Confronting Uncertainty in Climate Change

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Example based on Barnett, Brock and Hansen (2021 NBER Macro Annual)

Uncertainty tradeoffs

- How much weight do we assign to:
  - best guesses
  - potentially bad outcomes

  when making decisions?
- Do we act now, or do we wait until we learn more?

Uncertain climate economics

- climate sensitivity - the temperature responses to changes in emissions
- environmental tipping points - potentially dramatic consequences triggered after crossing a temperature anomaly threshold
- damages and adaptation - economic and social consequences of climate change

What are we aiming for?

Tractable quantitative methods for exploring subjective uncertainty including potential model misspecification and ambiguity across models.

Goals:

- assess the impact of uncertainty on climate policy outcomes
- isolate the forms of uncertainty that are most consequential for these outcomes.

Quantitative storytelling with multiple stories (models)

What types of uncertainty?

- ▷ risk: (uncertainty within a model) each model has explicit random impulses with known probabilities
- ▷ ambiguity: (uncertainty across models) alternative models have their own "stories" and implications
- ▷ misspecification: (uncertainty about models) each model is an abstraction and not intended to be a complete description of reality

What role does decision theory play?

Probability models we use in practice are misspecified, and there is ambiguity as to which among multiple models is the best one.

- aims:
  - use models in sensible ways rather than discarding them
  - use tools from probability and statistics to limit the type and amount of uncertainty that is entertained
- aversion - dislike of uncertainty about probabilities over future events
- implementation - target the uncertainty components with the most adverse consequences for the decision-maker

Uncertainty quantification

- Entertain uncertainty about probabilities from multiple sources
- Pose formally a decision problem under uncertainty that includes two penalty parameters
  - ambiguity over how to weight alternative models
  - potential model misspecification
- Solve a max-min dynamic decision problem with two outputs:
  - an altered probability specification that isolates the uncertainty components that are most consequential and adjusts the valuation
  - a decision rule that performs well for a range of alternative probability specifications
- Conduct a two-parameter sensitivity analysis by varying the penalty parameters

How much uncertainty aversion?

We have (two) penalty parameters that dictate the uncertainty aversion. Direct interpretation of their magnitude is challenging. Instead we follow the lead of "robust Bayesian Statisticians."

> *In what circumstances is a minimax solution reasonable? I suggest that it is reasonable if and only if the least favorable initial distribution is reasonable according to your body of beliefs. Irving J. Good (1952)*

Report implied probability adjustments for alternative penalizations and quantify their magnitude.

What does asset valuation provide?

Asset pricing theory: how do markets assess the investment opportunities in the face of uncertain future net payoffs?

- “assets” include financial, physical, human, organizational and environmental “capital”
- associated with each asset is a prospective sequence of net payoffs to investments (payoffs can be negative)
- apply asset pricing tools to social instead of market valuation!!
  - the SCC is an asset with adverse social “cash flow”
  - use the uncertainty adjusted probabilities when computing discounted expected present values

Climate policy under uncertainty

There are many calls for immediate climate policy implementation.

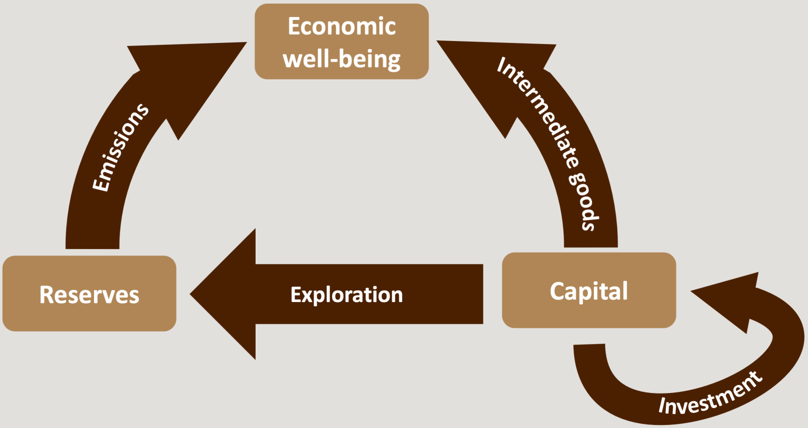
Existing limits to our understanding of the timing and magnitude of climate change impacts have led to apprehension by some.

We study how a decision-maker confronts uncertainty in a setting where:

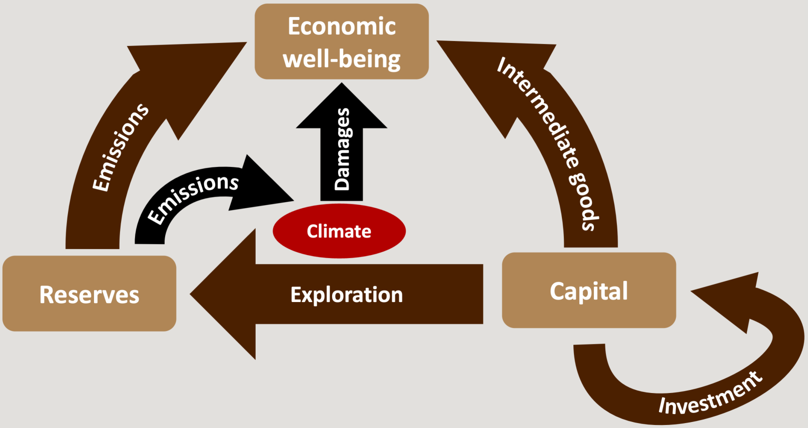
- there will be future information about damage severity;
- but the value of further empiricism in the near term is limited.

We apply recent developments in dynamic decision theory to guide how we incorporate uncertainty into policy decisions in this setting.

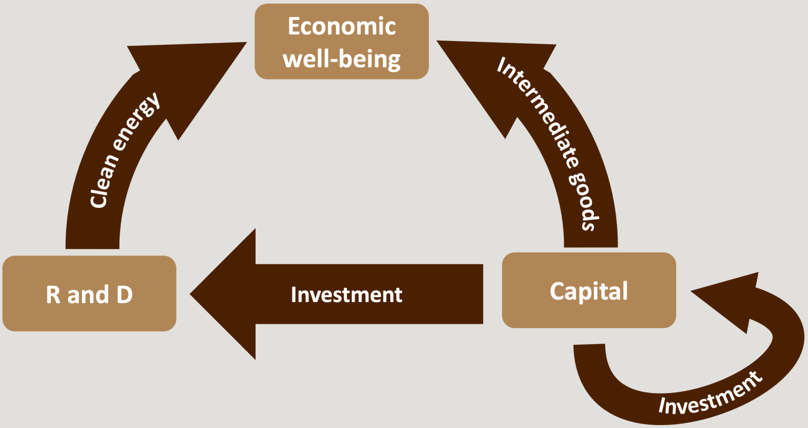
Model (without climate damages)



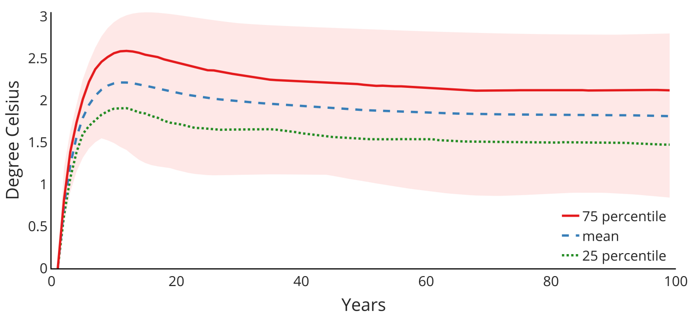
Model (with climate damages)



Model (without climate damages)

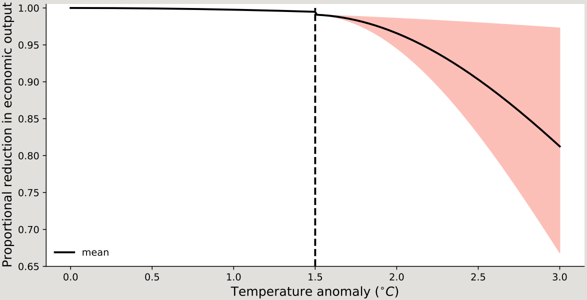


Divergent climate model predictions



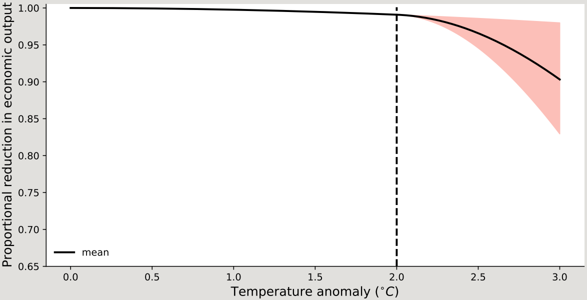
Percentiles for temperature responses to emission impulses. The emission pulse was 100 gigatons of carbon (GtC) spread over the first year. The temperature units for the vertical axis have been multiplied by ten. The boundaries of the shaded regions are the upper and lower envelopes based on 144 models.

A stochastic model of damages



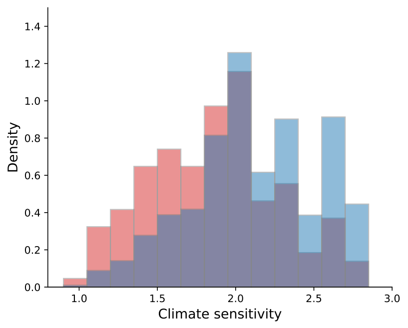
Possible proportional reductions of the productive capacity of the economy. Temperature anomaly threshold is 1.5 degrees celsius.

A stochastic model of damages



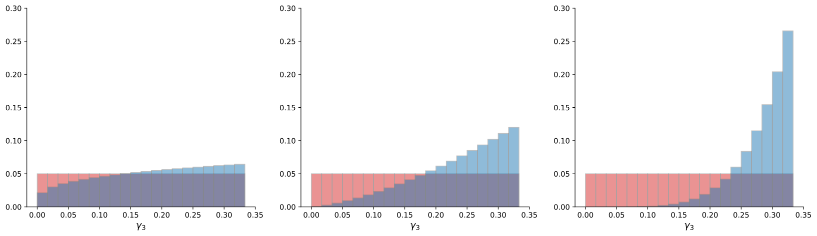
Possible proportional reductions of the productive capacity of the economy. Temperature anomaly threshold is 2.0 degrees celsius.

Ambiguity-adjusted climate model probabilities



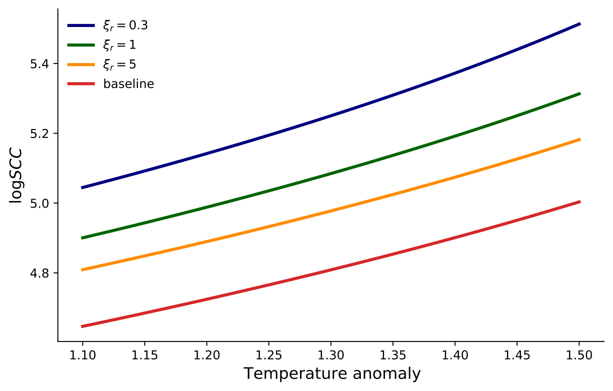
The red histogram is the outcome of equally weighting all 144 climate models. The blue histogram is the outcome of the minimization in the social planner's problem pertinent for social valuation.

Robust-adjusted damage function probabilities



Red bars are the baseline probabilities and the blue bars are robust adjustments to the probabilities induced by model misspecification concerns. Left panel: $\xi_u = 5$, center panel: $\xi_u = 1$, right panel: $\xi_u = 0.3$ where ξ_u is the penalization parameter.

Social cost of carbon with uncertainty



$$\underline{y} = 1.5, \bar{y} = 2$$

The logarithm of the social cost of carbon as a function of the temperature anomaly

Summary of findings

The solution to our decision problem identifies two key results:

- the planner exhibits initial caution until damages are more fully revealed;
- with this information, the decision-maker may be more wary or bullish;
- there is a pronounced asymmetry in the responses with a small fraction of more bullish responses and clustering of responses that are cautious.

Active research

- uncertain return to research and development (R and D) investments that seek less carbon intensive technologies
  - two policy aims: i) reduce emissions and ii) provide R and D subsidies to increase the likelihood of technological solutions in the future
  - uncertainty can have differential impacts on the two aims
- uncertain nonlinearity in the carbon/climate dynamics that could produce "tipping point" like behavior

Concluding remarks

- combine insights from control theory, decision theory, statistical approximation and asset pricing
- use the decision or policy problem to frame the uncertainty quantification
- deduce what uncertainty contributions are most consequential for the problem at hand

Decision theory contributions

- dynamic variational preferences (flexible representation): Maccheroni, Marinacci, and Rustichini, JET, 2006
- ambiguity about the local mean in the state dynamics captured by a recursive robust choice of priors: Chen-Epstein, 2003, Econometrica, Hansen-Sargent, 2007, JET and Hansen-Miao, 2018, PNAS, 2022, ET
- potential model misspecification - extensive literature on robust control and Anderson-Hansen-Sargent, 2003
- misspecification and ambiguity aversion - dynamic formulation: Hansen-Sargent, 2022, JET; axiomatic formulation: Cerreia-Vioglio, Hansen, Maccheroni, Marinacci, 2022, linkages to statistical decision theory: Hansen-Sargent, 2022