ECN 275/375 Environmental and natural resource economics
Exercise set 14 – Eirik's suggested answers

Exercise 14.1 – Climate emissions as a stock pollutant

Natural scientists often view climate gas emissions as an accumulation of CO_2 equivalents in the atmosphere. Denote climate gas emissions in CO_2 equivalents in time period *t* as *Mt*, and maximum allowed accumulated emissions as $\bar{M}$ to avoid a certain severe climate damage scenario.

(a) What is the "resource constraint" given this perspective on climate gas emissions? Briefly explain your answer.

Answer: The resource constraint: $\bar{M} \geq \sum_{t=0}^{\infty} M_t$. The sum of emissions over time cannot exceed the size of the carbon sink if we are to avoid the unwanted scenario.

(b) $\lim_{t=\infty} \frac{\bar{M}}{t} = 0$ of the resource constraint implies a zero emission policy. Why is this partly irrelevant?

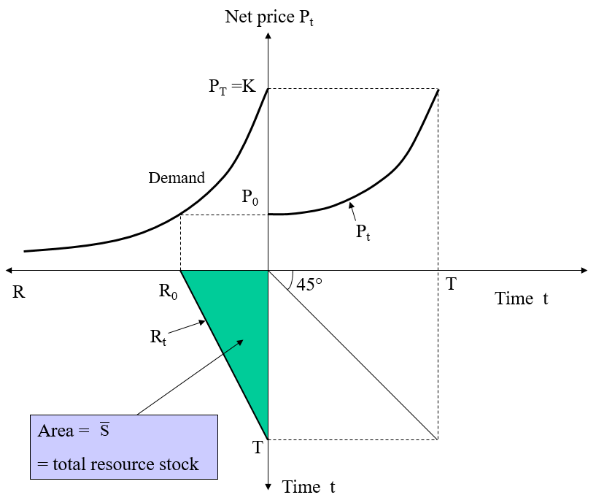
Answer: Because (i) this strict interpretation of the resource constraint means that some possible welfare from emissions, M_t, are forfeited, and (ii) it misses the possibility of the introduction of a backstop technology in finite time, which is very likely given the high costs of a zero emissions policy (strong incentives for developing zero emission technologies).

(c) The "arrival time" of *backstop technologies* is uncertain. How could uncertain "arrival time" for backstop technologies be incorporated in the resource constraint?

Answer: By introducing a safety margin for the expected arrival time. As more information about the expected arrival time and the uncertainty about the arrival time are known, the expected arrival time and the safety margin are updated.

Exercise 14.2 – Graphical analysis of the stock pollutant problem

4-quadrant graphs like the one presented in lecture 13 (see graph to the right), can be quite useful in terms of characterizing changes in management of non-renewable resources.



(a) What changes are needed in our explanation of the key elements in such graphs to make such a graph usable analyzing stock pollutants like emissions of CO_2-equivalents?

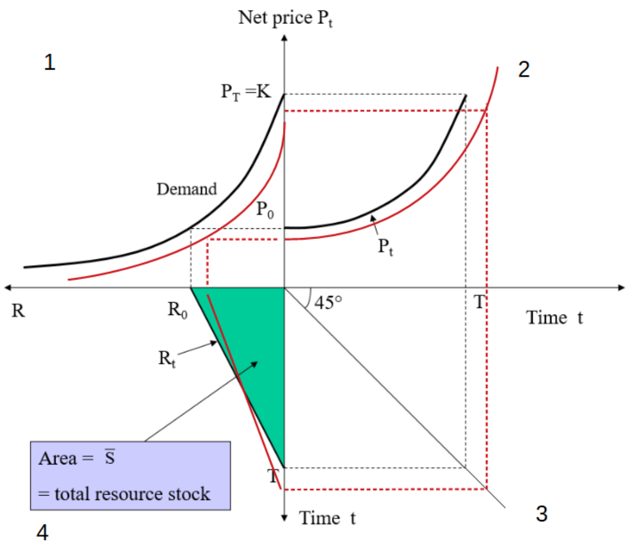
Answer: Three changes in our interpretation are neeeded:

(i) The Hotelling price path $P_t = (1+r)^t P_0$ is now the price put on CO2-equivalent emissions, for example through a tax on the tradable permit price for carbon.

(ii) The demand is now the demand for carbon emissions.

(iii) The resource (the green area) now becomes the total allowed carbon emissions (a bank that we deduct yearly emissions from) to avoid the undesirable climate change scenario . This permits us not to make any changes in the overall 4-quadrant graph perspectives.

(b) What are the impacts of technologies that reduce the demand for carbon emissions on the “resource” allowable carbon emissions to avoid an undesirable climate scenario? Use a 4-quadrant graph to illustrate your findings.



Answer: Start with a standard 4-quadrant graph (see graph to the right). Draw a new demand curve (red line in quadrant 1)) that reflects the reduced demand for carbon emissions. Lower demand is also going to lower P_0 and hence the Hotelling price path (red line in quadrant 2). We are now able to draw a situation where the lower price and demand will give us a lower R_0 where the red dotted line crosses the resource axis between quadrants 1 and 4. Given that the size of the carbon budget (the green area describing the “resource stock”) is unchanged, the steeper red line in quadrant 3 now depicts a carbon budget of the same size. The red dotted lines in quadrants 2 and 3 are strictly not needed for our analysis, but serve as some consistency check. Recall the remark from lecture 13 that the portion of the demand curve close to the choke price is most likely uncertain → full consistency may not take place.

Our analysis now suggests: initial carbon emissions will fall, and the carbon price is lower, which all together gives more time before the carbon budget to avoid the undesirable climate change scenario may take place.

(c) Explain why the reduced demand for carbon emissions may not lead to full use of the carbon budget, i.e., that carbon emissions continue until the new and higher time indicated by the red lines in quadrants 2 and 3.

Answer: The size of the carbon budget is not known with certainty as it is a best estimate of cumulative carbon emissions that can be permitted before the undesirable climate change scenario materializes. Uncertainty regarding how exact this estimate is, may therefore make it optimal not to fully use the (estimated) carbon budget. The decision on how much to use of the carbon budget depends on the trade-off between the expected marginal benefits of not using the full budget and the marginal costs of abating less than the carbon budget allows for.

Another way of looking at this is to steer away from the scenario-thinking, and instead take a continuous view of emissions: the more we can reduce emissions, the less the climate damages.

Remark: While scenarios are great for explaining consequences in an easy-to-understand way, they introduce artificial thresholds (constraints) that could mislead us to think as economists = always on the margin.