What don’t we know about climate change?

ECON-4210

Economics of Climate Change

Class 24

Prof. Casey Wichman

Georgia Institute of Technology

Today's class

1. Questions?
2. Attendance
3. Housekeeping
    1. No class Wednesday (Thanksgiving)
4. Uncertainty
    1. Risk aversion
    2. Insurance and correlated risk
    3. Precautionary principle
    4. Fat tails
5. For next class…

What's the "right" price of carbon?

- Three challenges in pricing CO_2 emissions:
  - Which discount rate?
  - How big are the damages from CO_2 emissions?
  - **How to account for uncertainty in climate change?**
    - Especially low-probability, high-damage outcomes.

Some classifications of uncertainty

- **Risk:** we know the outcomes and their probabilities.
- **Ambiguity ("deep uncertainty"):** we know the outcomes, but not their probabilities.
- **Unforeseen contingencies:** we don't know the outcomes.

“There are **known knowns**. There are things we know that we know.

There are **known unknowns**. That is to say, there are things we now know we don’t know.

But there are also **unknown unknowns**. There are things we do not know we don’t know.”

-Former Secretary of Defense, Donald Rumsfeld
News Briefing, Feb 12, 2002
https://www.youtube.com/watch?v=_RpSv3HjpEw

Climate damages in the SCC

Known knowns: counted in the EPA's SCC

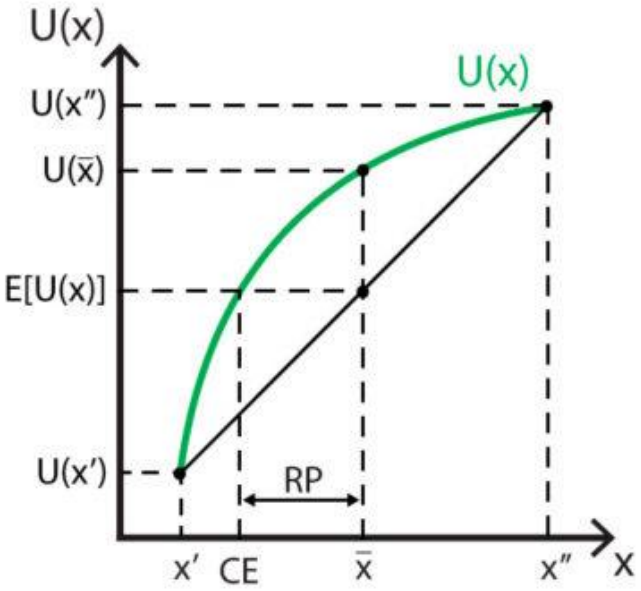
- Health (deaths from heat and cold)
- Agriculture
- Energy use
- Coastal damage from sea-level rise
- Labor productivity (in one of three models)

Known unknowns: mostly left out

- Changes in precipitation
- Extreme weather (hurricanes, floods)
- Wildfire
- Tipping points
- Interactions across natural and human systems

U.S. EPA (2023). Report on the social cost of greenhouse gases: Estimates incorporating recent scientific advances. Sections 2.3 and 3.2. PDF
Wildfire: U.S. EPA NCEE Working Paper 2025-01.

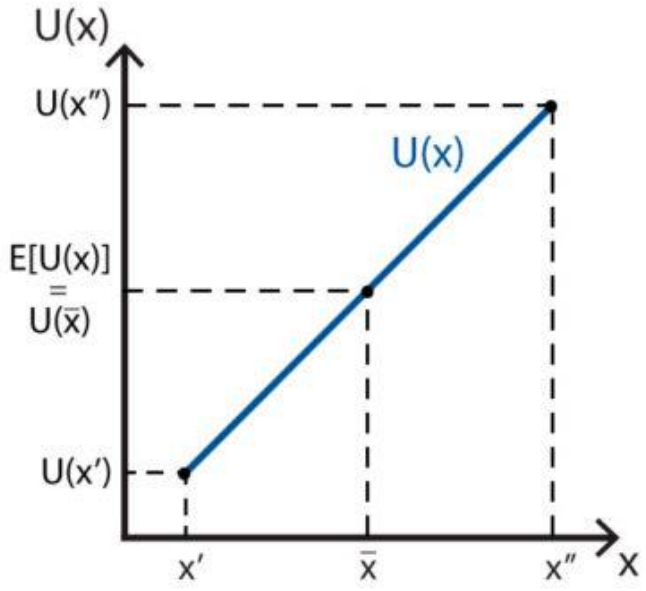
A very brief intro to risk aversion



Risk averse individual

$E[U(x)] < U(\bar{x})$

$CE < \bar{x}$



Risk neutral individual

$E[U(x)] = U(\bar{x})$

$CE = \bar{x}$

- **An uncertain gamble:** 50-50 chance of ending up with x' (bad outcome) or x'' (good outcome)
  - Expected payoff: $\bar{x} = 0.5x' + 0.5x''$.
- **Expected utility**: the probability-weighted average of utility, $E[U(x)]$.
- **Certainty equivalent (CE)**: the sure amount that gives the same utility as the gamble. $U(\text{CE}) = E[U(x)]$
- **Risk premium (RP)**: the expected payoff minus the CE. $\text{RP} = E[x] - \text{CE}$
- Risk averse → RP > 0.
  - You should be willing to pay some positive amount of $$$ to get rid of the risk.

Figure: Policonomics, risk aversion

Georgia Institute of Technology

What would you pay to insure your house against a fire?

- Your wealth (W) is $600,000: $100k in savings + a $500k house.
- Each year, there is a 1% chance it burns down.
  - **Expected wealth:** 0.99 × $600,000 + 0.01 × $100,000 = $595,000
  - **Expected loss:** 0.01 × $500,000 = $5000

- Suppose your wealth produces utility according to: U(W) = ln(W).
  - **Expected utility:** 0.99 × ln(600,000) + 0.01 × ln(100,000) = 13.2868
  - **Certainty equivalent:** the sure wealth with the same utility.
    - Set U(CE) = E[U], so ln(CE) = 13.2868.
    - Undo the log: CE = $e^{13.2868}$ = $589,345
  - **Risk premium:** $595,000 – $589,345 = $5,655

- The max you would pay for full insurance: $600,000 – $589,345 = $10,655
  - $10,655 = your expected loss ($5,000) plus your risk premium ($5,655).

Risk aversion in climate policy?

- The SCC is usually estimated with risk-neutral preferences.
- Most people are risk averse $\Longrightarrow$ They should be willing to pay a risk premium to reduce society's climate risk.
  - Adding risk aversion increases the SCC, especially when catastrophic outcomes are possible.

Why do we buy insurance?

- How many of you have been in a car accident in the last year?
  - Accidents and house fires are rare, but each one is costly.
  - We are required to have insurance to drive a car.
- Insurers pool many policies. If losses are ***independent*** (i.e., unrelated to each other), the number of claims each year is predictable.
  - 1,000 homes, each worth $500,000, each with a 1% chance of burning:
    - about 10 claims in a typical year
    - With independent fires, even the worst year in 200 has only about 19 claims, about twice a typical year.
- Insurers pay claims out of the premiums they collect. An insurer stays in business only if it can pay claims in its worst year.

Two towns, with similar fire risk

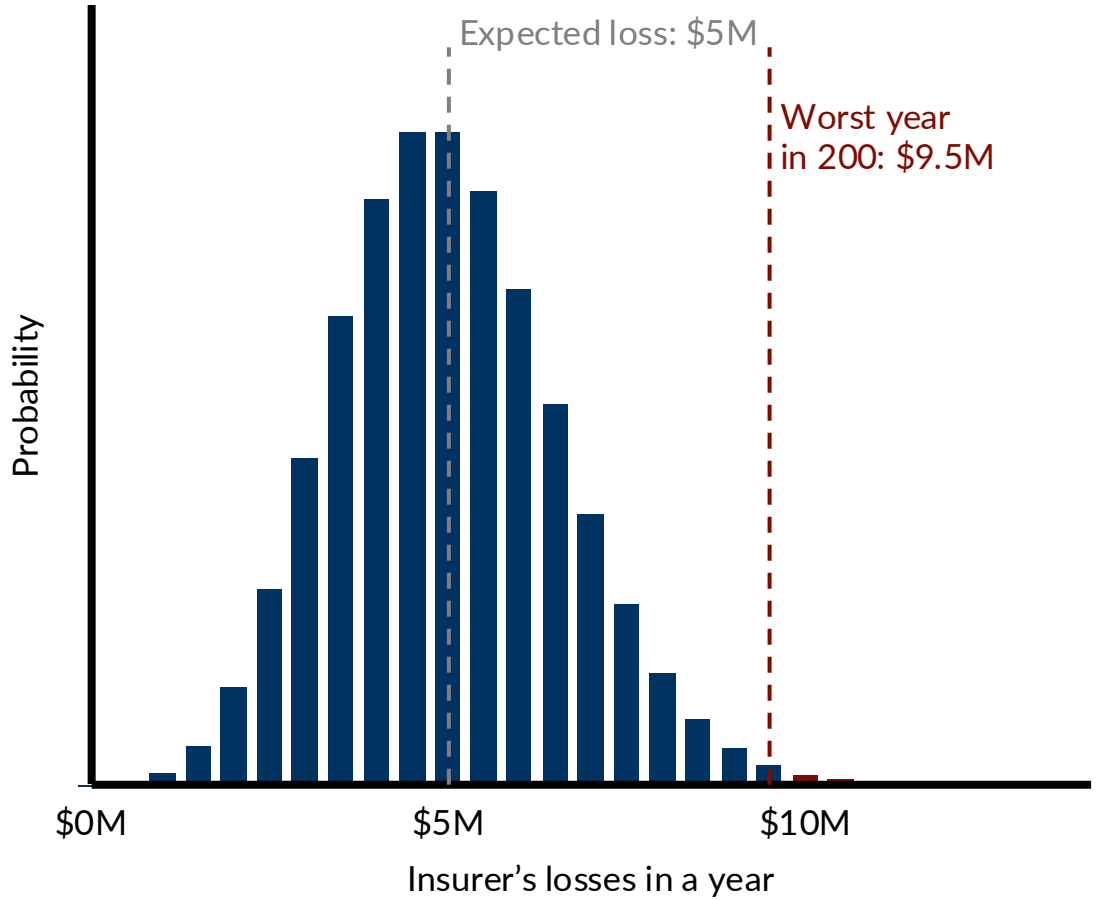
- Each town has 1,000 homes worth $500,000. One insurer covers each town.
- **Risk:** Every home has a 1% chance of burning each year.
- **Expected loss:** $5 million a year in both towns.

- **Town A**: fires are independent (e.g., a random kitchen fire, a lightning strike).
  - About 10 homes burn every year.
- **Town B**: fires are correlated. One wildfire destroys every home or none.
  - 99 years out of 100, nothing burns. 1 year in 100, the whole town burns.

- Both insurers charge $5,000 per home and collect $5 million a year.
  - Insurers plan for a bad year that comes once every 200 years. What does that year cost?

Independent vs. correlated losses

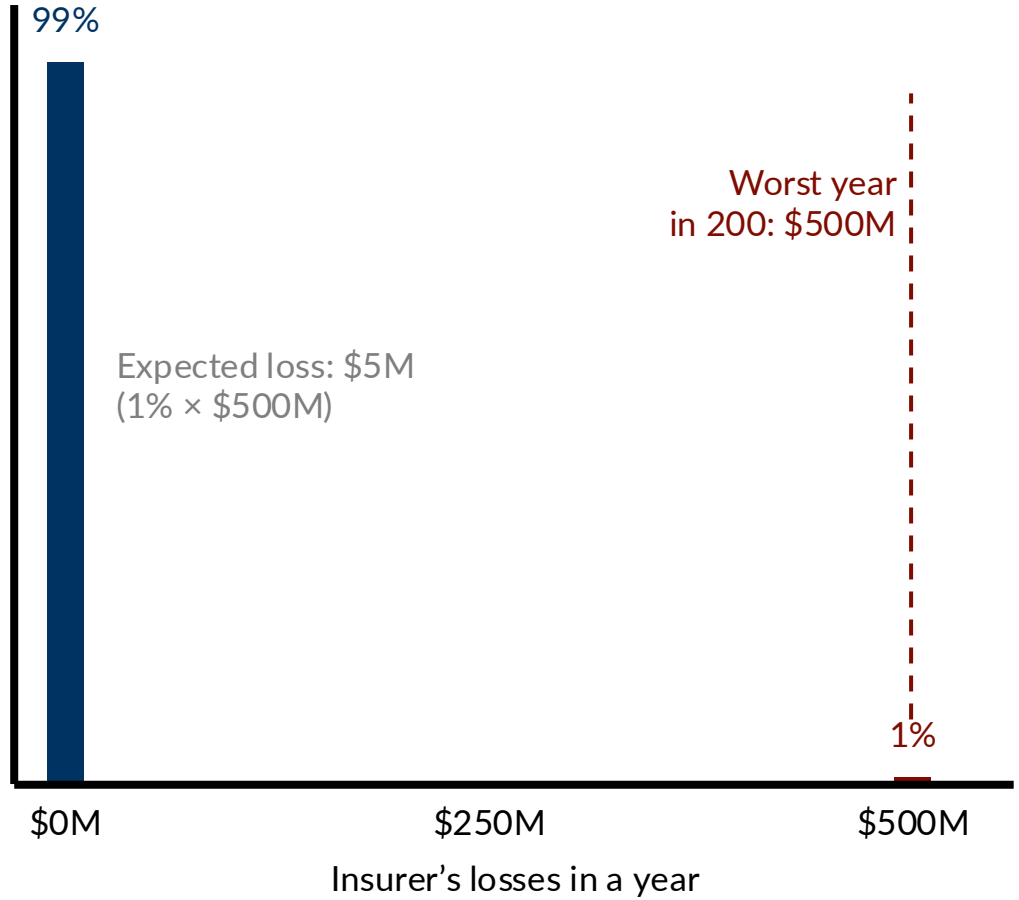
Town A: independent fires



Premiums: $5M a year. Worst year: $9.5M.

Cost to insurer: ~2 years of premiums.

Town B: correlated fires



Premiums: $5M a year. Worst year: $500M.

Cost to insurer: 100 years of premiums.

Georgia Institute of Technology

Can the town buy insurance?

	Town A: independent fires	Town B: correlated fires
Expected loss per home	$5,000	$5,000
Worst year in 200 (all 1,000 homes)	$9.5 million	$500 million
Reserve needed beyond expected losses	$9.5M − $5M = $4.5M	$500M − $5M = $495M
10% returns to insurer's shareholders, per home	$4.5M × 0.10 ÷ 1,000 = $450	$495M × 0.10 ÷ 1,000 = $49,500
Premium per home	**$5,000 + $450 = $5,450**	**$5,000 + $49,500 = $54,500**
Most the homeowner will pay	$10,655	$10,655
	Insured	**Uninsurable**

Premium = expected loss + a return to insurer's shareholders. Without the reserve, a town-wide fire bankrupts the insurer and claims go unpaid.

Town B: the premium the insurer needs is five times what the homeowner will pay. No one buys it. The town is uninsurable.

Climate risks are correlated risks

- One event hits many policies at once.
  - Wildfire: the January 2025 Los Angeles fires destroyed or damaged more than 16,000 structures. Insured losses were about $28 billion.
  - Hurricanes and floods on the Gulf and Atlantic coasts. Sea-level rise makes both worse.
- Insurers respond by raising premiums, dropping policies, or leaving markets.
  - State Farm stopped writing new home policies in California in 2023.

LA fires: Reuters (2025), via Business Insurance. State Farm General Insurance Co. (2023). Press statement, May 26.
Listen: Planet Money (2026). Are wildfires making the future uninsurable? NPR, Nov. 13. npr.org

Why care about insurers?

- Mortgages require homeowner's insurance.
  - No insurance → no mortgage. Fewer buyers, lower home values.
- When private insurers leave, the risk remains.
  - Either homeowners bear it independent, or taxpayers do (state FAIR Plans, the National Flood Insurance Program, disaster aid).
- Insurance premiums are a price signal about where to build.
  - Cheap public insurance subsidizes building in risky places.
  - Should taxpayers be subsidizing people to live in flood-prone coastal areas or fire-prone areas in the West?

"We don't know the full implications of an eventual 6°C (11°F) temperature change. We can't know. It's a blind planetary gamble. Devastating home fires, car crashes, and other personal catastrophes are almost always much less likely than 10 percent. And still, people take out insurance to cover against these remote possibilities, or are even required to do so by laws that hope to avoid pushing these costs onto society. Risks like this on a planetary scale should not—must not—be pushed onto society."

-Wagner & Weitzman (Climate Shock)

"We don't know the full implications of an eventual 6°C (11°F) temperature change. We can't know. It's a blind planetary gamble. Devastating home fires, car crashes, and
ays
much
take
o
possib
s that
hope
Risks
like thi
t—be
pushed onto society."

Not an ideal example, since car crashes, home fires, etc., are independently distributed (i.e., insurers can balance risk because insurance claims are uncorrelated).

With climate change, damages are not independent, and so they pose much greater risk to society.

-Wagner & Weitzman (Climate Shock)

Can we insure the planet?

- Insurance pools risks that are not perfectly correlated. We cannot pool risk with the residents of Mars.
- Three ways to manage risk (Ehrlich and Becker 1972):
  - **Market insurance**: pay someone else to bear the loss.
  - **Self-insurance**: make the loss smaller (adaptation).
  - **Self-protection**: make the loss less likely to occur (mitigation).
- For climate change, only the last two are available.

Ehrlich, I. and G.S. Becker (1972). Market insurance, self-insurance, and self-protection. Journal of Political Economy 80(4): 623–648. doi.org/10.1086/259916

The precautionary principle

(From the UN's 1992 Rio Declaration)

- *"Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."*

- Simpler version: 'Better safe than sorry.'

- **Critique** (Hahn and Sunstein 2005): *"Taken seriously, it can be paralyzing, providing no direction at all."*
  - Precaution has costs and risks of its own. Benefit-cost analysis weighs both sides.

Hahn, R.W. and C.R. Sunstein (2005). The precautionary principle as a basis for decision making. The Economists' Voice 2(2). PDF

A driving analogy…

- Imagine driving 75 mph down a road you've never driven before at night, with the headlights off. There's a 95% chance the road remains straight and a 5% chance the road dead-ends off a cliff.

- *What would you do?*

Climate sensitivity and "fat tails"

- Climate sensitivity: eventual warming from doubling CO_2.
- IPCC AR6: best estimate 3°C, very likely between 2°C and 5°C.
- **Fat tail**: the probability of extreme outcomes goes to zero slowly.

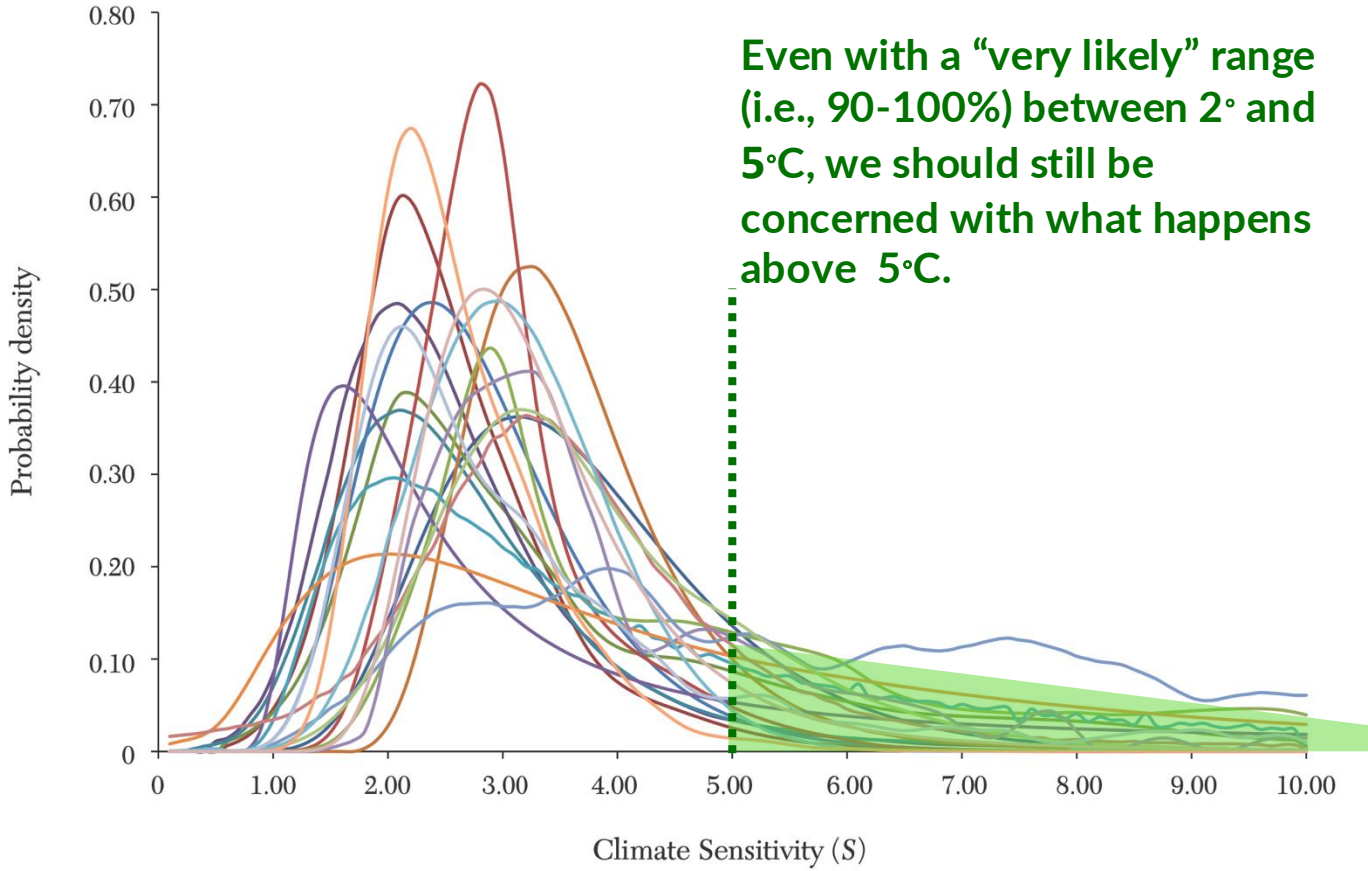


Figure 1. Estimates of the Probability Distribution for Climate Sensitivity

Source: Millner, Dietz, and Heal (2013)

Let's say that green area adds up to 5% likelihood of >5°C, which would result in irreversible changes in our climate. Should we insure ourselves against this risk?

How likely is 6°C of warming?

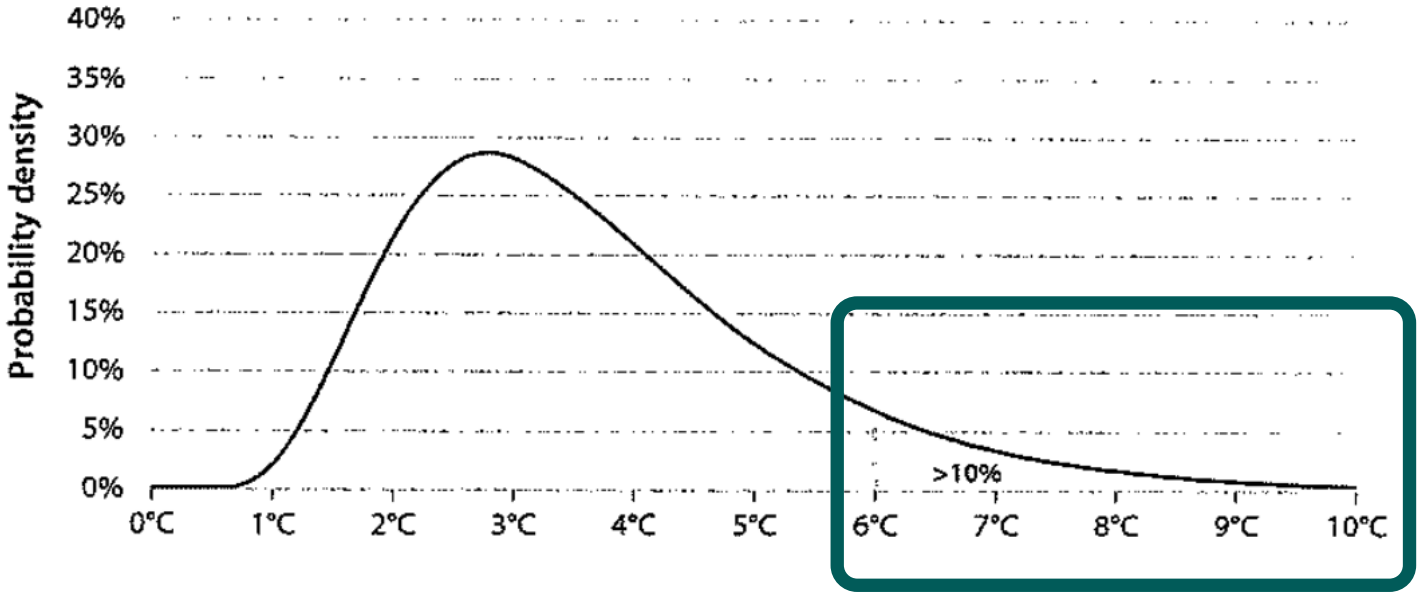


Figure 3.2 **Eventual global average surface warming based on passing 700 ppm CO_2e**

Table 3.1. Chance of eventual warming of >6°C (11°F) rises rapidly with increasing CO_2e concentrations

CO_2e concentration (ppm)	*400*	*450*	*500*	*550*	*600*	*650*	*700*	*750*	*800*
Median temperature increase	1.3°C (2.3°F)	1.8°C (3.2°F)	2.2°C (4.0°F)	2.5°C (4.5°F)	2.7°C (4.9°F)	3.2°C (5.8°F)	**3.4°C (6.1°F)**	3.7°C (6.7°F)	3.9°C (7.0°F)
Chance of >6°C (11°F)	0.04%	0.3%	1.2%	3%	5%	8%	**11%**	14%	17%

- Chance of eventual warming above 6°C (11°F), by CO_2e concentration:
  - 550 ppm: about 3%
  - 700 ppm: about 11%
- Climate sensitivity is warming per doubling of CO2 (280 to 560 ppm). 700 ppm is about 1.3 doublings, so the whole distribution shifts right.
- Based on IPCC AR5. AR6 narrowed that range.

Source: Wagner & Weitzman (Climate Shock)

Weitzman's "Dismal Theorem"

How to account for fat tails in benefit-cost analysis…

Fat Tails and the Social Cost of Carbon†

By Martin L. Weitzman*

At high enough greenhouse gas (GHG) concentrations, climate change might conceivably cause catastrophic damages with small but nonnegligible probabilities. Other things being equal, this should lower the discount rate used to evaluate mitigation-investment decisions and raise the social cost of carbon (SCC). If the bad tail of climate damages is sufficiently fat with probability, and if the utility function has relative risk aversion greater than one, then (at least in theory for at least some formulations) this insurance-like catastrophe-reducing aspect of mitigation investments can be very powerful. In the most extreme limit this tail-hedge insurance effect can be infinitely strong and can dominate the economic analysis by making the SCC infinite. This kind of extreme (and empirically unbelievable) limiting result is a version of what I have previously labeled the "dismal theorem."[1]

- **Dismal theorem**: with fat enough tails and enough risk aversion, SCC → ∞.
  - We should be willing to spend all of the world's income to mitigate the next ton of CO_2.
  - Weitzman calls this a "clearly absurd result"
- How much caution? Quantitatively hazy, qualitatively clear: act now.
- **Critiques**: the result needs a fat enough tail, enough risk aversion, and no learning as we go.

Key takeaways

- Uncertainty makes climate damages hard to pin down. Current estimates are likely too low.
- Risk-averse people pay to avoid risk. Insurance works when losses are independent.
- Correlated losses can bankrupt insurers, so risky places become uninsurable. Nobody can insure the planet.
  - Mitigation and adaptation are what is left.
- The precautionary principle and fat tails argue for acting before the uncertainty is resolved.
  - Neither says how much mitigation to do, but uncertainty $\Longrightarrow$ the SCC should be much higher.

For next class…

- **Monday 11/30:** *Can we fix climate change with this weird trick? Geoengineering.*
  - Guest lecture: Tony Harding, Georgia Tech School of Public Policy.
  - Read Wagner and Weitzman, Chs. 5 and 6 (Canvas).

- **No class Wednesday, November 25.** Happy Thanksgiving!
- **Problem set 4 due:** Sunday, December 6.

- www.caseyjwichman.com/econ4210#week15