Virtual Seminar on Climate Economics

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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 $\Delta T > 2.0^\circ C$. Must prepare for this!
  • Reduce emissions: What we *should* do versus what we *will* do.
  • Adaptation. Invest now.
**Temperature:**

**CO$_2$ Concentration:**

Latest CO$_2$ reading
June 26, 2019

413.51 ppm
• **CO₂ Emissions:**

![Graph showing annual CO₂ emissions by world region from 1900 to 2019.](image-url)
WHAT WE KNOW

• What Drives CO₂ Emissions:
  • Economic activity (GDP). But emissions also depend on how much CO₂ per $ of GDP, i.e., *carbon intensity*.
  • Carbon intensity is *energy intensity* times *energy efficiency*.
    • Energy intensity: Quad BTUs per $ billion of GDP.
    • Energy efficiency: Mt of CO₂ per quad BTUs.
    • Carbon intensity: (Quad BTUs/$ billion) X (Mt CO₂/quad BTUs) = Mt CO₂ /$ billion

• What Happened/Likely to Happen to Carbon Intensity?
  • Energy intensity: Declined in US, Europe, China (because GDP was so low); but not India or other developing countries.
  • Energy efficiency: Better in Europe, US. But no change in China, ...
  • Carbon intensity: For world, 0.69 Mt CO₂ /$B in 1980 to 0.50 in 2019, about 30% decline.
  • Problem: World GDP tripled, so CO₂ emissions increased.

Two ways to reduce future CO₂ emissions: (1) Reduce GDP; or (2) Reduce carbon intensity (via energy intensity or energy efficiency).

What will happen? 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:

Histogram of "Best Estimates" from Climate Sensitivity Studies

- Studies published 2010 onwards
- Studies published before 2010
UNCERTAINTY OVER CLIMATE SENSITIVITY

• High and Low Estimates:

"Minimum Estimates" from Climate Sensitivity Studies

"Maximum Estimates" from Climate Sensitivity Studies

- Studies published 2010 onwards
- Studies published before 2010

Number of Studies

Minimum of Climate Sensitivity Range (°C)

Maximum of Climate Sensitivity Range (°C)
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 $\times$ $S_0$ to 50 $\times$ $S_0$.

• 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 $T = 2^\circ$ or $4^\circ$ or $6^\circ$.

  • 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

Fig. 6.1 The “potential wheat-producing area” in the United States in 1858
Source: Compiled from Klippart (1860).
RESPONSE TO HURRICANE 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

  $$L(T) = \frac{1}{1 + \alpha T + \beta T^2}$$

  • This is an *arbitrary function*, made up to describe how $T$ affects GDP. *It is not based on any theory or data.*

  • Parameters $\alpha$ and $\beta$ chosen so $L(T)$ for $T = 2$ to $3^\circ$C is consistent with “common wisdom,” e.g., $L(1) = 1$ (no loss), $L(2) \approx 0.99$ or $0.98$, and $L(3) \approx 0.96$. Again, *no data, no theory.*

• Problem: The models create a perception of knowledge and precision that is illusory and misleading.
ANOTHER PROBLEM: THE DISCOUNT RATE

- Reduction in emissions ($\Delta E$) reduces damages, and thus gives higher GDP over time. So benefit from $\Delta E$ is present value of gains in GDP, i.e., $\text{PV}(\Delta \text{GDP}_t)$, and $\text{SCC} = \frac{\text{PV}(\Delta \text{GDP}_t)}{\Delta E}$.
- **Problem**: Need *discount rate* to get $\text{PV}(\Delta \text{GDP}_t)$. 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 $\delta$ is rate of time preference, $g$ real GDP growth rate, and $\eta$ index of risk aversion.
  - So we need values for $\delta$ and $\eta$. 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 any abatement policy.
  - So some argue for $\delta = 0$ and $\eta = 1$ on “ethical” grounds, and get large SCC. But whose ethics?
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.
Consistent with SCC > $200.
Dispersion implies uncertainty.  
Mean SCC = $291.0
Do nothing? Wait for more information?
No! Insurance value of early action is large.
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, CO₂ 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.)