How Should Climate Change Uncertainty Impact Social Valuation and Policy?

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Climate Change Challenge

"The economic consequences of many of the complex risks associated with climate change cannot, however, currently be quantified. ... these unquantified, poorly understood and often deeply uncertain risks can and should be included in economic evaluations and decision-making processes."

Rising, Tedesco, Piontek, Stainforth, Nature, 2022

How could uncertainty matter?

- more or less proactive?
- reduce future exposure to uncertainty?

The answers depend in part on how much or little confidence decision-makers have in their baseline probabilistic predictions and how sensitive policy objectives are to those predictions.

What are the uncertainties?

Four channels:

- productivity: how capital investment today alters future output
- geosciences: how CO_2 emissions today impact the future climate
- economics: how climate change in the future alters economic opportunities and human well-being
- technology: how research and development invested today may eventually lead to economically viable technologies

What are the consequences of the uncertainties?

Two policy levers:

- reduce fossil fuel emissions
- invest in the discovery of new technologies that are clean replacements

Advances in decision theory under uncertainty

Decision theory seeks to develop and justify approaches that are "rational" or perhaps better described as "prudent." allows for a broad perspective on uncertainty.

Do not know:

- outcomes with known probabilities - risk
- which among multiple probability models is best - ambiguity (prior uncertainty)
- ways in which a model might give flawed probabilistic predictions - misspecification (likelihood uncertainty)

Three layers of uncertainty.

Implementation

Use tools from statistics, control theory, probability theory, and asset pricing theory to:

- isolate the components of uncertainty that are most consequential when designing a prudent policy
- construct uncertainty adjustments to "shadow prices" such as the social cost of global warming or the social value of research development
- assess how much should future concerns impact current shadow prices
- explore the consequences of uncertainty aversion on the design of prudent policy

Decision problem

- formulate a recursive max-min game where we
  - minimize over the possible probability distortions subject to the penalization (with parameter ξ)
  - maximize over the possible control processes
- sometimes there is an equivalent risk aversion interpretation which I find hard to interpret for our application
- valuation (perhaps shadow) represented in terms of the minimizing probability measure
- as external analysts, we explore sensitivity of the minimizing distributions to the choice of ξ
- distinguish concerns about model misspecification from ambiguity over subjective inputs with two distinct forms of penalization

Today I will focus on potential misspecification in my extended example.

Some recent references

- Making Decisions under model misspecification, Cerreia-Vioglio, Hansen, Maccheroni, Marinacci, 2023
- Risk, ambiguity, and misspecification: Decision theory, robust control, and statistics, Hansen Sargent, *Journal of Applied Econometrics*, 2023
- Structured ambiguity and model misspecification: Hansen and Sargent, *Journal of Economic Theory*, 2022
- Aversion to ambiguity and model misspecification in dynamic stochastic environments, Hansen and Miao, *PNAS*, 2018

Uncertainty aversion/robustness

- Borrow insights from derivative claims pricing and from robust Bayesian theory to:
  - deduce a "worst-case" probability distribution isolating where potential misspecification is most concerning by solution to penalized minimization;
  - use this as an uncertainty-adjusted probability measure for social (in place of market) valuation;
  - represent marginal social valuations.

Uncertainty quantification and decomposition I

- explore sensitivity of prudent decisions to the degree of uncertainty aversion.
- quantify the most important channel of uncertainty by:
  - ▷ solving four decision problems by restricting the uncertainty to one of four channels at a time: i) productivity; ii) geo-scientific, iii) economic damages, and iv) technology;
  - ▷ comparing the outcomes to a decision solution when all four are simultaneously considered.

Uncertainty quantification and decomposition II

- Depict prudent decisions as dependent on marginal valuations.
- Represent marginal valuations as asset prices with uncertain payoffs.
- Separate marginal valuations into distinct components based on alternative contributions to the payoffs.

In the case of climate change, two marginal valuations are particularly relevant:

- social cost of global warming
- social value of research and development.

Risk components and uncertainties

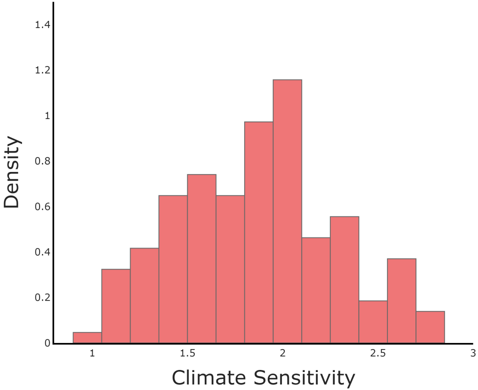
- vector Brownian (normally distributed) shocks
- Poisson two (big) events
  - tipping point in the climate/economic system: reveal damage function curvature for larger values of warming - intensity increases with global warming
  - technological breakthrough: discover a new technology that eliminates the need for the dirty energy input - intensity increases with the knowledge stock

Relax full confidence in the probabilistic model (explore sensitivity to misspecification)

A few more details

- AK technology with adjustment costs and a dirty energy input
- output split between an investment in productive capital, investment in R&D knowledge capital, and consumption
- climate externality is a proportional reduction in the productive capacity that depends on the temperature anomaly

Divergent climate model predictions



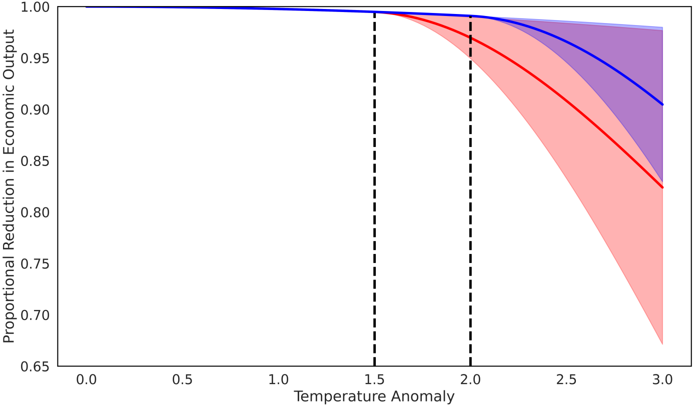
Histograms for the exponentially weighted responses of temperature to an emissions pulse from 144 different models

Stochastic model of damages

Poisson jump process

- jump intensity increases substantially over the temperature anomaly degree interval $[1.5, 2]$
- at the time of the jump, the damage curvature from that point forward is revealed where the tail curvature coefficient takes on one of twenty values

Damage curves



Range of possible damage curves for two cases with different jump thresholds.

Findings

Our initial research shows that:

- the unknown timing of the success of the R&D investment is the most potent contributor to uncertainty for climate-economics policy;
- this source of uncertainty leads to doing more green R&D investment;
- reduce emissions in the short term to allow for R&D to have a chance to be successful, even though this response is less sensitive to uncertainty.

Represent marginal valuations as asset prices

Examples:

- social cost of climate change
- social benefit of research and development

Inputs into marginal valuations

- stochastic discounting (utility-based)
  - subjective discount rate
  - state-dependent jump intensities
  - uncertainty-adjusted probability measure from minimization
- stochastic social cash flows
  - marginal utility contributions
  - prospective jump contributions
    - marginal impacts of alternative jumps
    - marginal impacts when you jump

  Note: jumps are associated with forward-looking value functions depending on new technologies or damage curve realizations.

Uncertainty-adjusted probabilities for the timing of the first jump

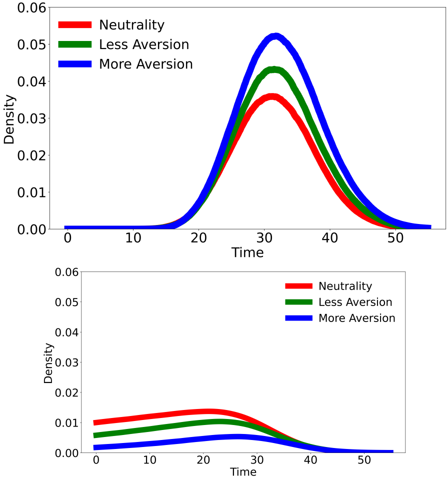
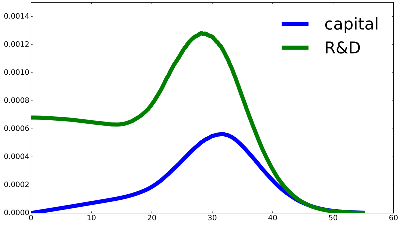
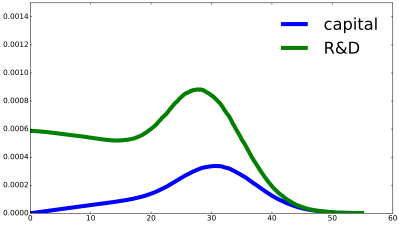


Figure: Two components to the jump densities. Top: damage jump contribution. Bottom: technology jump contribution.

Pre-jump marginal value contributions for different horizons



aversion

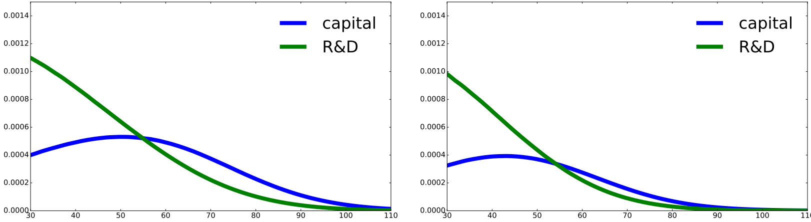


neutrality

	capital	R&D
aversion	0.011 (25%)	0.034 (79%)
neutrality	0.007 (22%)	0.025 (80%)

Note: the flow contributions from temperature responses are negligible

Post-jump marginal value contributions for different horizons



aversion neutrality

	capital	R&D
aversion	0.025 (47%)	0.028 (53%)
neutrality	0.015 (43%)	0.020 (57%)

Note: the flow contributions from temperature responses are negligible

Why is R&D investment more attractive?

There are offsetting impacts of uncertainty aversion that we study with our asset pricing representation:

- the uncertainty-adjusted probability measure pushes the prospects for successful $R\&D$ into the more distant future;
- the change in continuation values associated with jumps become substantially larger.

The second impact dominates over a range of uncertainty aversion that we find to be interesting.

Conclusions

- Sometimes the best response to uncertainty is to be more proactive.
- The extensions and refinements of uncertainty quantification that I described have more general applicability to the study of dynamic models.
- This research is part of a larger agenda to explore uncertainty impacts on both private and public sector decision making.