The Macroeconomic Consequences of Uncertain Climate Change

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Based in part on joint work with William Brock and Mike Barnett

Haunted by Hayek's forewarning

"Even if true scientists should recognize the limits of studying human behaviour, as long as the public has expectations, there will be people who *pretend* or *believe* that they can do more to meet popular demand than what is really in their power."
(From Hayek's Nobel address, 1974)

For quantitative policy analysis, how should we acknowledge the limits to our understanding?

Confronting policy uncertainty

Tension:

- limited understanding of the mechanism by which policy influences economic outcomes
- demand for precise answers by the public and/or government policymakers

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

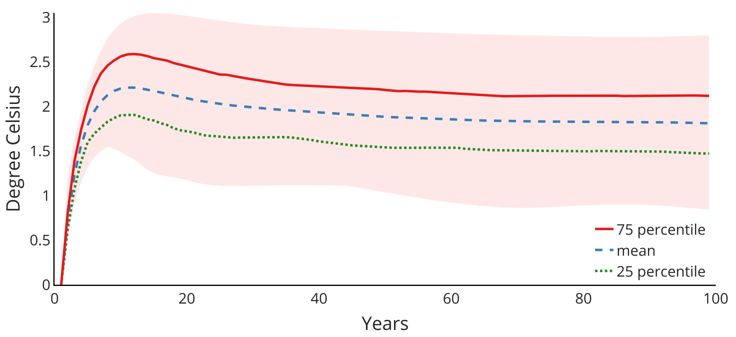
Much of the quantitative research in climate economics has targeted the SCC (social cost of carbon) - fiscal policy

Modular approach to the SCC

- socio-economic module - the projected future evolution of the economy, including emissions of CO_2, characterized without the explicit impact of climate change;
- climate module - the earth system response to emissions of CO_2 and other anthropogenic forcings;
- damages module - the economy's response to changes in the Earth system;
- discounting module - a time series of future damages is compressed into a single present value.

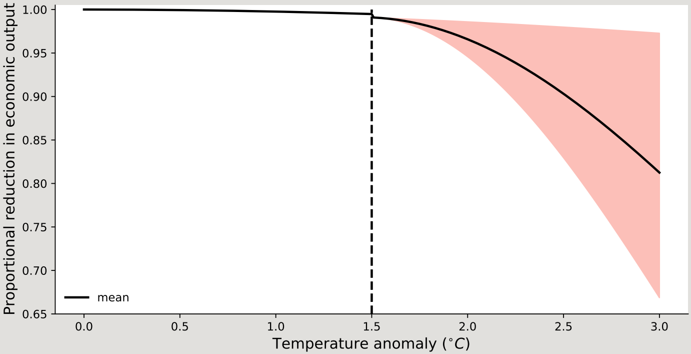
National Academies of Sciences, Engineering and Medicine Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide, 2017.

Divergent climate model predictions



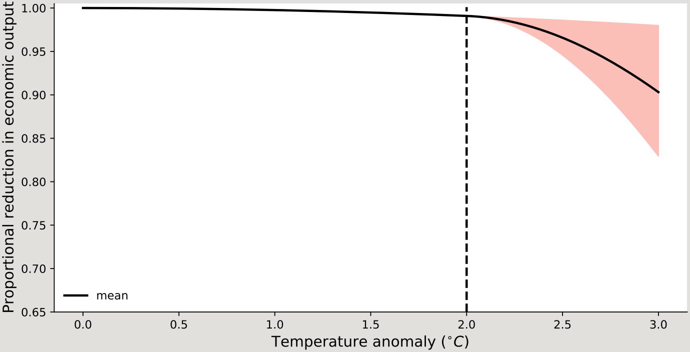
Percentiles for temperature responses to emission impulses. The emission pulse was 100 gigatons of carbon (GtC) spread over the first year. The temperature units for the vertical axis have been multiplied by ten. The boundaries of the shaded regions are the upper and lower envelopes based on 144 models.

A stochastic model of damages



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

A stochastic model of damages



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

Pitfalls in the Modular Approach

Modules: i) socio-economic, ii) climate, iii) damages, iv) discounting

- emissions scenarios are typically specified exogenously - in reality will respond to the environmental and economic damages
- discounting - often a constant discount rate with external sensitivity
  - should be probabilistic to accommodate adjustments for uncertainty
  - probabilistic adjustments depend on how macroeconomic uncertainty will play out in the future

There are important interactions across the proposed modules!

Confront two uncertainty tradeoffs

Use mathematical models informed by expert judgement and empirical evidence to answer:

- How much attention do we pay to best guesses versus possible bad outcomes?
- What should we do now versus waiting for better information to become available?

Role for decision theory under uncertainty

Take a broad perspective on uncertainty

- risk - unknown outcomes with known probabilities
- ambiguity - unknown weights to assign to alternative probability models
- misspecification - unknown ways in which a model might give flawed probabilistic predictions

Build better ways to do uncertainty quantification for dynamic economic models used for policy analysis

Navigating uncertainty

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 discard 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
- outcome - an uncertainty adjusted probability measure pertinent for valuation along with robust decision rules

Climate policy under uncertainty

There are many calls for immediate climate policy implementation.

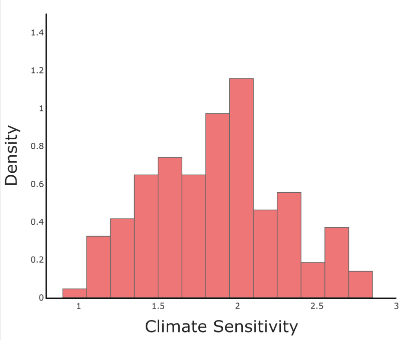
Existing limits to our understanding of the timing and magnitude of climate change impacts have led to apprehension by some.

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.

Uncertain temperature response to emissions

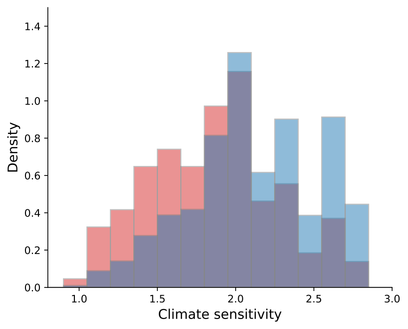


Histograms for the exponentially weighted average responses of temperature to an emissions pulse from 144 different models using a discount rate $\delta = .01$

Uncertain damage thresholds

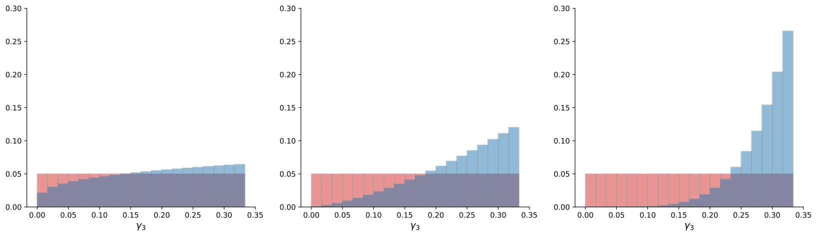
- Threshold uncertainty captured by a jump process with $m = 20$ absorbing states.
- Each state corresponds to a value for the curvature of the damage function beyond the jump date
- Prior to the jump, there is a uniform distribution over the $m = 20$ potential damage curvatures
- The decision maker does not know when the jump will be triggered - impose a jump intensity that is increasing and concentrated on interval $[\underline{y}, \bar{y}]$ for the temperature anomaly

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: $\xi_u = 0.3$.

Social Cost of Carbon (SCC)

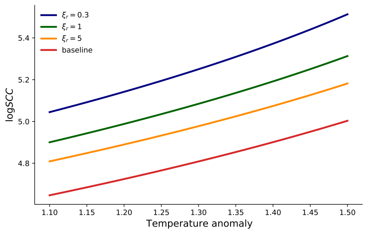
Commonly referred to in policy discussions but meanings and targets of measurement *differ* across two applications.

We use one version as an analytical tool to assess the impact of uncertainty.

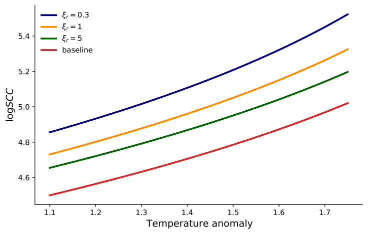
- externality - carbon emissions alter the climate, which in turn impacts economic opportunities and social well-being in the future
- social cost of carbon includes the socially efficient (Pigouvian) tax on carbon emissions that "corrects" this "externality"

Another version measures the discounted social cost of a small change in emissions

Social Cost of Carbon with Uncertainty



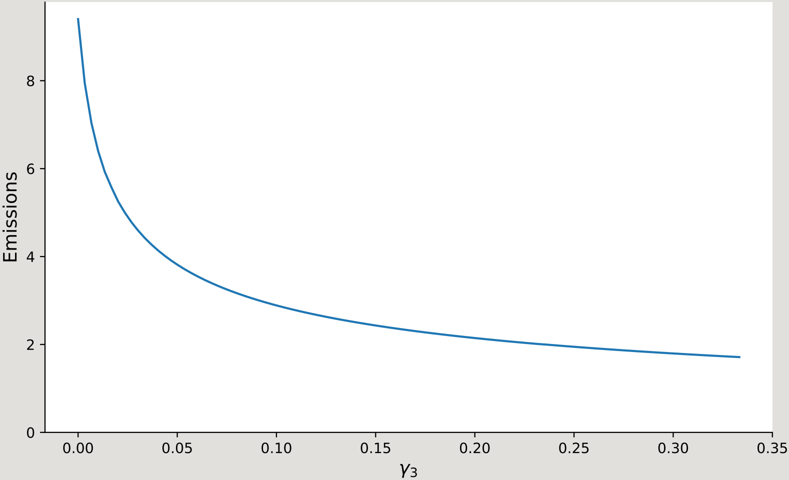
$\underline{y} = 1.5, \bar{y} = 2$



$\underline{y} = 1.75, \bar{y} = 2.25$

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

Post jump emissions as a function of future damage curvature



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.

Financial stability challenges

- What is systemic risk? - modeling successes have been largely qualitative
- How do we integrate climate change into our current understanding?
- Over what time scale should we seek to quantify climate change uncertainty?
- Whose models do we use for assessing the exposure of financial institutions to climate change: regulators' or the ones of those who are regulated? - see Behn, Haselmann, and Vig, "The Limits of Model-Based Regulation."

Quantifying Exposures to Climate Uncertainty

Well-articulated mandate for the regulatory/supervisory role for the banking sector.

- ▷ does climate change induce systematic uncertainty or systemic risk?
- ▷ what can we learn from historical measurement? - push economies in realms that we have yet to experience
- ▷ perhaps the private sector will collectively under-estimate magnitudes of their exposure to climate change

Scenario-based stress tests

Aims:

- confront "extreme uncertainty" connected to climate change without resort to probabilities
- explore events through well-defined scenarios that can extend over three decades
- investigate tail events that stress the financial system

Scenario based stress tests

Figure 3.1 Illustrative variable pathways in each scenario

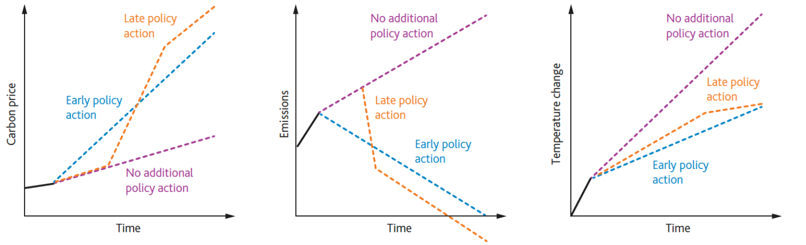


Figure taken from the Bank of England report: The 2021 Biennial Exploratory Scenario on the Financial Risks from Climate Change

Limits to stress tests

Static with no uncertainty along a path.

- miss or disguise two important lessons from decision theory:
  - tradeoff between guarding against possible bad outcomes that could happen versus performing well over more likely outcomes
  - decisions respond recursively to state dynamics and information revelation
- provides potentially misguided paths for economic and environmental outcomes without explicit dynamic modeling
- opens the door to stress test answers that condition on the path

Shunting probabilities and pushing dynamic information revelation to the background is counter-productive.

Conclusion/Summary

- Fiscal policy has the biggest potential as a tool for confronting climate change, with monetary policy playing more of a supportive role.
- The time horizon over which climate change uncertainty plays out is different than in other forms of turbulence on the radar screen of central banks, creating unique challenges for oversight and regulation.
- Understanding the sources of subjective uncertainty in models used by the private sector and by governments will make oversight more effective.