ECN 275/375 Environmental and natural resource economics
Exercise set 6 – Eirik's suggested answers

Exercise 6.1 – The "downstream problem" (and an extension)

There is a polluting factory in a river that leads to pollution downstream. The polluting factory creates no externalities where it is located. Current emissions and damages from these emissions are as follows:

- At the site of origin: emissions M_0' = 100, marginal damages MD_0 = 0
- At the first site downstream: emissions reaching site M_1 = 0.6 M_0, where M_0 is emissions at the pollution site.
- At second site downstream: M_2 = 0.3 M_0

The marginal abatement cost function is: $MAC_0(M_0)=50-\frac{M_0}{2}$, where the current.

It is assumed to be far more costly to clean the polluted river water downstream than to reduce emissions at the site.

At both sites the marginal damage function is the same i.e., $MD_i(M_i)=M_i \forall i=1,2$, where M_i is the amount of pollution reaching site *i*.

(a) The environmental protection agency (EPA) has decided that the maximum allowed damages at any site is 40. How much are missions needed to be reduced at the polluting site?

Answer: If emissions reaching site 1 (the first downstream site) adhere to the standard, the standard will also be met at site 2. It is therefore only site 1 that decides how much that should be reduced: MD_1 = 40 ==> M_1 = 40 ==> emissions at the polluting side cannot exceed 2/3 of its initial level, i.e., max emissions at the polluting site is 66 2/3.

(b) After some consideration, the EPA has figured out that the standard in (a) may not be optimal. How can the EPA find the optimal pollution level, i.e., to maximize the welfare in society? And if so, what is the optimal pollution level?

Answer: The transmission coefficients (0,6 and 0,3) are given at the bullets at the top. As half of the emissions reaching site 1 also reaches site 2, the marginal damage function is constructed as a vertical summation of the two damage functions with half weight given to damages at site 2. This yields $MD(M_0)=0{,}9\,M_0$ Equate this with the MAC function, and solve for M_0:

$0{,}9\,M_0=50-0{,}5\,M_0 \Rightarrow 1{,}4\,M_0=50 \Rightarrow M_0=50/1{,}4=35{,}71$ (= 36 for simplicity)

Remark: if you doubt this answer, draw the MD- and MAC-functions in the same graph and look at the intersection point.

(c) Suppose that the two downstream locations are located in two other countries than where the polluting site is located. Why is it difficult to reach the optimal solution in (b)?

Answer: Suppose the polluting factory's marginal abatement cost function is known with certainty, which allows for price discrimination in the compensation. Reducing emissions M_0 to 36 yields a compensation of $\int_{36}^{100}(50-M_0/2)\,dm_0=|_{36}^{100}(50\,M_0-M_0^2/4)=1024$

Now suppose site 1 (country 1) moves first, and decides to optimize only with regard to its own welfare. This gives emissions: $0{,}6\,M_0=50-0{,}5\,M_0 \Rightarrow 1{,}1\,M_0=50 \Rightarrow M_0=50/1{,}1=45{,}45$. It then compensates the factory with $\int_{45}^{100}(50-M_0/2)\,dm_0=|_{45}^{100}(50M_0-M_0^2/4)=756$. The welfare gains to country 2 of reducing emissions further (from 45 to 35, the social optimum) requires paying the polluting firm $\int_{36}^{45}(50-M_0/2)\,dm_0=|_{36}^{45}(50M_0-M_0^2/4)=268$ while it only gains $\int_{35}^{45}0{,}3M_0\,dM_0=|_{35}^{45}0{,}3M_0^2/2=109$. It will therefore not do this, and the social optimum will not emerge. The same kind of calculation could be undertaken for site 1 (country 2).

This result emerges because when one country moves first, it removes the most serious damages for free to the other country, and the welfare losses of the emissions that remain are possibly not worth paying for, even if the joint benefits from reducing emissions to 36 is worth paying for when both countries pay.

In general, agreeing on how to split these kinds of bills, is one of the major obstacles of reaching international agreements.

Exercise 6.2 – Different marginal damages at different locations (2)

In a country there are two rivers, one with a highly valuable fishery, and the other without any extra environmental value (besides the ordinary). Located by each of the rivers, there are three paper mills, each mill producing a special quality paper for a limited (niche) market, using similar production technologies. Together the mills cover a large share of the market supply of this quality paper.

While being concerned about the environment, the government also worries about international competitiveness. Hence, it has hired in a private consulting firm, Quick & Dirty Ltd.

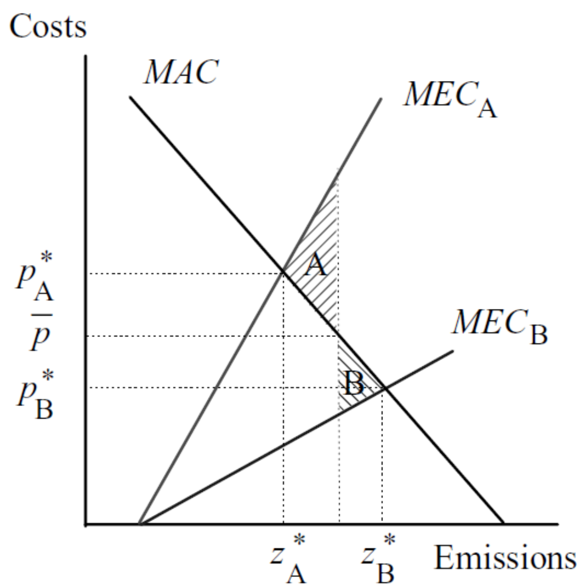
The main points in the recommendations of Quick & Dirty are:

- making a joint market for tradable emission permits in the two rivers, and
- grandfathering out permits to firms of approximately 50% of current emissions.

As an external expert reviewer comment on the recommendations of Quick & Dirty.

(a) What specific problems, if any, do you see with Quick & Dirty's recommendations? Justify your answer.

Answer: With the government's concerns regarding competitiveness of the ndustry, the immediate reaction may be that Quick & Dirty's suggestions are sound. However, there are several problems with their suggestions:



1. The marginal economic costs in the two rivers are likely to vary considerably (indicated by MEC_A and MEC_B – proxies for MD_A and MD_B in 275-notation – see figure right). Assuming that the abatement cost curves are the same (indicated by the joint *MAC* curve in the figure), the optimal emission level in the two rivers differ (z_A and z_B respectively). This results in two different optimal prices in the two rivers, p_A and p_B respectively.

Having a joint trading area results in a joint price ($\bar{p}$ the "law of one price" in integrated markets) in the emission permit market somewhere between p_A and p_B, resulting in the welfare loss equaling the area A in river A from excessive emissions, and B in river B from too little emissions.

2. Given (1) it follows that one may want to restrict trades to take place only within the two receptor areas (rivers), i.e., what is termed a "trading bubble" within the literature.

   In each of the rivers there are only three firms, which is a very small number of potential traders to be certain that price taking behavior on behalf of the firms would result (the problem of "thin markets"). In short, the conditions for a well working tradable permit markets are not met.

3. Grandfathering out permits to the polluters is the same as a welfare transfer from society at large to polluters. If such policies were to become a norm in this economy, one could have many interesting entry-exit issues on hand.

(b) What policy changes, if any, would you suggest? Justify your answer.

Answer: No easy solution exists here (it is always "tricky" to regulate situations where there is market power involved, there is a low number of polluters, and location damages vary). Some solutions that at least are better than those proposed by Quick & Dirty:

1. A **differentiated tax on emissions** (equal to p_A in A and p_B in B) appears an interesting possibility. With the higher tax in the environmentally sensitive area (A) this would also provide incentives for firms relocating to the less sensitive area (B) as taxes are lower.

2. A **command-and-control approach** (like non-tradable permits) where differential environmental standard are set, but where firms are free to choose technological approaches to reduce emissions. Maximum freedom for firms' choices for abatement approaches is always desirable, as firms then will choose the least costly abatement solution given the emission/environmental standard (this also follows from the core proposition from operations research on the objective value of less versus more constrained problems).

   There are two weaknesses of this approach: (i) the regulator receives little (if any) price signal on the development of firms' abatement costs over time, and (ii) with so few polluters, the total emission load, and hence the optimality of the single firm's actions, depends on the actions of the other firms. A command-and-control scheme is generally unable to solve this interaction problem.