ESM 204 HW 4:
Calculating the social cost of carbon (SCC) and policy choice under uncertainty

Spring, 2023 (due June 2, 11:59 pm)

In September of 2022, the U.S. EPA released a report on the Social Cost of Greenhouse Gases. This report aimed to update prior U.S. government estimates of the value of global damages caused by emitting *one more ton* of carbon dioxide, methane, and nitrous oxide, all potent greenhouse gases. As discussed in class, these estimates play a critical role in shaping which environmental policies and projects are pursued by the federal government, state governments, and other actors, including many outside the U.S. In this homework, you will use some of the data underlying recent EPA estimates to derive your own social cost of carbon (SCC), investigate how discounting influences its calculation, and assess how uncertainty influences climate policy choices.

We recommend using `R` and writing functions to compute your answers when possible.

You have been provided with two datasets:

- "damages.csv" contains new model estimates of the annual *total* damages from climate change at different levels of global mean temperature warming (in °C relative to the pre-industrial period), derived from new research from the Climate Impact Lab.
- "warming.csv" contains estimates of a baseline future climate warming trajectory (in °C relative to the pre-industrial period) until 2100, and a second trajectory that adds a one-time pulse of CO_2 today to the atmosphere. The pulse is 35 billion tons of carbon, which is roughly equal to annual global emissions. You can think of this as a "small" one-time pulse in carbon emissions.

Please answer the following questions.

1. Using damages.csv, estimate a quadratic damage function relating the dollar value of damages to the change in global mean temperature. Omit an intercept term; damages by construction must equal zero when there is no climate change. Plot your estimated damage function, overlaid with a scatterplot of the underlying data.
2. Use warming.csv and your estimated damage function to predict damages in each year under the baseline climate trajectory and under the pulse scenario. Make four plots: (1) damages over time without the pulse, (2) damages over time with the pulse, (3) the difference in damages over time that arises from the pulse, and (4) the difference in damages over time from the pulse *per ton of* CO_2 (you can assume that each ton of the pulse causes the same amount of damage).
3. The SCC is defined as the present discounted value of the stream of future damages caused by one additional ton of CO_2.[1] The Obama Administration used a discount rate of 3% to discount damages. The recent EPA update uses a discount rate that changes over time, but starts at 2%. Calculate and make a plot of the SCC (y-axis) against the discount rate (x-axis) for discount rates ranging from 1% to 8%.

[1] For the purposes of this homework, you may ignore damages after the year 2100.

4. The National Academies of Sciences, Engineering, and Medicine advised the government in a 2017 report to use the Ramsey Rule when discounting within the SCC calculation, a recommendation the EPA considered. Recall the Ramsey Rule:

$$r = \rho + \eta g$$

   Using $\rho = 0.001$, $\eta = 2$, and $g = 0.01$, what is the SCC? Locate this point on your graph from above.

5. Now suppose there are two possible climate policies that can be pursued. Policy A is business as usual emissions, without any substantial climate change mitigation. Policy B is to take immediate and strong action on climate change. Use these facts:

   - If you undertake Policy A there are two possible outcomes. Either warming will occur as in the "baseline" (i.e. "no-pulse") dataset above (this happens with probability 0.5) or warming each year will be 1.5 times that in the "baseline" dataset (with probability 0.5).
   - Under Policy B, warming will continue until 2050 as in the "baseline" dataset, and then will stabilize at 1.29 degrees and stay that way forever.
   - Society is risk neutral
   - Use a discount rate of 2%

   What is the expected present value of damages up to 2100 under Policy A? What is the expected present value of damages up to 2100 under Policy B? Suppose undertaking Policy A costs zero and undertaking Policy B costs X. How large could X be for it to still make economic sense to pursue Policy B instead of Policy A? Qualitatively, how would your answer change if society were risk averse?