

Lecture Notes: Systems Competition  
Chapter V: Ecological Dumping -  
International Spillover, Pigovian Taxes,  
Certificates and Rent Dissipation

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# 5 Ecological Dumping

## 5.1 Introduction & Basic set-up

- There exist a potential conflict between economic and ecological goals.
- Unregulated firms have incentive to pollute more than what is optimal from the society's perspective.
- In other words, there will typically be a negative externality created by the firms.
- When there is international competition these externalities will be enlarged since national governments have no incentives to care about environmental effects in other countries.

- However, this problem can be remedied through
  - taxes
  - regulation
  - market for tradeable permits.
  
- The major question of chapter 5 is: Is systems competition compatible with ecological goals?
  
- It will be shown that an optimistic view about systems competition is not always justified.
  
- We have to distinguish between national and international spillover of pollution.

## Model set-up

- A small open economy is considered.
- Labor,  $L$ , is internationally immobile. The wage rate,  $w$ , is determined endogenously as to clear the labor market.
- The amount of capital,  $K$ , is used in domestic production. Capital is perfectly mobile across countries and the market rate of interest,  $r$ , is fixed at the world capital market.
- Overall wealth of households is given by  $\bar{K}$  (endowment with capital). Since the amount  $K$  is used within domestic production, the fraction  $(\bar{K} - K)$  determines the domestic country's net foreign wealth position.
- Industrial production results in waste such that the environment becomes a production factor.

- The production function is given by  $f(L, S, K)$  where  $S$  is the waste emission of domestic/local firms.
- The amount of immissions, the national habitants suffer from, are denoted by  $S^*$ .
- Larger pollution / emission allows for a larger production of firms. Accordingly, pollution exhibits positive, but declining marginal returns  $f_S > 0$ ,  $f_{SS} < 0$ .
- An ecological (or Pigovian) tax rate,  $p$ , per unit of waste emissions is levied by the government to regulate emissions,  $S$ .
- The tax revenue,  $T$ , stemming from the taxation of emissions,  $T = pS$ , is redistributed to the households.
- In the following we have to distinguish between national spillover, where waste settles only within national borders, and international spillover, where the pollution spreads across national borders.

## 5.2 No International Spillover

- We start with the benchmark-model without any international spillover. Accordingly, where waste settles only within national borders.
- The firms maximize their profits and the respective problem states

$$\max_{L,S,K} f(L, S, K) - wL - pS - rK.$$

- Solving this problem gives the following first order conditions:

$$\begin{aligned}f_L(L, S, K) &= w, \\f_S(L, S, K) &= p, \\f_K(L, S, K) &= r.\end{aligned}$$

- Tax revenues from the Pigovian tax,  $T$ , go back to the households.

- Households also earn a wage income,  $wL$ , and capital income  $r\bar{K}$  such that the representative household's income can be written as

$$Y = wL + T + r\bar{K}.$$

- Apart from income  $Y$ , pollution is assumed to be included in the utility function, which is given by

$$U(Y, S^*).$$

- where  $U_Y(Y, S^*) > 0$  and  $U_{S^*}(Y, S^*) < 0$ .
- In case waste settles only within national borders, the amount of emissions,  $S$ , is equal to the amount of immissions,  $S^*$ , such that  $S = S^*$  is true. This assumption will later be relaxed.
- The (benevolent) government acts as to maximize the citizen's utility by setting the amount of emission,  $S$ , and therewith indirectly the Pigovian tax rate,  $p$ .

- In doing so, the government has to take into account of the endogeneity of the wage rate. Why is it the case and why should we care?
- Making use of the Euler theorem and substituting in we finally infer, that income is given by domestic output plus capital income earned abroad

$$Y = f(L, S, K) + r(\bar{K} - K).$$

- As mentioned before, the government selects the Pigovian tax through the level of pollution  $S$ .
- Therefore, the (benevolent) government's problem is to solve

$$\begin{array}{ll} \max_S & U(Y, S^*) \\ \text{s.t.} & f_L = w, f_S = p, f_K = r, \\ & S = S^*, \\ & Y = f(L, S, K) + r(\bar{K} - K). \end{array}$$

- Therefore, the marginal condition states

$$U_Y f_{S^*} + U_{S^*} = 0.$$

- Since firms maximize their profit such that  $p = f_S$  we get

$$p = f_S = -\frac{U_{S^*}}{U_Y}.$$

- Note that total differentiating the utility function,  $U(Y, S^*)$ , holding  $U$  constant implies

$$U_{S^*} dS^* + U_Y dY = 0$$

or

$$-\frac{U_{S^*}}{U_Y} = \frac{dY}{dS^*}.$$

- Finally, we achieve the result that

$$p = f_S = -\frac{U_{S^*}}{U_Y} = \frac{dY}{dS^*} \Big|_U.$$

- Accordingly, in the optimum, the marginal rate of substitution (l.h.s.) has to be equal to the marginal rate of transformation (r.h.s.).
- The Pigovian tax equates these two expressions.

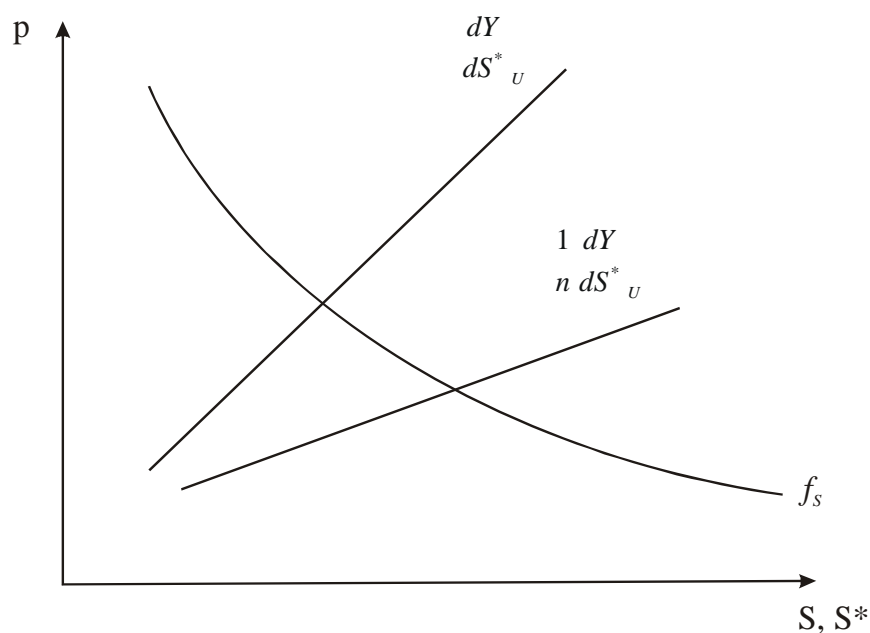


Figure 1: Optimal Pigovian Tax Rate

- A benevolent planner who do not need to take into account the firms' profit maximization, constraint,

$f_S = p$ , would select the same stock of capital and the same level of pollution as the equilibrium outcome.

- A supra-national planner would also allocate capital such that all countries follow the rule  $f_K = r$  and have the same level of pollution as in the national equilibrium.
- Hence, in this simple setup, there is no need to fear that systems competition will lead to ecological dumping.
- *Proposition 5.1:* As long as environmental damage only occurs within the country's borders and is regulated by the means of Pigovian taxes, the national government has no incentive to engage in ecological dumping. Its environmental policy is efficient both from a national and international perspective.

## 5.3 International Spillover

- However, CO<sub>2</sub>, rusty tankers, pollution in water, etc., will not stay within the borders of different countries.
- So, let's consider the more realistic model where pollution in one country affects the utility of people in other countries.
- In particular, it is assumed that one country's emission of pollution spreads evenly over  $n$  countries.
- In terms of the model, this implies that

$$S_i^* = \sum_{j=1}^n \frac{S_j}{n}, \quad i = 1, \dots, n$$

- Accordingly, the amount of immissions hitting country  $i$  is given by one  $n^{\text{th}}$  of total pollution.

- The income for country  $i$  is (as before) given by

$$Y_i = f(L_i, S_i, K_i) + r(\bar{K}_i - K_i)$$

- In case of national spillover, the government solves

$$\begin{aligned} \max_{S_i} \quad & U(Y_i, S_i^*) \\ \text{s.t.} \quad & f_L = w, f_S = p, f_K = r, \\ & S_i^* = \sum_{j=1}^n \frac{1}{n} S_j, \quad i = 1, \dots, n \\ & Y_i = f(L_i, S_i, K_i) + r(\bar{K}_i - K_i) \end{aligned}$$

- Assume that the countries play *Cournot*, that is each country optimizes its waste emission under the assumption that its behavior has no influence on the emissions of the other countries.
- The first-order condition now looks somewhat different from before

$$f_S U_Y(Y_i, S_i^*) = -\frac{1}{n} U_{S^*}(Y_i, S_i^*).$$

- From the firms' first-order condition we have as before

$$p_i = f_{S_i}.$$

- We therefore get

$$\begin{aligned} p_i = f_{S_i} &= -\frac{1}{n} \frac{U_{S^*}(Y_i, S_i^*)}{U_Y(Y_i, S_i^*)} \\ &= \frac{1}{n} \frac{dY_i}{dU_{S^*}} \Big|_U \quad \forall i = 1, \dots, n. \end{aligned}$$

- Compared to the case without spillover, it differs with the factor  $\frac{1}{n}$ .
- The intuition is that each country does only take into account the pollution on its own inhabitants, neglecting the effect on the  $n - 1$  other countries.
- Therefore, the tax rate,  $p_i$ , it selects will be too low (and certainly not optimal).

- Moreover, we have

$$\frac{\partial p_i}{\partial n} = -\frac{1}{n^2} \frac{dY_i}{dS_i^*} \Big|_U$$

- Thus, the more countries, the larger is the externality and the lower the tax rate. In fact, if there are infinitely many countries,  $\lim n \rightarrow \infty$ , in the world, then the tax rate will be equal to zero.
- This is a strong argument in favour of coordinated environmental policy.

## 5.4 Optimal Pollution in case of International Spillover

- There exists however a mechanism, which can create an optimal solution.

- The idea is to let countries that inflict pain on other countries pay for the damage it causes.
- In other words, each country is forced to internalize the costs it causes on all other countries, i.e. by side payments.
- In particular, we now want to derive the Pareto optimal allocation of pollution if pollution causes international spillover. Therefore we set up a countries maximization problem and assume that the country has to make sufficient side payments to all other countries so as to compensate for the damage imposed upon them.
- So, we consider an efficient policy where each country makes side-payments to the other countries to compensate for the costs it inflicts on them.

- The compensation from country  $i$  to country  $j$  is given by  $(Y_j - \bar{Y}_{ij})$ , where  $\bar{Y}_{ij}$  is country  $j$ 's income resulting from its own actions and the side payments of all other countries except of country  $i$ .
- If we account for the side payments, income of country  $i$  is given by

$$Y_i = f(L_i, S_i, K_i) + r(\bar{K}_i - K_i) - \sum_{j=1 \neq i}^n (Y_j - \bar{Y}_{ij})$$

- The government's problem in country  $i$  thus states

$$\max_{S_i} U(Y_i, S_i^*) \quad \forall i = 1, \dots, n, \quad j \neq i.$$

s.t.

$$S_i^* = \sum_{j=1}^n \frac{1}{n} S_j, \quad i = 1, \dots, n$$

$$Y_i = f(L_i, S_i, K_i) + r(\bar{K}_i - K_i) - \sum_{j=1 \neq i}^n (Y_j - \bar{Y}_{ij})$$

$$U(Y_j, S_j^*) = \text{constant}$$

- Note that the government's choice of the level of pollution,  $S_i$ , determines also implicitly the size of the side payment it has to pay to all other countries.
- As mentioned before, the side payment of country  $i$  to country  $j$  should be sufficient to compensate for the damage imposed upon country  $j$  due to country  $j$ 's emission.
- The marginal damage on part of country  $j$  is given by

$$-\frac{U_{S_j^*}}{U_{Y_j}} = \frac{dY_j}{dS_j^*} \Big|_{U_j} \quad \forall i = 1, \dots, n, \quad j \neq i.$$

- Since only  $\frac{1}{n}$  of country  $i$ 's marginal emission hits country  $j$ , the side payment of country  $i$  to country  $j$  has to be of the size

$$\frac{1}{n} \frac{dY_j}{dS_j^*} \Big|_{U_j}$$

- Since all countries except for country  $i$  are entitled to side payments from country  $i$ , the total amount of side payment refunded by country  $i$  amounts to

$$\sum_{j=1 \neq i}^n \frac{1}{n} \frac{dY_j}{dS_j^*} \Big|_{U_j}$$

- Therefore, the first order condition with respect to  $S_i$  is

$$U_{Y_i} \left( f_{S_i} - \sum_{j=1, j \neq i}^n \frac{1}{n} \frac{dY_j}{dS_j^*} \Big|_{U_j} \right) + \frac{1}{n} U_{S_i^*} = 0,$$

- Since

$$-\frac{U_{S_i^*}}{U_{Y_i}} = \frac{dY_i}{dS_i^*},$$

- we finally arrive at

$$p_i = f_{S_i} = \sum_{j=1}^n \frac{1}{n} \frac{dY_j}{dS_j^*} \Big|_{U_j},$$

what resembles the Samuelson condition for the provision of public goods.

- Accordingly, The Pigovian tax rate,  $p_i$ , is chosen such that the marginal product of emission in country  $j$  is equal to the sum of the marginal damages in all countries.
- In case all countries are identical, it follows that the optimal tax rate is given by

$$p_i = f_{S_i} = \frac{dY_j}{dS_j^*} \Big|_U \quad \forall i = 1, \dots, n.$$

- *Proposition 5.2:* Proposition: In the case of international waste spillover, the Pareto optimal pollution policy is given by the equality between the national marginal product of the waste emission and the sum of the world marginal damages that this emission causes.

- *Proposition 5.3:* In the case of international waste spillover, the national government will choose a too low tax rate: that is, it will engage in ecological dumping.
- Importantly, for the solution to be efficient all countries have to commit to the transfer/side payment system.
- However, all countries have incentives to deviate. Therefore, only collective action can overcome the misallocation problem.
- But history has shown that it is very difficult for countries to agree upon environmental policy, i.e. neither Bush nor Putin signed the “Kyoto agreement”.
- Next, we want to see how pollution certificates work and whether this instrument could assure a efficient allocation of pollution.