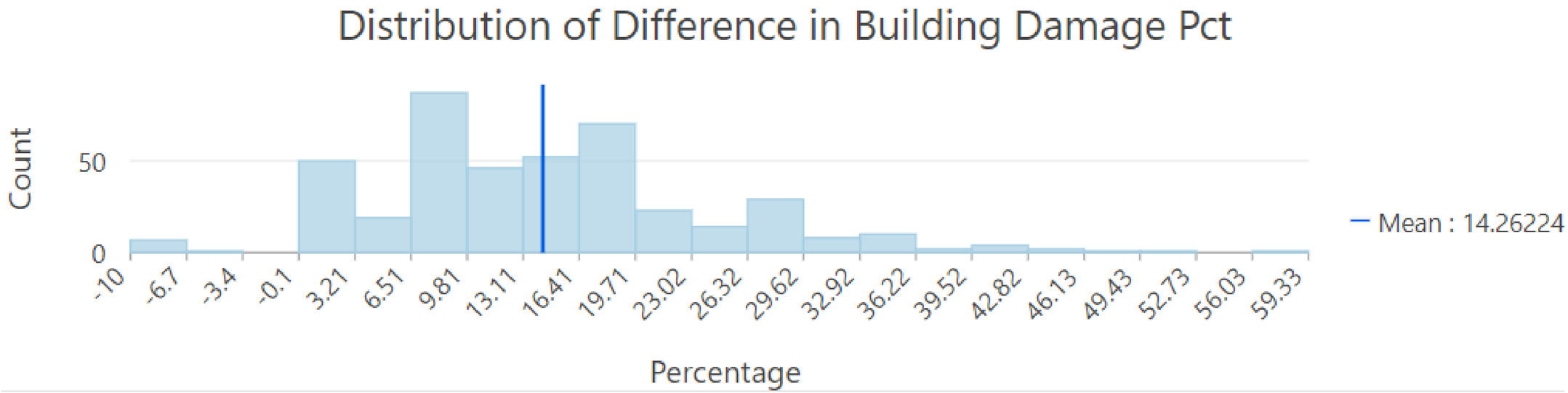
In addition to building stock uncertainties, structural uncertainty exists in mapping larger-scale hazards to local-scale assumptions.

For example, certain modeling groups and foundations may claim high accuracy, but their model isn't publicly available.

This raises the issue of implementation uncertainty, as well as those emerging from any modeling choices and issues of resolution/scale.

Structure Inventory

The FEMA HAZUS database is commonly used to estimate structures at risk, but exposure estimates are sensitive to building stock uncertainties:

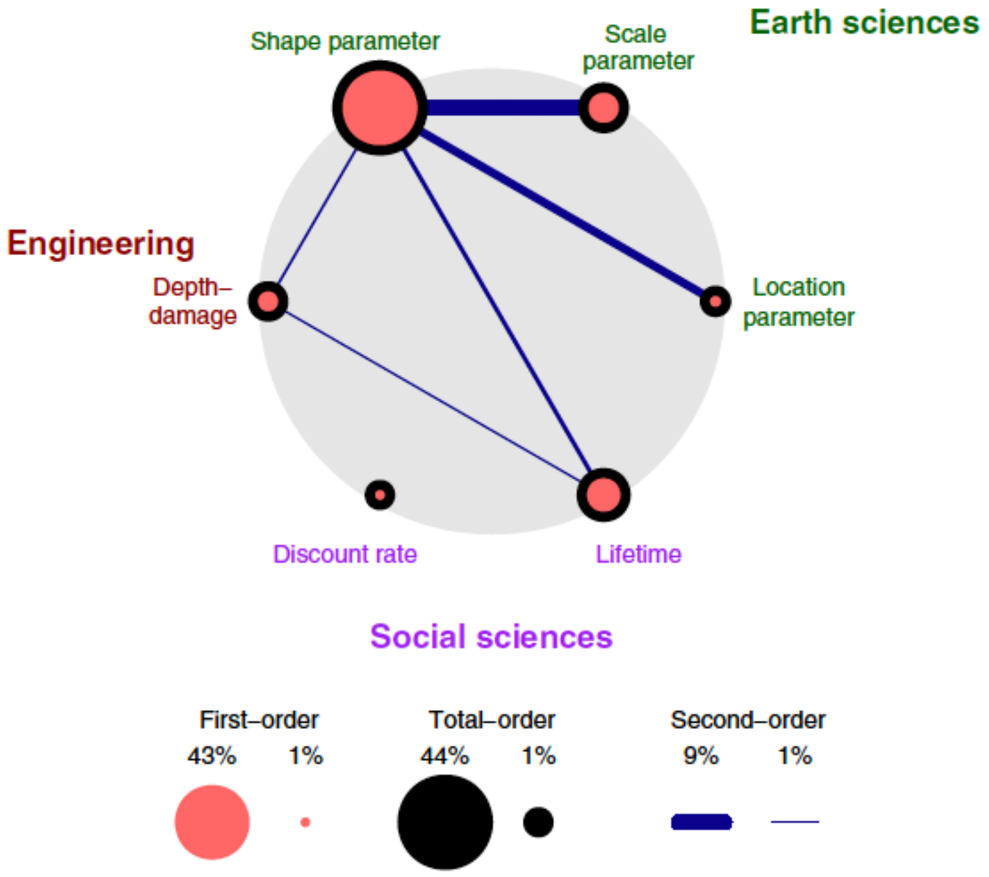


Source: Hurricane Idea in Manville, NJ

Uncertainty in Damage Estimates

How can we account for:

- Elevation;
- Moving appliances/electrical equipment out of the basement;
- Other floodproofing measures.



Source: Zarekarizi et al (2020)

Socioeconomic Data

Census/American Community Survey data provide a means to get at socioeconomic data.

- Census is more thorough, but only conducted every 10 years.
- ACS: Relatively small sample size

> *The ACS sample size is simply insufficient to provide high-frequency data at high spatial resolution with low uncertainty levels...*
>
> *Source: Spielman et al (2014)*

Socioeconomic Data

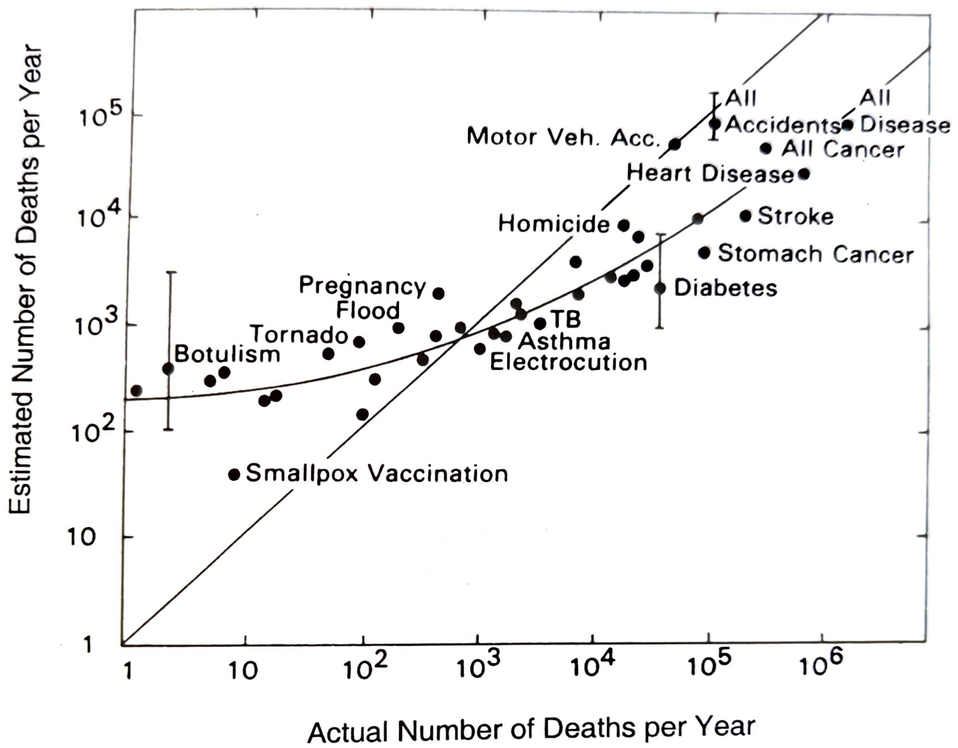
This is a fundamental challenge:

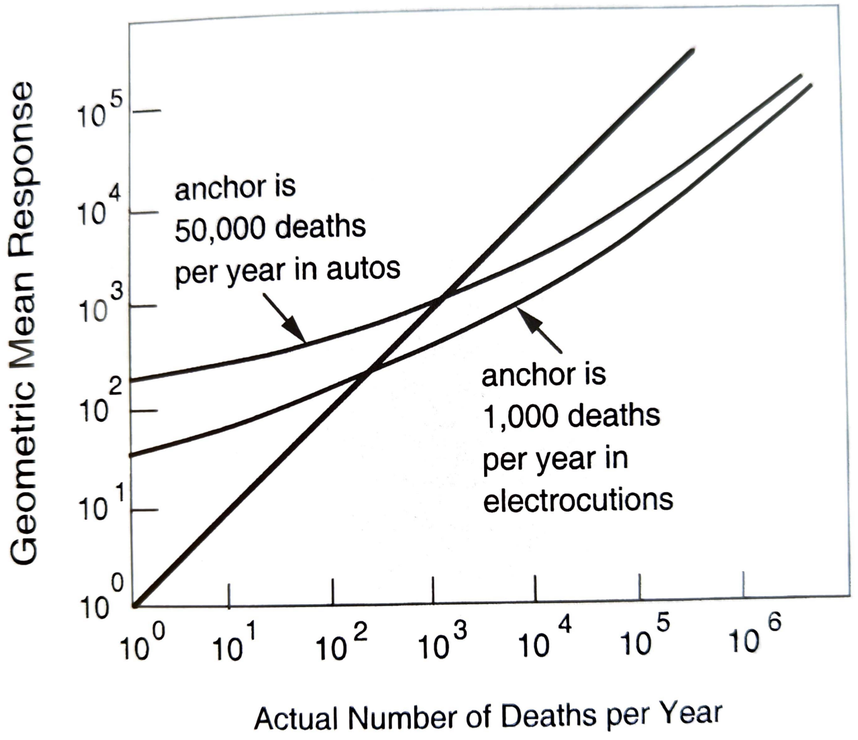
How to get high-resolution socioeconomic data without violating privacy or introducing biases?

Endogenous Response Dynamics

How to account for how people respond to dynamic hazards?

Hazard Perception and Anchoring





Source: Morgan et al (2002), Risk Communication: A Mental Models Approach
Adapted from Lichtenstein et al (1978)

Risk Tolerance Can Be Subjective!

Source: SMBC 05/17/2013

Review: Attitudes Towards Risk

Two scenarios:

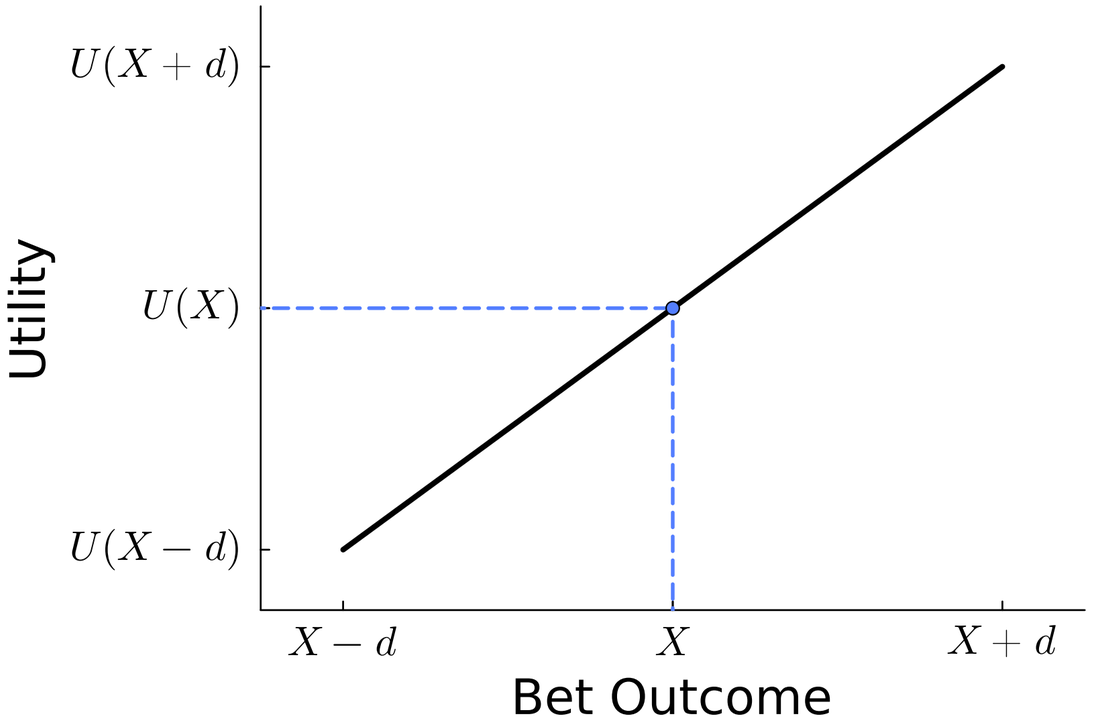
1. A certain payout of X?
2. An uncertain payout of $X - d$ or $X + d$, both equally likely?

Note that both of these "bets" have the same expected payout X. But there are a variety of responses!

Risk Neutral

Linear utility function:

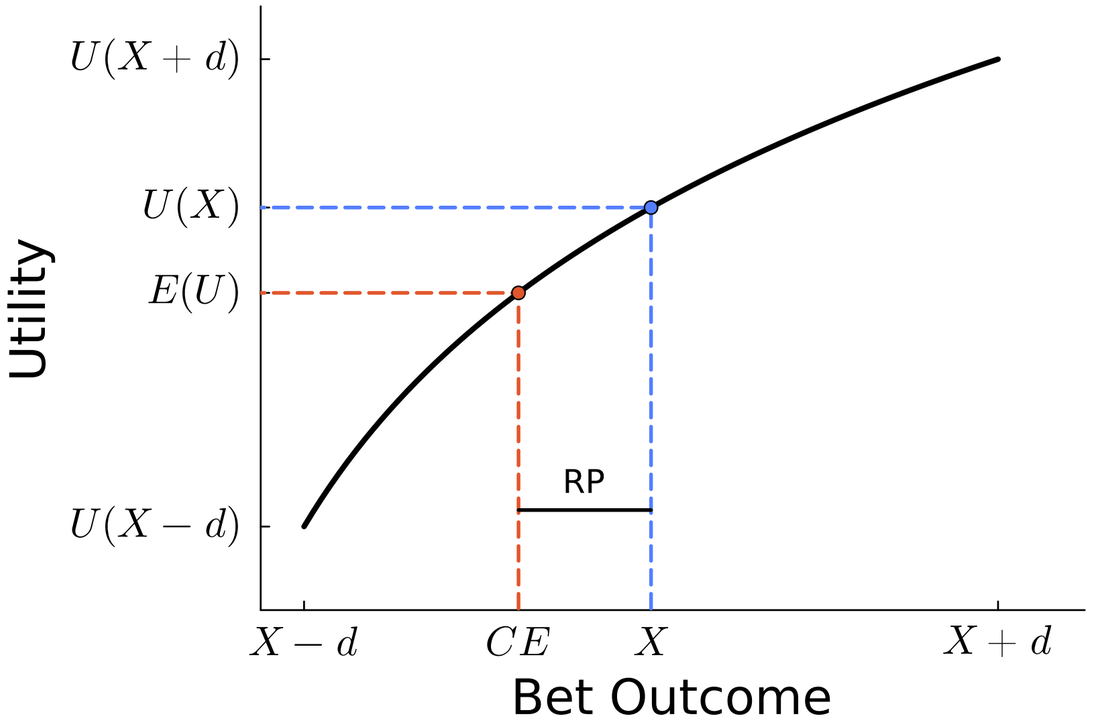
- Expected utility matches expected bet outcome.



Risk Averse

Concave utility function:

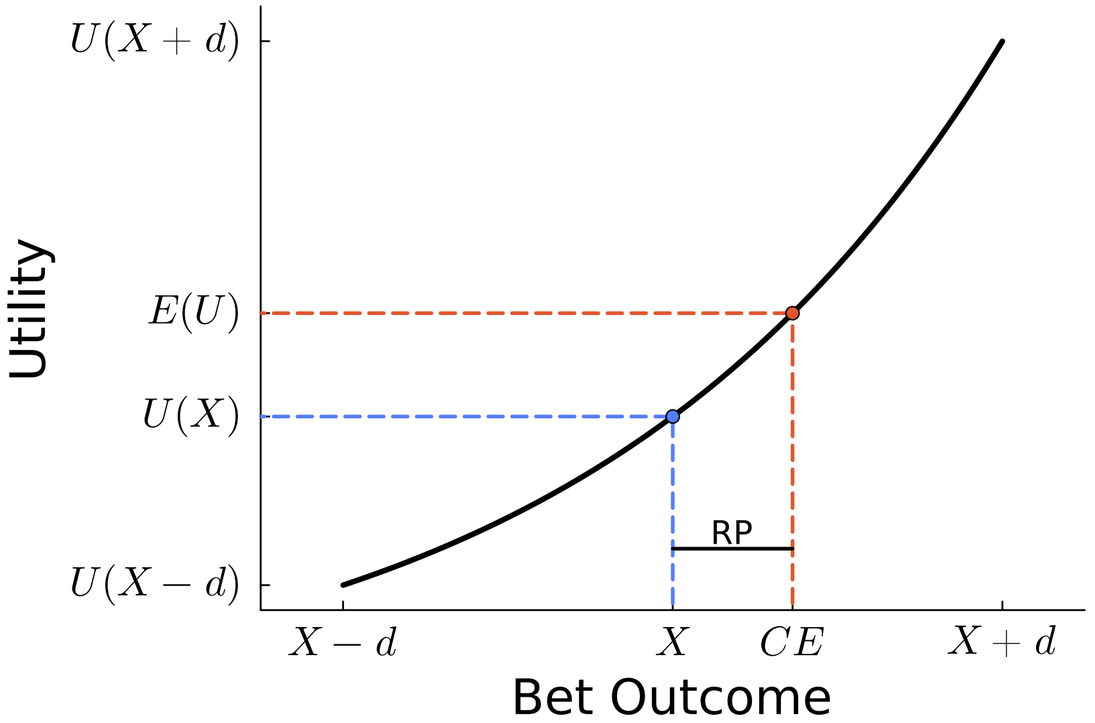
- Greater utility impact from the downside of the bet than upside.
- *Risk Premium (RP)*: "penalty" that would be acceptable to avoid the uncertainty of the gamble.



Risk Seeking

Convex utility function:

- Greater utility impact from the upside of the bet than downside.
- *Risk Premium (RP)*: "bonus" that would be needed to avoid taking the bet.



Implications for Modeling Responses

1. How is the system state translated into risk assessment?
2. Are decisions modeled directly or more abstractly?
3. What is the:
    i. utility function of the decision-makers?
    ii. mathematical representation of response?

Challenges for Modeling Responses

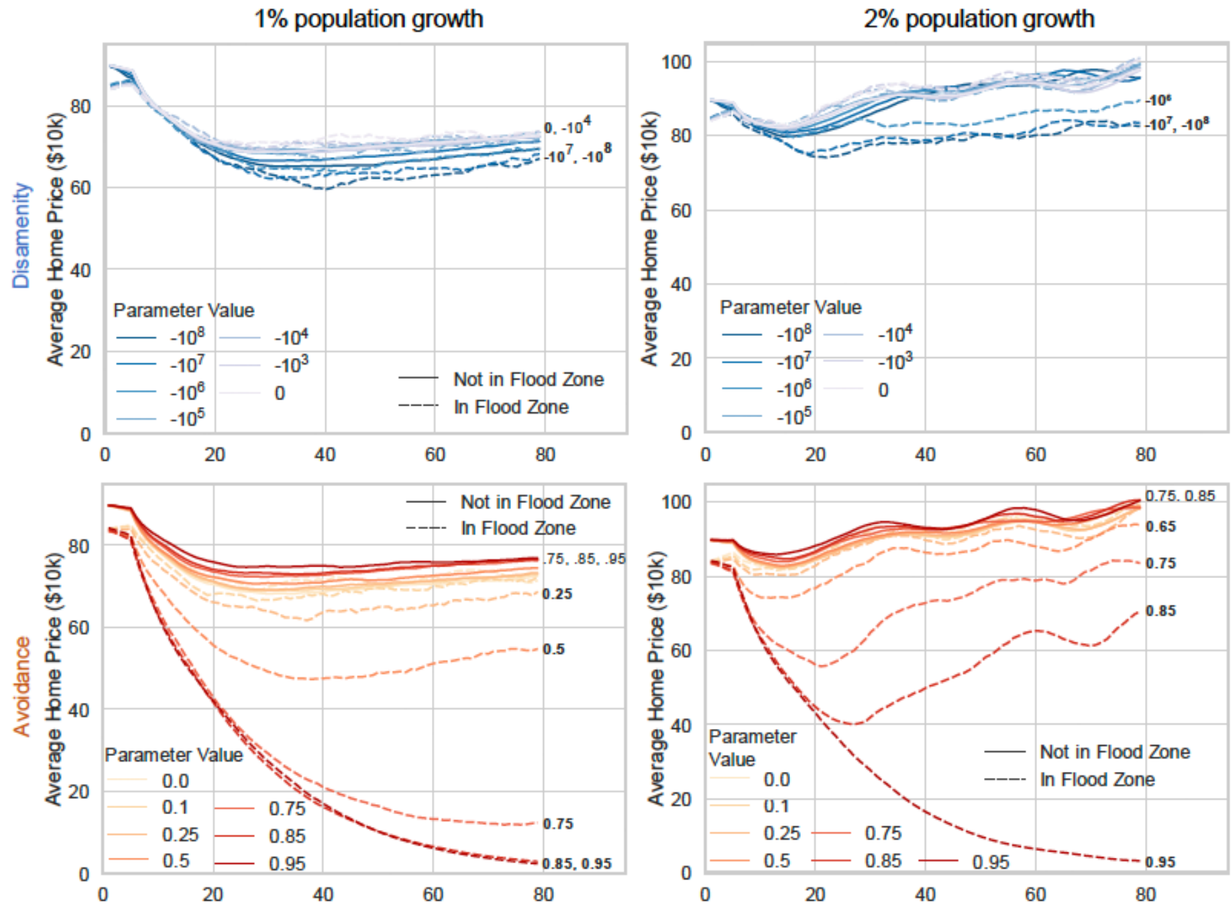
- Available information
- Resolution/scale of agents/decision-makers
- Agent/decision-maker representation
- Decision rules/utility functions

Challenges: Calibrating Decision Rules

How can we calibrate decision rules?

- Data on outcomes or decision processes (surveys, experiments?)
- Statistical calibration can be challenging.
  - Often intractable likelihoods.
  - Hard to assess data biases.
- Often done through hand-tuning.
  - Overfitting?
  - Overconfidence?

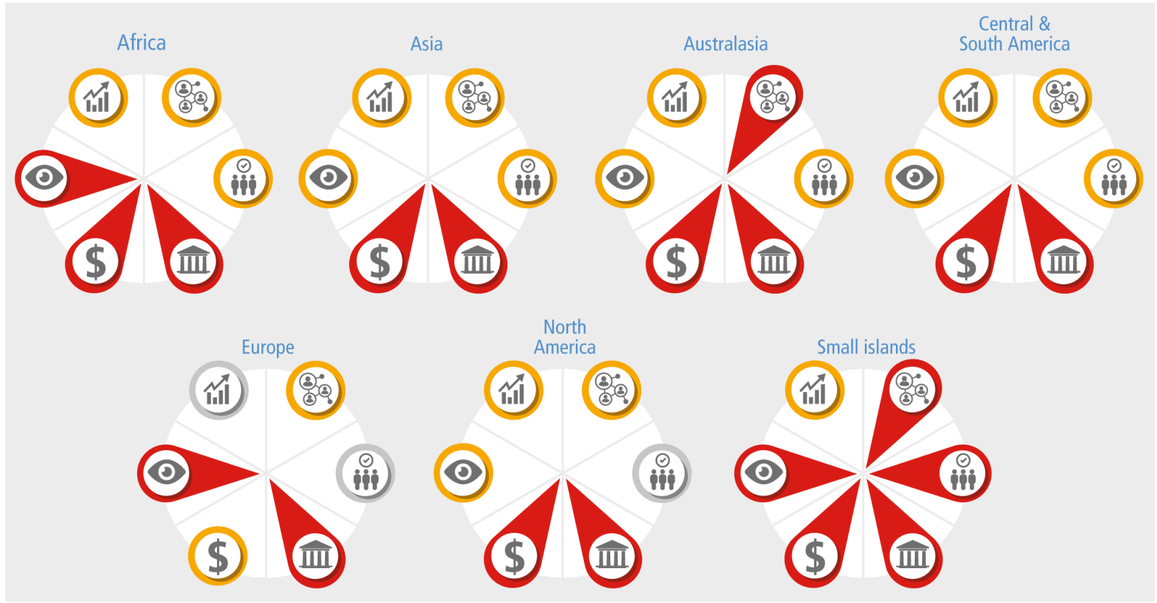
Decision Structural Uncertainty



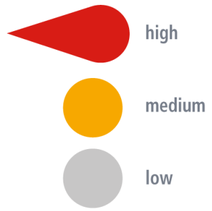
Source: Yoon et al, Structural model choices regularly overshadow parametric uncertainty in agent-based simulations of household flood risk outcomes, Accepted

Institutional Constraints

(d) Constraints that make it harder to plan and implement human adaptation



Constraints associated with limits to adaptation for regions across all sectors:



Source: *IPCC Assessment Report 6, Working Group II*

Key Takeaways

Key Takeaways

- Modeling exposure, vulnerability, and response is challenging for a variety of reasons.
- Data concerns/insights into decision processes can benefit from stakeholder engagement and input.
- Should consider structural uncertainty in all facets (including damage estimates);
- Think in terms of generative social science/exploratory modeling, not just for agent-based models.
- Institutional constraints add more complexity. and are often neglected or simplified.

Upcoming Schedule

Upcoming Schedule

Wednesday: Work on HW4

Monday: Project Presentations.

Next Friday: Project Posters Due.