Climate Change Economics Lecture Notes

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1 Introduction to Climate Change Issues

1.1 Environmental Economics versus Climate Change Economics

Environmental is micro. Includes the study of natural resource extraction and use, waste products and pollution, evaluation and design of environmental policies, etc.

Climate change is macro. The focus is on how man-made emissions of greenhouse gasses is affecting the climate and the effedcts of this climate change on the economy or on certain markets.

1.2 Global Warming

1. Measure temperature in Celcius
$$\Delta F^o = \frac{9\Delta C^o}{5}$$

2. It is common to benchmark to pre-industrial times (Industrial revolution 1760-1840).

3. Temperature has increased about 1^oC since 1860.

4. People feel an additional 2^oC warming forms a tipping point. Paris agreement aimed to limit warming to 2^oC by 2100.

5. Some basic facts about warming from Berkeley Earth http://berkeleyearth.org/2018-temperatures/

6. Climate scientists pay attention to mean surface air temperature, mean sea level mean snow cover. In economics, we focus on surface air temp.

1.3 Four main greenhouse gases (GHG)

1. Carbon dioxide CO_2. The main GHG, produced by burning fossil fuels, solid waste, trees and other biological materials.

2. Methane CH_4.is natural gas. Burped up by cows, released by decay of organic waste in landfils. Sequestered in the frozen tundra.

3. Nitrous oxide N_2O. Burning fossil fuels, solid waste, runoff from farms treated with nitrogen fertilizers.

4. Ozone.

   The main GHG is CO_2. Climate scientists often convert the other three GHGs into CO_2 equivalents. We should also note that water vapor is a GHG. It's not usually mentioned because it's concentration isn't affected by human activity.

- Basic facts about Greenhouse Gases GHGs from the US EPA. https://www.epa.gov/ghgemissions

1.4 The Greenhouse Effect

1. Warming occurs because solar energy passes through the atmosphere. About 30 percent of sunlight is reflected back into space.

2. The other 70 percent is absorbed by GHG molecules, which emit energy in all directions (including back to the surface). Therefore, GHGs in the atmosphere makes it difficult for energy to leave the planet.

3. Equilibrium occurs when energy in = energy out.

4. The Greenhouse Effect: https://www.pbslearningmedia.org/resource/phy03.sci.phys.matter.greenhouse2/global-warming-the-physics-of-the-greenhouse-effect/

5. There exists a good deal of uncertainty about climate change. Why?

   (a) Warmer air has more water vapor

   (b) Clouds keep sun heat out but keeps earth's warmth in.

   (c) Oceans absorb heat, but absorption fluctuates.

   (d) Aersols reflect energy but don't last long. They are created by fuel combustion.

6. CO_2 stays in the atmosphere for a long time. What matters for warming is the stock of CO_2, and of course the flow adds to the stock.

7. NASA says, once added to the atmosphere, CO_2 can hang around between 300 to 1,000 years.

   https://climate.nasa.gov/news/2915/the-atmosphere-getting-a-handle-on-carbon-dioxide/

8. Climate sensitivity refers to how much global mean temperature increases due to a doubling of CO_2 from pre-industrial times. Current estimates are between 1.5^oC to 4.5^oC

9. Climate scientists run climate computationally intensive and complicated climate models. They model temperature at different altitudes, wind speeds, snow cover. Tested for ability to reproduce the past and then used to simulate current and future climate effects.

10. Economists run integrated assessment models (IAMS). Compared to the climate models, they are simple and usually understandable.

1.5 Carbon Sinks

1. **Rising temperature**, changes in rainfall patterns affect natural carbon sinks:
2. **Natural land carbon sink**: plants, trees, forests. Initally, this may increase, but later, due to nutrient and water availability, it will decline.
3. **Natural ocean carbon sink**: Organisms in the ocean absorb CO_2.
4. **Methane**: Permafrost stores a large amount of carbon. Methane is released from peat, wetlands, thawing permafrost. Also in Hydrate stores: Large quantities of methane trapped under the oceans under high pressure. But if oceans warm enough, the methane could destabilize and be released.

1.6 Linking GHG concentrations to temperature

1. Pre-industrial times: 280 ppm (parts per million particles of air).
2. 2019: 409.8 ppm
3. Temperature has increased about 1^oC since 1860.
4. People (Intergovernmental Panel on Climate Change or IPCC) think a doubling of $\mathrm{CO_2}$ concentrations (from pre industrial times) will raise temperature by $2^o - 4.5^oC$ by 2100.
5. Range of forecasts: 450 ppm will cause $1.7^oC - 2^oC$ rise by 2100.
6. On average, concentrations rise by 2 ppm per year.
7. The average American contributes 5 tons of $\mathrm{CO_2}$ per year.
8. Even if emissions are cut to zero, the earth still gets warmer. https://www.nature.com/articles/s41598-020-75481-z

1.7 Predicted Consequences of Climate Change

1. Changing weather patterns (precipitation, floods, drought)
2. Human migration
3. Melting glaciers, reduced snow cover.
4. Rising sea level (water expands when it warms)
5. Disease
6. Agriculture
7. Labor productivity
8. Structural change (ski resorts)

- Water stress
    1. Worldwide water use decomposition: 70% irrigate crops. 22% manufacturing, 8% use by households and businesses for drinking, sanitation, recreation.

2. Models predict intensification of water cycle (more evaporation, heavier rainfalls/monsoons).
3. Melting glaciers. Glaciers feed river systems, major water supply source in India, China, the Andes.
4. Models predict more rain at high latitudes, less in dry tropics. Uncertain about the tropical areas.

- Food stress
  1. Agriculture is 24% of world GDP. 22% of world population employed in agriculture.
  2. Crop yields might increase for moderate temperature increases, but will decline for higher temperatures.
  3. Carbon fertilization effect: CO_2 basic building block for plant growth. Wheat and rice yields increase at $2-3^oC$ warming but start to fall at $3-4^oC$. Agricultural collapse could occur at $5-6^oC$
- Ocean Acidification
  1. Rising CO_2 in ocean makes water more acidic.
  2. Kills plankton, which are eaten by salman, mackerel. Could damage fish stocks.
- Labor Supply and Health
  1. Reduced labor supply and effort at high temperatures.
  2. increased malnutrition with heat stress
  3. Changing mosquito distributions increases malaria and dengue fever. Sick people can't work
  4. Slum populations most susceptable to heat stress. No air conditioning.
  5. Peak temperatures in Indo-Gangetic plain (northern India) now often 45^oC (113^oF) before monsoon season.
- Sea Level
  1. Loss of wetlands. Coastal erosion. Saltwater intrusion into surface and groundwater
  2. 200 million people live in coastal flood plains. 25% of Bangladesh's population do. These people will be displaced.
  3. Vulnerable cities: Tokyo, Shanghai, Hong Kong, Mumbai, Miami, New York City, London.
- Geographic heterogeneity
  1. Higher latitudes (especially at the poles) warm faster than the global average. The least warming is over oceans and tropical coastal regions.

     https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

     A global mean increase of 4^o is distributed as 3^o increase on tropical coasts, 5^o increase in mid latitudes, and 8^o increase at the poles.
  2. Climate models predict more rain at high latitutdes, drying of subtropics (northern Africa and Meditarrean). Substantial uncertainty about rainfall changes in tropics, due to interactions with El Nino, which dominates tropical climate.

3. Greater evaporation and more intense rainfall increases risks of drought and flooding
4. Hurricanes become more intense, and more frequent.
5. Canada, Greenland, Russia, Scandanavia stand to benefit from $2-3^oC$ increase.
   - Improved agricultural yields
   - Fewer cold weather related deaths
   - Lower heating costs
   - More tourism
6. Poor people most vulnerable. They live in higher risk areas and in poorer quality housing.

1.8 Kaya Identity

In logarithms, let m be GHG emissions, p be population, y per capita GDP, e energy use per unit of GDP. The Kaya identity decomposes $\Delta m = \Delta m$ thusly,

$$\Delta m = \Delta p + \Delta y + \Delta \underbrace{(e-y)}_{(i)} + \Delta \underbrace{(m-e)}_{(ii)}$$

Term (i) is primary energy use per unit of GDP. Call it energy intensity. Term (ii) is carbon intensity. The decomposition tells you how to cut emissions. Stop population growth, reduce consumption, reduce energy intensity through green technology, reduce carbon intensity by switching to renewables or implement carbon capture and sequestation.

1.9 Market Failure/Externalities/Free Rider Problem

These are the special problems of climate change.

1. Good climate is a public good. GHG emissions are an externality.
2. Social costs of GHG emissions
   (a) Born by the world society.
   (b) Not born by the emitter. Emitter has no incentive to reduce emissions (free rider problem).
3. SCC (the Social Costs of Carbon) is the present value of future damages from emitting an extra ton of GHGs today.

1.10 Other special aspects of climate change

1. The impact of emitting GHG is independent of emission location (unlike other types of pollution).
2. The effects of emissions is highly persistent and the climate response is subject to lags.
3. There are potentially large effects (tipping point/disasters). These are not marginal effects on society. Marginal analysis won't work.
4. Current thinking is that climate change will be most costly to poor countries (and poor people within a country). Why? Poor countries are already hot. Agriculture is a bigger share of their economies. They lack resources to adapt.

5. Rich countries are responsible for most of the GHGs in the atmosphere.
   (a) Ethical considerations about who should pay?
   (b) How do we compute welfare across countries and across generations?
   (c) Is utility defined over consumption appropriate, or should we express environmental quality and health in consumption equivalents?
   (d) Who is the decision maker? Is a social planning framework realistic?
   (e) Nonlinearity in warming, possible threshold effects. Tipping point into catastrophic climate.

2 Heal and Park. "Temperature Stress and the Direct Impact of Climate Change: A Review of an Emerging Literature"

1. Environmental and agricultural economists have conducted studies on how temperature affects agricultural productivity. This is an example of an indirect economic impact of climate.
2. This paper talks about direct impacts. How climate affects health, labor productivity, labor supply, and human capital accumulation.
3. Biology of Temperature Stress
   (a) Too hot, and you get dizzy, have muscle cramps, fever.
   (b) Too cold, you experience cardiovascular, respiratory, brain reactions.
   (c) Cognitive performance declines when it's too hot (above $77^o F$) or too cold (below $68^0 F$).
4. Economically relevant contexts. If you are a farm worker, the effects are obvious. But what if you work in manufacturing? If there's no air conditioning, then a direct effect on productivity is obvious. Labor works less intensively, wants to take more breaks, leaves work early, change jobs. Firms may decide to employ more capital intensive technology. Most of the labor supply reduction from hot days is at the end of the day when workers are tired.

   Clear difference between piece rate and hourly wage workers.
5. Panel data evidence
   (a) Evidence at the plant level: Reduced productivity observed in U.S. automobile plants. A week above $90^o F$ lowers production by 8%.
   (b) Evidence at county and sectoral level
   (c) Evidence at regional and national level
6. Does temperature just affect levels or growth as well? We don't know.
7. Temperature and Health
   (a) Extreme heat waves cause spike in deaths, especially amongst old people.