WHAT WE KNOW AND DON'T KNOW ABOUT CLIMATE CHANGE, AND IMPLICATIONS FOR POLICY

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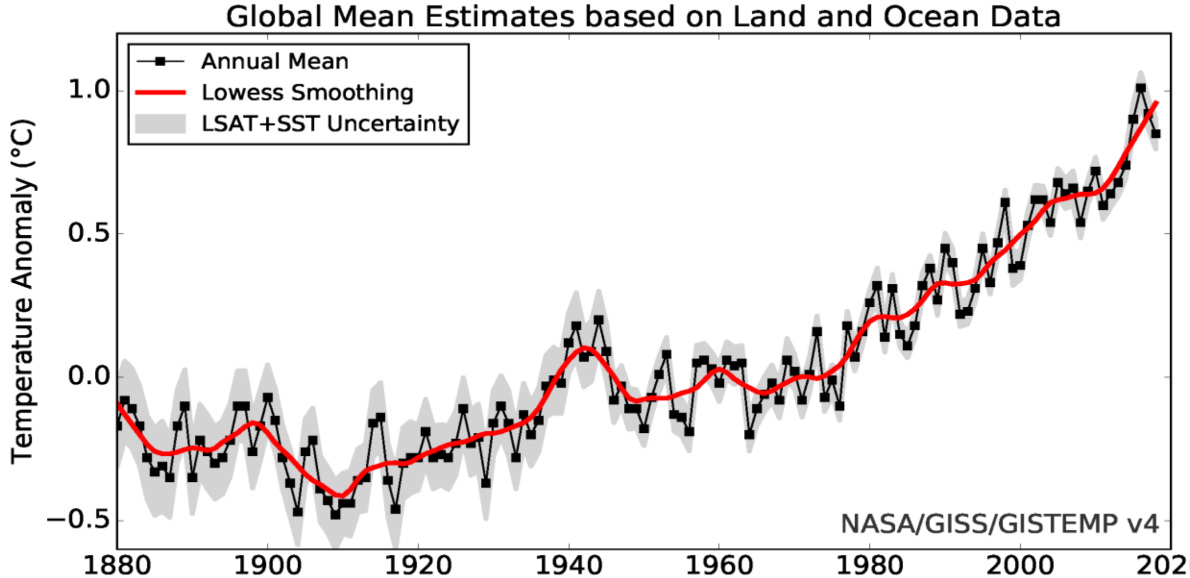
INTRODUCTION AND OVERVIEW

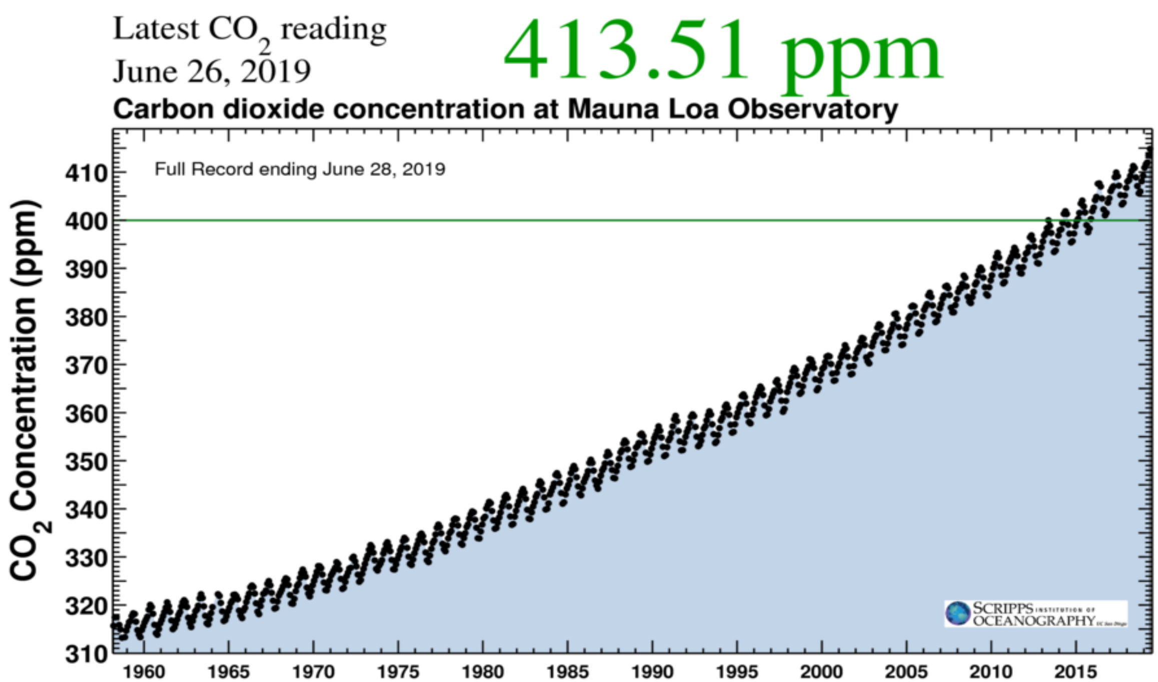
- What We Know and Don't Know about Climate Change:
  - Things we know (or sort of know).
  - Things we don't know, and why we don't know them.
  - What is the Social Cost of Carbon (SCC)? Estimates vary widely.
  - Use *Integrated Assessment Models* (IAMs) to estimate SCC? No.
- A Possible Catastrophic Outcome:
  - What matters for policy is the chance of catastrophic outcome.
  - How to assess likelihood and possible impact of catastrophe?
- Policy Implications of Uncertainty.
  - Before imposing costly policies, wait until we know more? No.
  - Insurance value of early action, and role of irreversibilities.
- What to Expect and What to Do.
  - Likely $\Delta T > 2.0$°C. Must prepare for this!
  - Reduce emissions: What we *should* do versus what we *will* do.
  - Adaptation. Invest now.

SOME BASIC FACTS

Temperature:

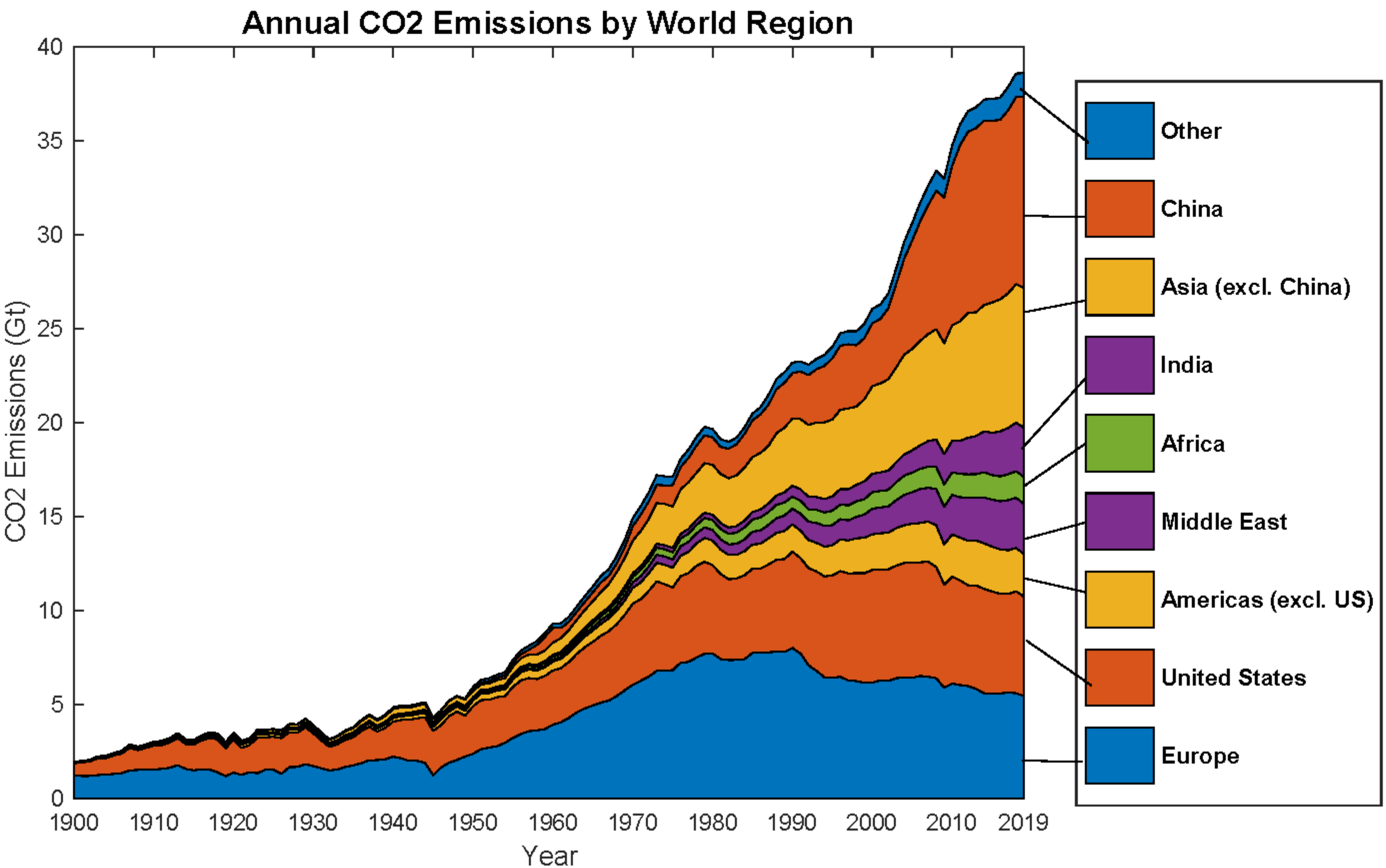


CO_2 Concentration:



SOME MORE FACTS

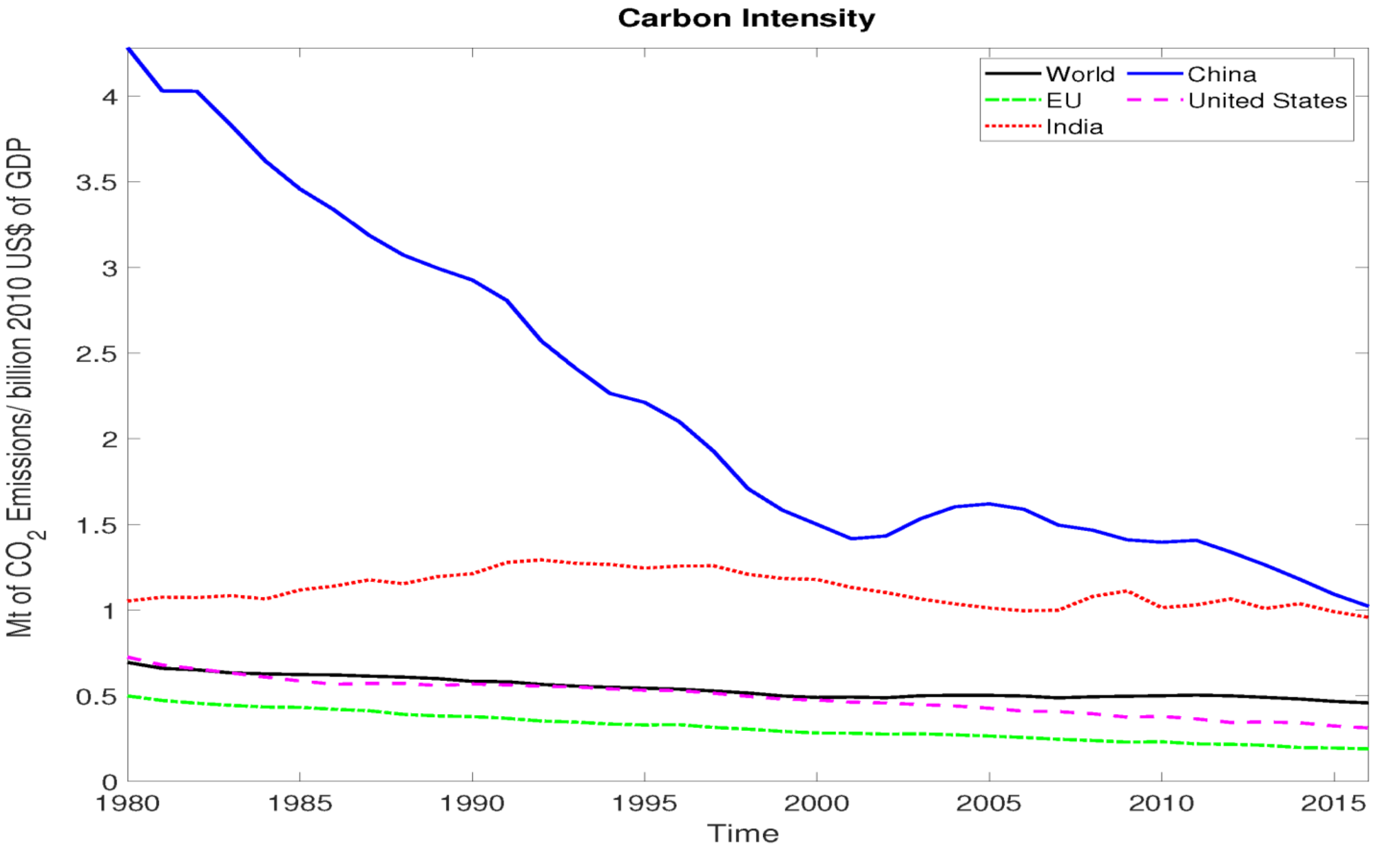
- CO_2 Emissions:



WHAT WE KNOW

- <u>What Drives CO_2 Emissions</u>:
  - Economic activity (GDP). But emissions also depend on how much CO_2 per $ of GDP, i.e., *carbon intensity.*
  - Carbon intensity is *energy intensity* times *energy efficiency*.
    - <u>Energy intensity</u>: Quad BTUs per $ billion of GDP.
    - <u>Energy efficiency</u>: Mt of CO_2 per quad BTUs.
    - <u>Carbon intensity</u>: (Quad BTUs/$ billion) X (Mt CO_2/quad BTUs) = Mt CO_2 /$ billion
- <u>What Happened/Likely to Happen to Carbon Intensity?</u>
  - <u>Energy intensity</u>: Declined in US, Europe, China (because GDP was so low); but not India or other developing countries.
  - <u>Energy efficiency</u>: Better in Europe, US. But no change in China, …
  - <u>Carbon intensity</u>: For world, 0.69 Mt CO_2 /$B in 1980 to 0.50 in 2019, about <u>30% decline</u>.
  - <u>Problem</u>: World GDP <u>tripled</u>, so CO_2 emissions increased.

CARBON INTENSITY



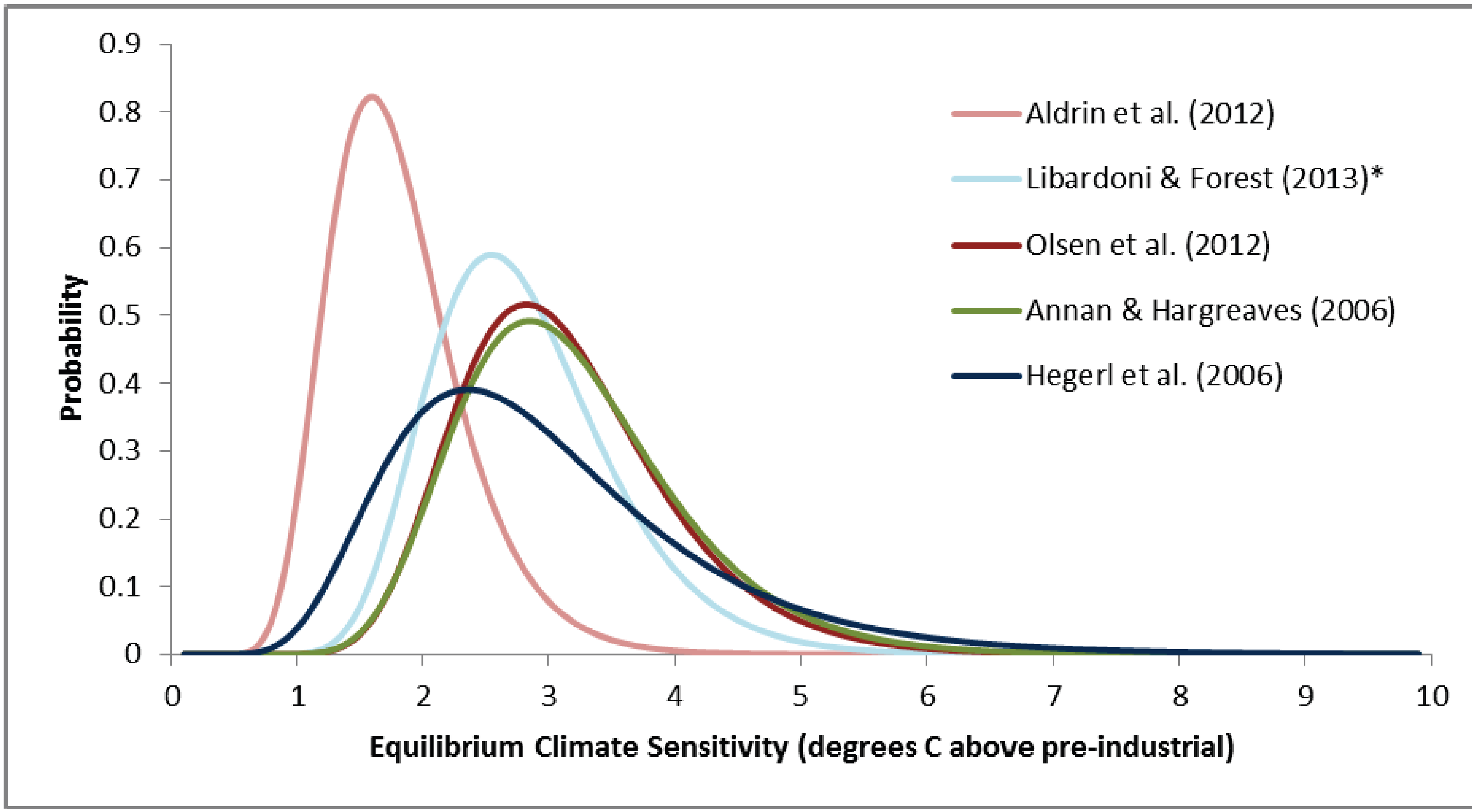
<u>Carbon intensity</u>: 30% global decline. But from 1980 to 2019, world GDP <u>tripled</u>. Hence growth in emissions.

<u>Two ways to reduce future CO_2 emissions</u>: (1) Reduce GDP; or (2) Reduce carbon intensity (via energy intensity or energy efficiency).

<u>What will happen</u>? We don't know.

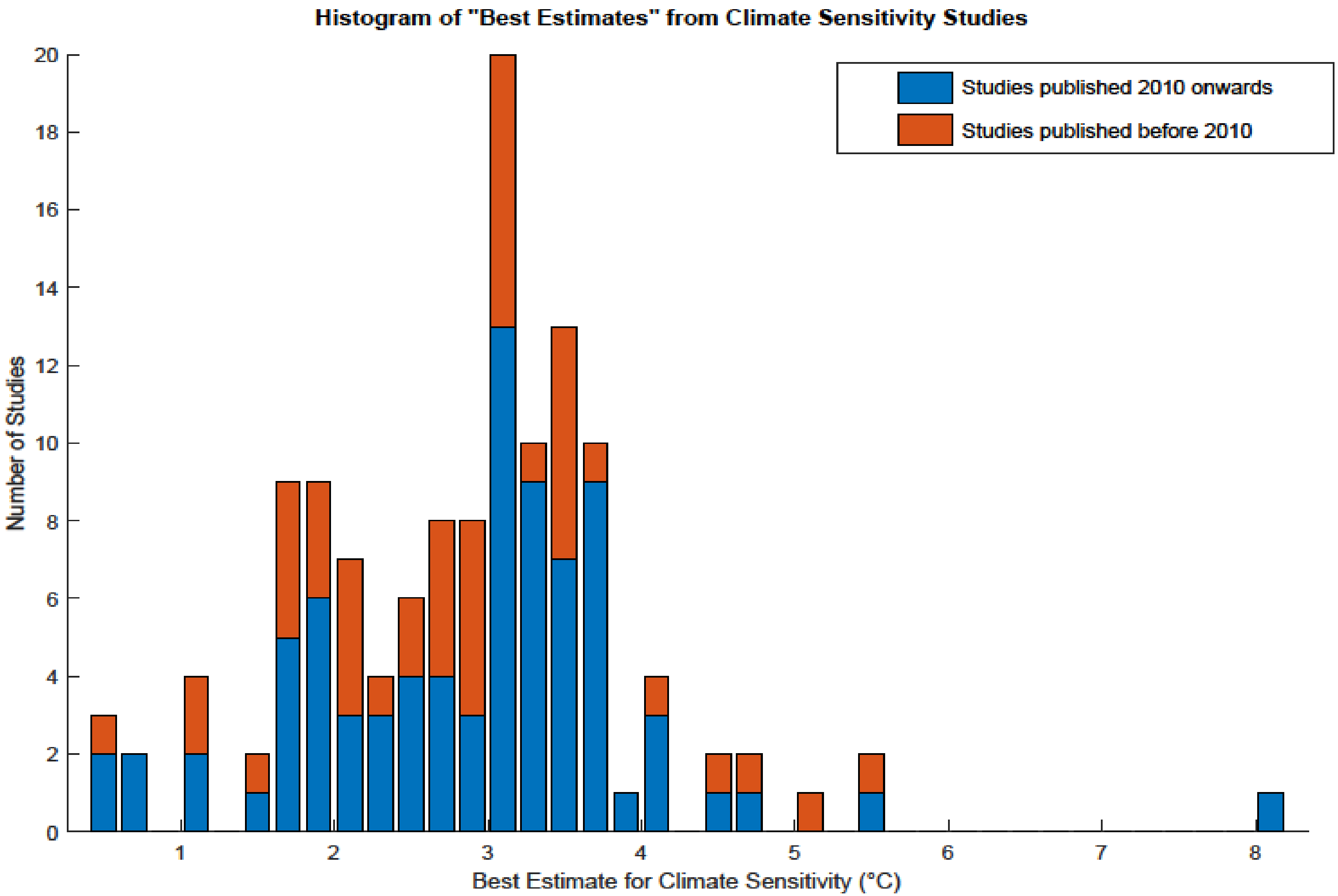
WHAT WE DON'T KNOW: TEMPERATURE CHANGE

- Depends on *climate sensitivity* – increase in *T* that *eventually* results from doubling of atmospheric CO_2 concentration.
  - IPCC: "most likely" range is 1.5 to 4.5°C. "Less likely but possible" range is 1.0 to 6.0°C. *Considerable uncertainty*.
  - August 2021 update: "most likely" range is 2.5 to 4.0°C.



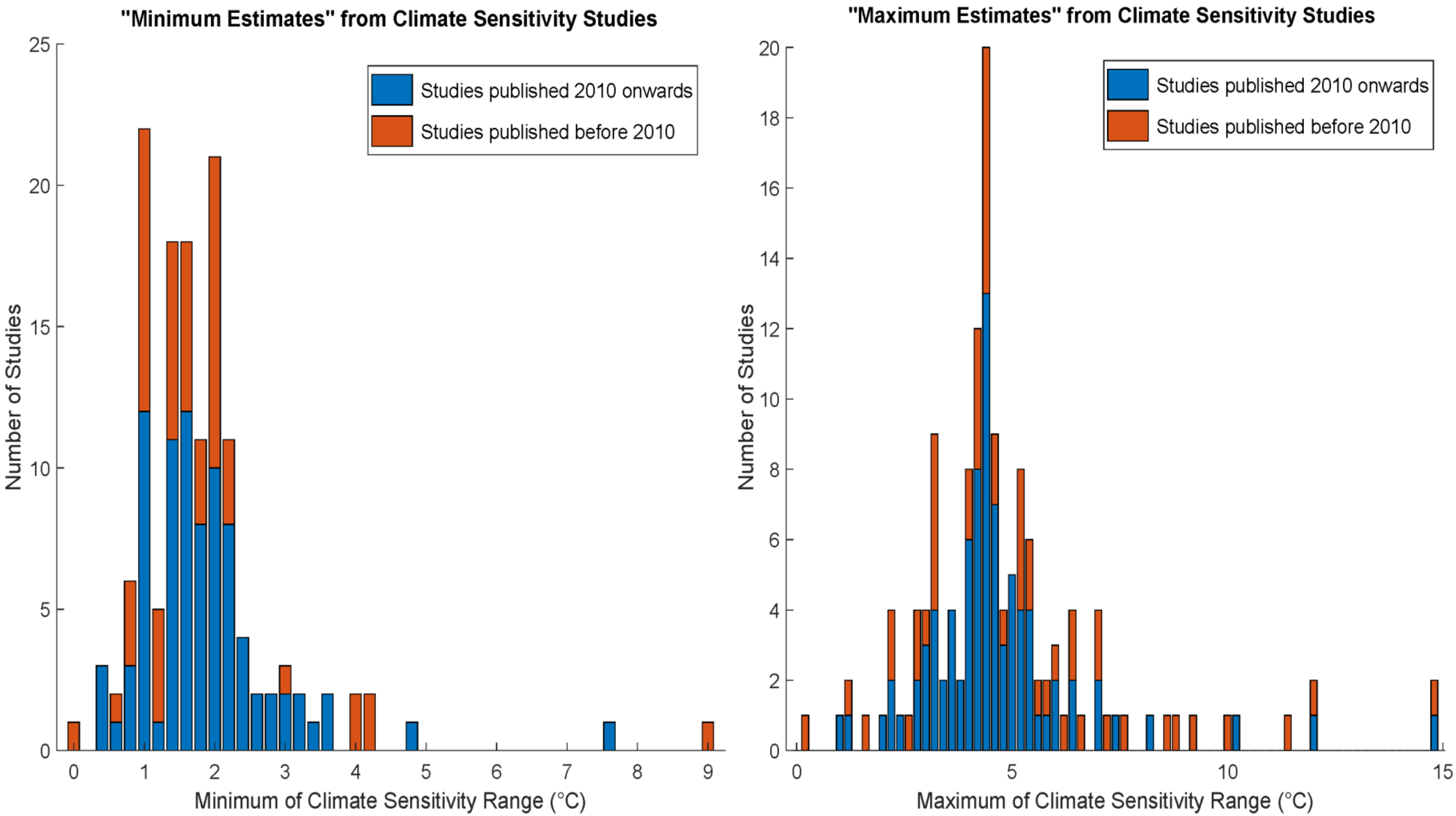
UNCERTAINTY OVER CLIMATE SENSITIVITY

- “Best estimates” from 131 studies:



UNCERTAINTY OVER CLIMATE SENSITIVITY

- High and Low Estimates:



WHY IS CLIMATE SENSITIVITY UNCERTAIN?

- Mechanisms that determine climate sensitivity involve feedback loops. Strengths of those feedback loops are uncertain.
  - Let S_0 be CS with no feedback effects. Then actual CS is

$$S = \frac{S_0}{1 - f}$$

  where $f < 1$ is the total feedback factor. So if f is close to 1, uncertainty over f amplifies uncertainty over S.

- Suppose best estimate of f is 0.95, but uncertainty is +/- .03, i.e., range is 0.92 to 0.98. Then S could be 12.5 X S_0 to 50 X S_0 .
- So small uncertainty over f implies large uncertainty over CS.

THE IMPACT OF CLIMATE CHANGE

- With climate sensitivity, research results let us argue coherently about probability distributions, etc. But when it comes to *impact* of climate change, we know next to nothing.

- Suppose we could accurately predict climate change through 2100 -- increase in temperature, rise in sea levels, etc.

- What would be the *impact* of those changes? What would it do to GDP, broadly defined? The impact is what matters.

- Answer: We don't know. Why?

- *No theory* and *no data*. No experience with $T = 2°$ or $4°$ or $6°$.

- Climate change occurs slowly, allows for *adaptation*.

- Example of adaptation: Grain production 1850 to 1930 as people moved west, encountered harsh climate.

ADAPTATION: WHEAT PRODUCTION, 1850 TO 1929

(A. OLMSTEAD AND P. RHODE, "RESPONDING TO CLIMATE CHALLENGES: LESSONS FROM U.S. AGRICULTURAL DEVELOPMENT," *THE ECONOMICS OF CLIMATE CHANGE*, CHAP. 6, NBER, 2011)

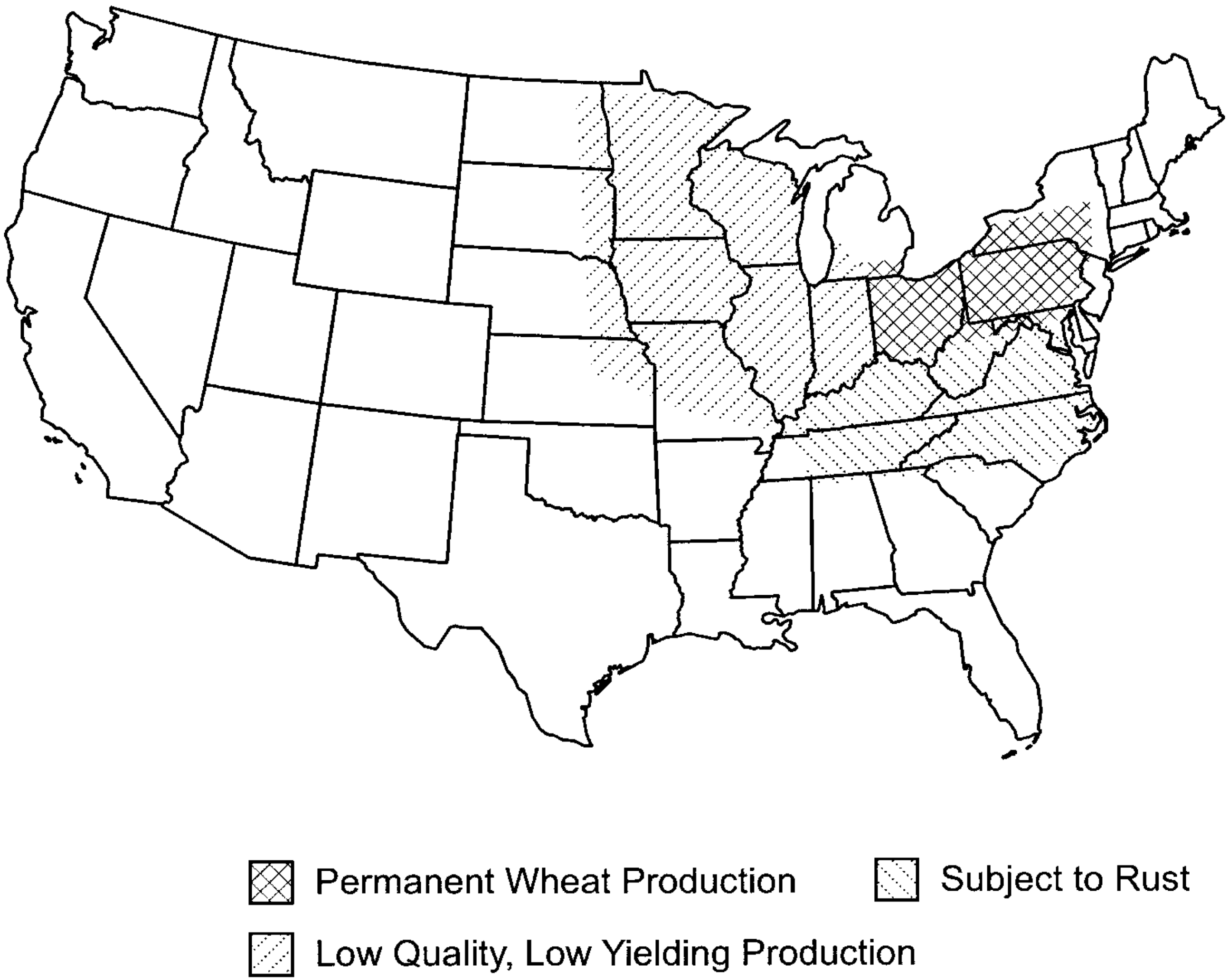


Fig. 6.1 The "potential wheat-producing area" in the United States in 1858

Source: Compiled from Klippart (1860).

RESPONSE TO HURRICAINE SANDY

PLANNED SEA/FLOOD WALLS AROUND MANHATTAN

WE DON'T KNOW THE IMPACT OF HIGHER *T*

- But Integrated Assessment Models (IAMs) are used to predict impacts, and estimate Social Cost of Carbon (SCC). How?

- Most models relate *T* to GDP via "loss function," *L*(*T*).
  - GDP = *L*(*T*)GDP*, where GDP* = GDP with no warming.
  - For example, Nordhaus DICE model uses

$$L(T) = 1/[1 + \alpha T + \beta T^2]$$

  - This is an *arbitrary function*, made up to describe how *T* affects GDP. *It is not based on any theory or data*.
  - Parameters α and β chosen so *L*(*T*) for *T* = 2 to 3°C is consistent with "common wisdom," e.g., *L*(1) = 1 (no loss), *L*(2) ≈ 0.99 or 0.98, and *L*(3) ≈ 0.96. Again, <u>no data, no theory</u>.

- <u>Problem</u>: The models create a perception of knowledge and precision that is illusory and misleading.

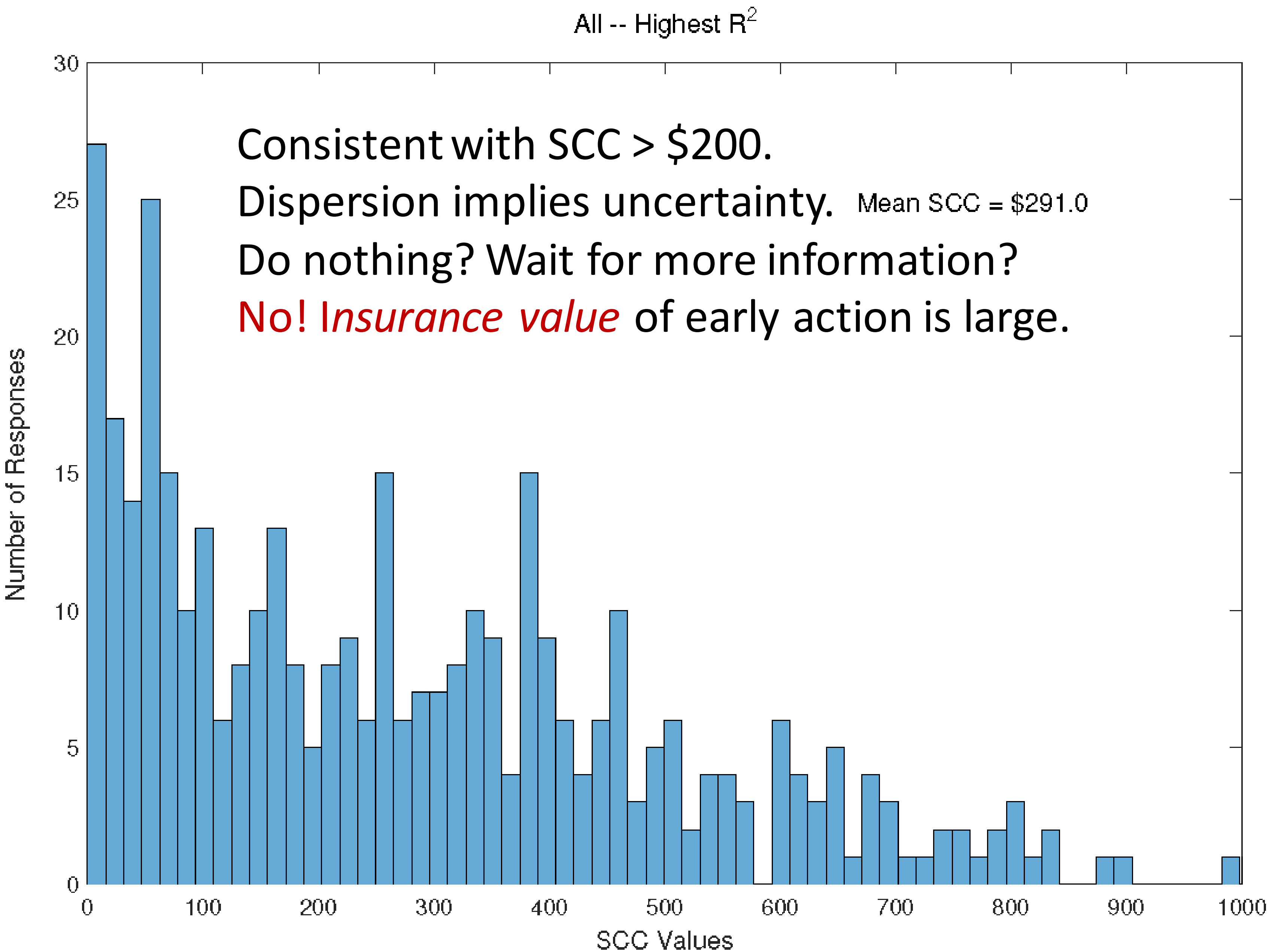
ANOTHER PROBLEM: THE DISCOUNT RATE

- Reduction in emissions (ΔE) reduces damages, and thus gives higher GDP over time. So benefit from ΔE is present value of gains in GDP, i.e., $PV(\Delta GDP_t)$, and $SCC = PV(\Delta GDP_t)/ \Delta E$.
- <u>Problem</u>: Need *discount rate* to get $PV(\Delta GDP_t)$. What is the "correct" discount rate? Market-based discount rate implies SCC is tiny. Need very low rate (1 – 2%) to get high SCC.
- But huge disagreement over what discount rate to use.
- Ramsey formula (with no uncertainty): $r = \delta + g\eta$, where δ is rate of time preference, g real GDP growth rate, and η index of risk aversion.
  - So we need values for δ and η. Suppose we use financial market data? Then $\eta \approx 2$ to 5 and $\delta \approx .02$ to .05.
  - But if $\delta = .02$, $\eta = 2$, and $g = .02$, $r = .06$. This makes SCC tiny, and hard to justify <u>any</u> abatement policy.
  - So some argue for $\delta = 0$ and $\eta = 1$ on "ethical" grounds, and get large SCC. But whose ethics?

CATASTROPHIC OUTCOMES

- If discount rate > 2%, "most likely" scenarios imply small SCC. What about a catastrophic outcome? "Catastrophic" = extreme economic impact, perhaps 20% or 40% drop in GDP. Can result in higher SCC.
- But how likely and how extreme are the possible outcomes? Models can't help us here, so what to do? Rough, subjective estimates:
  - Analogous to assessing risk of U.S.–Soviet nuclear exchange during Cold War: No data or reliable models, so analyses based on the plausible.
  - Consider *plausible* range of catastrophic outcomes and probabilities, i.e., acceptable to economists and climate scientists.
- Or expert elicitation. I surveyed economists and climate scientists.
  - Want probabilities of extreme economic outcomes. Also, what *reduction in emissions growth* is needed to avert those outcomes?
  - With this information, compute *average SCC* = total benefit from truncating impact distribution/total emission reduction.
  - Details: R. Pindyck, "The Social Cost of Carbon Revisited," *JEEM*, 2/2019.

ALL INDIVIDUAL ESTIMATES



CLIMATE CHANGE: WHAT TO EXPECT?

- CO_2 Concentration Will Increase. The U.S. and Europe will reduce emissions (not to zero), but unrealistic to expect similar reductions from China, India, Russia, Brazil, ... Do you really believe net-zero *global* emissions will happen by 2050?
- Global Mean Temperature Likely to Rise More than 2.0°C. Lots of uncertainty – we may be lucky, but don't count on it. We may be very unlucky and see a temperature increase of 3°C or more.
- Other Climate Effects Hard to Predict. They depend on temperature increase, which we can't predict. And even if we could, huge uncertainty over impact on sea levels, rainfall, etc.
- What Will Be the Impact of Climate Change. We don't know. Even if temperature rises by 3°C, impact may be limited, in part because of adaptation. But we can't count on that.

CLIMATE POLICY: WHAT TO DO?

- Reduce *Global* GHG Emissions. Reductions by U.S. and Europe won't nearly suffice. China, India, Russia, ... must also sharply reduce net emissions. Need an international agreement that can be enforced.
- Reduce Emissions as Efficiently As Possible, i.e., at lowest possible cost. Study after study has shown most efficient way is a carbon tax. If politically infeasible, use directed subsidies and mandates. And expand use of nuclear power.
- Remove Carbon from the Atmosphere. How? Planting trees? Would take a huge number of trees to have an impact. Carbon removal and sequestration (CRS)? Not close to economical. But invest in the R&D to develop new technologies for CRS.
- Invest in Adaptation. Despite best efforts, CO_2 concentration will increase, temperature may rise more than 2°C, sea levels may rise, and … . We must prepare by investing in adaptation: New heat-resistant crops, construction of sea walls, and – yes – solar geoengineering.

CONCLUSIONS

- There is a lot we don’t know about climate change: Climate sensitivity, impact of warming. A world of uncertainty!
- Not good to make believe we know more than we really do.
- What matters is the possibility of catastrophic outcome.
  - Consider plausible catastrophic outcomes and probabilities, i.e., acceptable to a range of economists and climate scientists.
- Given uncertainty, should we wait to reduce emissions? No. Insurance value of acting now. So focus on the uncertainty and evaluate insurance value of early action.
- Other potential catastrophes: Pandemics (worse than Covid), nuclear and bio-terrorism, nuclear or cyber war, gamma ray bursts, mega-earthquakes. Not in the news, but can’t ignore.

WANT TO READ MORE?

- *Climate Future: Averting and Adapting to Climate Change*
- (Oxford University Press.)