ECON 4910 Environmental economics; spring 2015

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Lecture note 10: Climate policy I (taxes, quotas)

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Please bring lecture note and EEAG report to lecture.

Reading:

Perman et al. (2011). Sections 9.5 and 16.1

EEAG (2012)

Important features of the climate issue:

- stock pollution
- The stock of greenhouse gases in the atmosphere affects climate (with a lag)
- Greenhouse gases consist of
  - CO2 from fossil fuel use, approx 60%
  - Other CO2 (mostly deforestation), approx. 20%
  - Other greenhouse gases; approx. 20%
  - We shall only consider CO2 from fossil fuel use
- potentially large damage; partial equilibrium analysis may be misleading (see below and Perman 16.1)
- large uncertainties
- distributional issues
- CO_2 from burning exhaustible fossil fuels (Lecture 13)
- international dimension (Lecture 12)

Some physics related to climate change

Measurements

- Emissions (flow): 1 tonne C = 3,67 tonnes CO_2
- Concentration in atmosphere (stock): 1 Gt (=10^9 tonnes) C = 0,47 ppm (parts per million)
- Preindustrial CO2: approx 280 ppm
- Current CO2: approx 400 ppm

A very rough description of the carbon cycle:

Emissions of CO2 give an increase of the concentration of CO2 in the atmosphere. This concentration gradually declines as CO2 is absorbed in the ocean and other carbon sinks. As a rough approximation, we have

- 25% of carbon emissions remain in the atmosphere "for ever"
- 75% of carbon emissions depreciate at a rate of 1-1.5% a year

Hence, if a total amount of 4(S*-S(0)) is extracted we thus get a development of carbon in the atmosphere as in figure 1, with A representing slow extraction and B representing fast extraction:

Relationship between carbon stock S and temperature change ΔT (ignoring the time lag):

$$\Delta T = \lambda (Ln2)^{-1} Ln \left(\frac{S}{N} \right)$$

Where N is the natural (preindustrial) amount of carbon in the atmosphere (approx 280 ppm) and λ is the climate sensitivity. According to IPCC it is most likely that $\lambda \in [1.5, 4, 5]$. If e.g. $\lambda = 2.5$ a doubling of the amount of carbon in the atmosphere will give a temperature increase of 2.5^0C.

Notice that ΔT is a concave function of S, while climate damage costs are probably a convex function of ΔT. It is therefore not obvious that climate costs are a convex function of S.

Alternative approach:

Allen et. al 2009: Warming caused by cumulative carbon emissions towards the trillionth tonne. See *http://www.nature.com/nature/journal/v458/n7242/full/nature08*

Quotation:

the relationship between cumulative emissions and peak warming is remarkably insensitive to the emission pathway (timing of emissions or peak emission rate). Hence policy targets based on limiting cumulative emissions of carbon dioxide are likely to be more robust to scientific uncertainty than emission-rate or concentration targets. Total anthropogenic emissions of one trillion tonnes of carbon (3.67 trillion tonnes of CO2), about half of which has already been emitted since industrialization began, results in a most likely peak carbon-dioxide induced warming of 2^0C above pre-industrial temperatures, with a 5-95% confidence interval of 1.3-3.9°C.

Necessary carbon tax q to achieve 2^0C target:

USD_{2010} per tonne CO2

Source: IPCC 2014 Figure TS12

	q range	q mid	q growth
2020	40-70	55	
2030	70-150	110	7.2
2050	150-300	225	3.6
2100	900-2500	1700	4.1

A simple IAM (Integrated Assessment Model)

Time references are omitted where this cannot cause any misunderstanding. Maximize

$$\int_0^\infty e^{-\rho t} W(\underset{+}{C}, \underset{-}{S}) dt$$

s.t.

$$\dot{K} = F(K, x, t) - C$$
$$\dot{S} = x - \delta S$$

To simplify the analysis we assume

$$W(C, S) = u(C) - hS$$

Notice that the marginal cost (WTP) of S is hC^{α} under the assumption that $u(C) = \frac{1}{1-\alpha} C^{1-\alpha}$, i.e. $u'(C) = C^{-\alpha}$.

The current value Hamiltonian is

$$H = u(C) - hS + \lambda \left[F(K, x, t) - C \right] + \mu \left[x - \delta S \right]$$

and the optimum conditions are

$$\dot{\lambda} = \rho\lambda - \frac{\partial H}{\partial K} = (\rho - F_K)\lambda \tag{1}$$

$$\dot{\mu} = \rho\mu - \frac{\partial H}{\partial S} = (\rho + \delta)\mu + h \tag{2}$$

$$H_C = u'(C) - \lambda = 0 \tag{3}$$

$$H_x = \lambda F_x + \mu = 0 \tag{4}$$

Using $u' = C^{-\alpha}$ and $g = \frac{\dot{C}}{C}$, equations (1) and (3) give

$$F_K = \rho + \alpha g \equiv r \tag{5}$$

Rewriting (4) gives

$$F_x = \frac{-\mu}{\lambda} \equiv q \tag{6}$$

which together with (2) implies

$$\frac{\dot{q}}{q} = \frac{\dot{\mu}}{\mu} - \frac{\dot{\lambda}}{\lambda} = \left[\rho + \delta + \frac{h}{\mu}\right] - [\rho - r]$$

Using (6) this may be rewritten as

$$\frac{\dot{q}}{q} = r + \delta - \frac{h}{qu'}$$

or

$$\dot{q} = (r + \delta)q - hC^{\alpha} \tag{7}$$

If we as a simplification regard r as constant, this gives (using the transversality condition of the optimization problem)

$$q(t) = \int_t^{\infty} e^{-(r+\delta)(\tau - t)} hC(t)^{\alpha} e^{\alpha g((\tau - t))} d\tau$$

or, using (5)

$$q(t) = hC(t)^{\alpha} \int_t^{\infty} e^{-(\rho+\delta)(\tau - t)} d\tau = \frac{h}{\rho + \delta} C(t)^{\alpha}$$

or, if $C(t) = C_0 e^{gt}$

$$q(t) = \frac{hC_0}{\rho + \delta} e^{\alpha g t} \tag{8}$$

which is incrasing over time. Using (6) we also see that

$$e^{-rt} q(t) = \frac{hC_0}{\rho + \delta} e^{-\rho t} \tag{9}$$

which is declining over time.

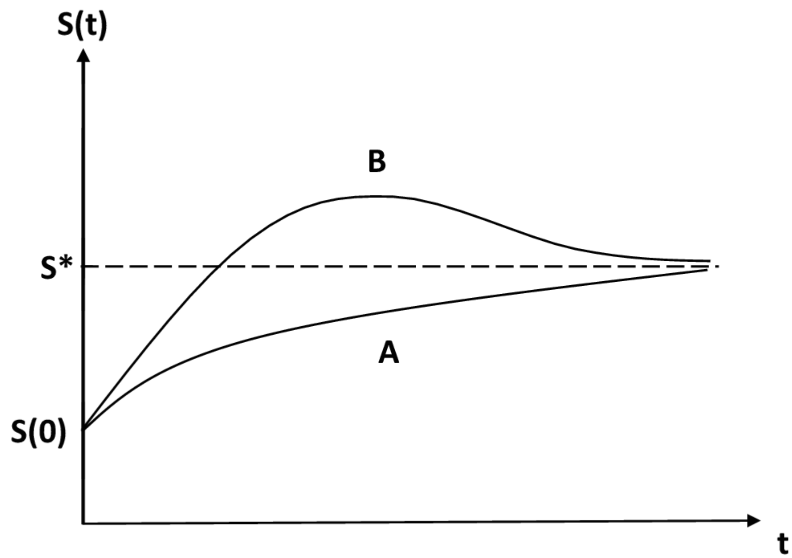

Figure 1: Carbon in the atmosphere for alternative emission paths