Economics of climate change

Lecture 11

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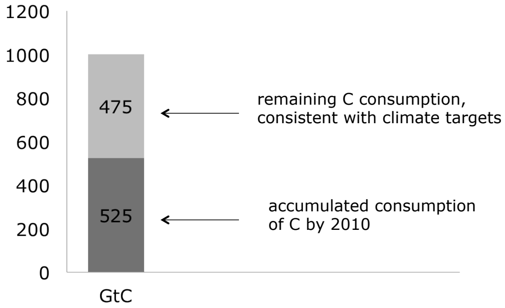
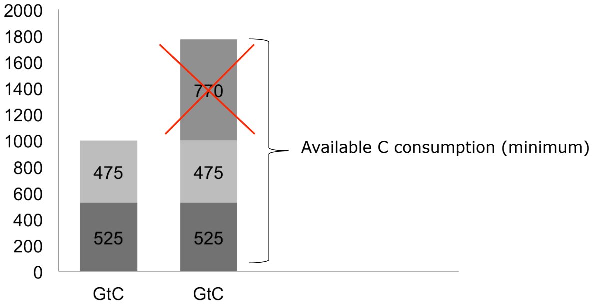
Three main topics

1. The social cost of carbon (SCC)
   - How do economists quantify SCC?
2. Climate treaties
   - Kyoto Protocol: why is participation difficult to achieve?
3. The reading: climate clubs (Nordhaus)
   - The issue of linkage

How much Carbon (C) has been and can be consumed?



The amount that needs to be left in the ground: what is the appropriate price on carbon that achieves this?



A two-period model: A simple framework for capturing the principles of carbon pricing

- preferences

$$w = u_1(c_1) + \delta u_2(c_2)$$

  - u_t, c_t utility and consumption, resp.
  - discount factor captures the time preference, $0 < \delta \leqslant 1$
  - w is the welfare to be maximized

A two-period model

- budgets, technologies

$$c_1 + k_2 = f_1(k_1, z)$$
$$c_2 = f_2(k_2, z)$$

  - $MCP \equiv \frac{\partial f_1}{\partial z} > 0$, marginal carbon product $t = 1$
  - $MCD \equiv -\frac{\partial f_2}{\partial z} > 0$, marginal carbon damage $t = 2$
  - $R_{1,2} \equiv \frac{\partial f_2}{\partial k}$, capital return
  - $MRS_{1,2} \equiv \frac{u_1'}{\delta u_2'}$, marginal rate of substitution

A two-period model

- restating welfare

$$w(k_2, z) = u_1(f_1(k_1, z) - k_2) + \delta u_2(f_2(k_2, z))$$

Savings:

$$-u_1'(.) + \delta u_2'(f_2(k_2, z))\frac{\partial f_2}{\partial k} = 0 \qquad (1)$$

$$\Rightarrow 1 = \frac{R_{1,2}}{MRS_{1,2}}$$

A two-period model

Carbon:

$$u_1'(.)\frac{\partial f_1}{\partial z} + \delta u_2'(f_2(k_2, z))\frac{\partial f_2}{\partial z} = 0 \quad (2)$$

$$\Rightarrow MCP = \frac{MCD}{MRS_{1,2}}$$

A two-period model

Combining (1)-(2):

The general equilibrium Pigouvian tax

$$MCP = \frac{MCD}{R_{1,2}}$$

Lessons from the two periods

- damages typically modeled as production losses
- equilibrium tax (=MCP) is the discounted loss in the future
  - discounting with the capital return $R_{1,2}$
- equilibrium tax depends on
  - technologies: f_1 and f_2
  - preferences: u_1, u_2, and δ
- How to think of the impact of current z on future $f_2(k_2, z)$?
  - natural-science insights: emissions-temperature response
  - longer-term climate dynamics
  - impacts of temperature increases on the economy

Lessons

- Demand and supply for savings determine $R_{t,t+1}$ to be used for policies
  - represent preferences such that, in principle, consumption choice data can be matched (not all agree with this requirement)
  - descriptive and prescriptive determinants of policies
  - uncertainty and discounting
- economists use ”integrated assessment models” (IAMs): large scale computational models to assess the ”carbon price” i.e., €/ton of C (or /ton of $CO2$). See readings in the end of the slides.

Let us use an IAM to see how temperatures depend on emissions:

- Hypothetical exercise 1: Assume current annual global emissions for the next 100 years (ca. 40 $GtCO_2$/yr.). Then, assume emissions drop to zero.
- Next figure: temperatures over time. Note the extreme persistence of the temperature impulse

Experiment 1

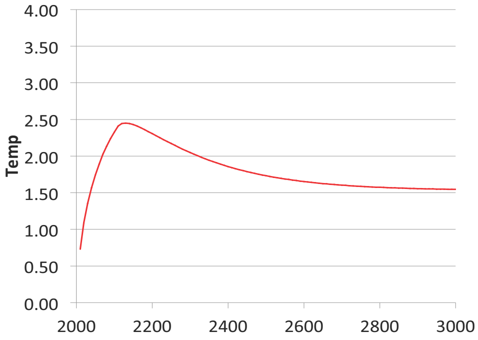


Figure: Source: own calculations using Nordhaus DICE type of model (DICE is discussed in the reading). Note: temperatures in degrees of Celsius above pre-industrial levels.

Experiment continued

- Hypothetical exercise 2: Assume current annual global emissions for the next 100 years. Then, emissions drop to zero.
- However: now we eliminate post-war emissions from the system to see how much one generation can affect the temperatures
- Next figure: temperatures over time

Experiment 2

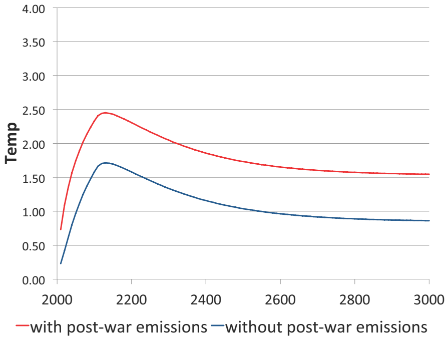


Figure: Source: own calculations using Nordhaus DICE type of model. Note: temperatures in degrees of Celsius above pre-industrial levels.

Questions

- Where is the temperature response coming from?
  - Fundamental question in climate science
- How do the economic losses from climate change arise?
- Can we use the model to find a price for carbon?
  - Such a price does not exist in the markets so we must compute it and, as a remedy for the missing market, impose this price as a tax on emissions in the economy.

First step in deriving the response: system of carbon reservoirs (carbon cycle)

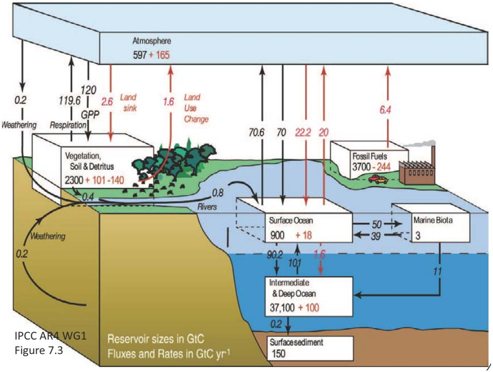


Figure: Source: IPCC

Carbon cycle formally

Describe the "carbon cycle" as a linear Markov diffusion process to derive (I'll explain this intuitively)

Remark

Consider a carbon diffusion process, described by a set of impulse-responses $\mathcal{I}$, *with fraction* $0 < a_i < 0$ *of emissions having decay rate* $0 \leqslant \eta_i < 1$, $i \in \mathcal{I}$. *For temperature sensitivity* π *and adjustment speed* ε, *the impact of emissions at time* t *on temperatures at time* $t + \tau$ *is*

$$\frac{dD_{t+\tau}}{dz_t} = \mathcal{R}(\tau) = \sum_{i \in \mathcal{I}} a_i \pi \varepsilon \frac{(1-\eta_i)^\tau - (1-\varepsilon)^\tau}{\varepsilon - \eta_i} > 0. \qquad (3)$$

Emissions temperature response

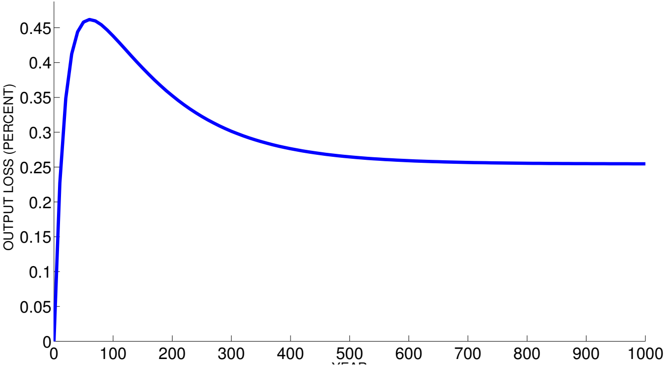


Figure: Multiplying temperature change by a given output-loss coefficient, say, $\Delta_y > 0$, we can interpret the emissions-temperature response as an emissions-damage response. Fig. shows the life path of damages (percentage of total output) caused by an impulse of one Teraton of Carbon [TtCO_2]. One TtCO_2 equals about 25 years of global CO_2 emissions at current levels (40 GtCO_2/yr.). The output loss is thus measured per TtCO_2, and it equals $1 - \exp(-\Delta_y \mathcal{R}(\tau))$, τ periods after the impulse.

The optimal price on carbon

- Take the description of the climate dynamics as above
- We also need a description for the economy: what is the World GDP in the future? The IAMs produce the future GDP as a function of productivity and population growth scenarios (among other things).
- How much of that GDP is lost because of climate change?
- Discounting the future impacts to the present gives the full cost of current emissions: the optimal price on carbon is equal to the cost that one additional ton of carbon emissions today causes in the future.

- Nordhaus, W. D. (2008), A Question of Balance: Weighing the Options on Global Warming Policies. (Yale University Press, New Haven, CT).
- Stern, N. (2006), ”The economics of climate change: the Stern review”, Cambridge, UK: Cambride University Press.
- A simple formula for the social cost of carbon, with Inge Bijgaart, and Reyer Gerlagh, The Journal of Environmental Economics and Management, 2016.