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Horst Siebert

International Aspects of Environmental Allocation

1. The Spatial Dimension of Environmental Problems

Similar to economic activities, which take place in space, environmental media and environmental pollution are also defined over space. Viewing space as a set consisting of a finite number of spatial points or as a grid system, environmental quality is related either to a specific spatial point — a specific grid — or to a set of spatial points. Emissions are linked to space as well; stationary sources of pollution are fixed to a specific point in space, mobile sources move over space. Moreover, pollutants migrate in space via the environmental media or through other mechanisms such as biodiffusion. Last but not least, the definition of property rights for environmental use or of other environmental policy instruments also have a spatial dimension.

A starting point for analyzing the spatial dimension of the environmental problem is to define subsets in the set of spatial points and to delineate environmental media according to their spatial extent. Environmental systems or goods then range from microsystems, such as a small pond, to global environmental media, such as the ozone layer. Depending on the spatial extent of environmental media, we can distinguish among the following types of environmental goods:

- Local environmental systems, which represent elements in a disaggregated spatial picture, such as small-scale ecological systems, for instance, small lakes.
- Regional environmental systems, which are spatial subunits of a nation, such as a tributary of a main river (the Neckar as a tributary of the Rhine), or a geographic subarea with specific characteristics, such as the coastal region of the North Sea or the Black Forest.
- National environmental goods, which coincide with the territory of countries within political frontiers.
- Transfrontier environmental systems, which transport pollutants from one nation to another. Transfrontier pollution can be subdivided into two types: unidirectional, or one-way, and multidirectional, or two-way. Unidirectional, or one-way, transfrontier pollution occurs when the emissions from one country are transported to another and environmental quality in the country

of origin remains unaffected. Classic examples are the pollutants carried from a source upstream to a location further down the river and the pollutants transported by the westerly winds to the east. Consider the potassium salt carried by the Rhine and the acid rain originating in Western Europe and falling on Sweden. In two-way transfrontier pollution, pollutants are transported in both directions, for instance, as a result of atmospheric conditions and by changing winds. The situation becomes more complex when different pollutants are transmitted by different environmental media.

- International environmental goods, which are limited to spatial subsystems of the world, such as the Mediterranean and the Baltic Sea. These goods extend over at least two nations. Diffusion processes within the environmental system are not of major importance.
- Global environmental goods, such as the earth's atmosphere or the ozone layer, which are used as a public consumer good and as a receptacle of wastes by the earth as a whole.

The spatial extent of environmental media is defined by the role of the environment as a public good. The analysis is severely complicated if the environment receives emissions from other points in the spatial structure, i.e., if pollutants ambient in a spatial system do not correspond to pollutants emitted in the same region. In that case, we have spatial externalities. Another important complication is that the spatial dimension of the institutional setting is different from the spatial extent of the environmental media. This implies that property rights for emissions, i.e., specific policy instruments, may be different within the same environmental medium. And existing institutional arrangements may not be consistent with the spatial dimension of an environmental medium. Thus, regions delineated according to economic, ecological and institutional (or political) criteria need not overlap.

Neglecting the local and the regional dimension, three major spatial aspects of environmental problems can be distinguished: i) national environmental endowment as a determinant of competitiveness and trade; ii) transfrontier pollution; and iii) global environmental problems. These aspects will be studied in the following sections.

2. National Environmental Endowment, Competitiveness and Trade

In many cases, the environment can be interpreted as a national public good. This approach is valid with national or regional river systems, national ground water systems, national or regional air sheds, soil deterioration and the absence of noise as well as with respect to the amenities of the landscape. In these cases, environmen-

tal media fall more or less within the national boundaries. Both roles of the environment, namely, the role as a public good for consumption and as a receptacle for wastes, occur in the subset of spatial points that belong to a nation. In this category of problems, externalities between countries are not too important and can be neglected.

In such a context, environmental pollution is a national allocation problem. The trade-off between improving environmental quality and the opportunity costs of foregone production, i.e., determining the maximum net benefit in a benefit-cost approach, is a national issue.

The environment is a factor of endowment and it therefore is a determining factor of competitiveness in world trade. One country may have a higher assimilative capacity than another. Assimilative capacity is determined by four key factors:

- The natural assimilative capacity of the environment.
- The value accorded to the environment as a consumer good, that is, national preferences for environmental quality.
- The demand for the assimilative services of the environment. This is measured by the amount of pollutants released into the environment, which is dependent on the consumption, production, and emissions technology, as well as on the level of development of the national economy.
- The public or private investments undertaken to increase the assimilative capacity of the environment or to decrease the demand for this service.

A country may also be richly endowed with certain public goods, such as amenities of the landscape. To the extent that these goods are nationally restricted, the foreign trade position of the country in the service sector (for example in the tourism branch) is improved. I will not pursue this type of case here.

Viewing environmental endowment as a factor of production as well as a consumption good, an increase in environmental scarcity shifts the traditional transformation curve of two private goods inward. In an analysis in which environmental quality is explicitly considered as a good in its own right, the production possibility set is a three-dimensional space with an output of two traditional goods and environmental quality on the axes [Siebert, 1991]. This analysis can be used to study the impact of environmental policy on the international division of labor.

The environmental policy of a country evaluates the trade-off along the transformation space between an improved environmental quality and the corresponding loss of output by equating the marginal rate of transformation between environmental quality and private production with the sum of the marginal rates of substitution. Thus the optimal environmental quality is determined. Either an ambient standard of environmental quality is set and prices are determined endogenously through marketable permits or emission prices (emission taxes, effluent fees) are used in order to attain environmental quality.

Consider the case in which environmental endowment, i.e., the tolerable level of emissions, is reduced by environmental policy. In this case the relative price of the pollution-intensively produced commodity will rise; the country undertaking environmental policy will lose comparative advantage in the pollution-intensively produced good. The wedge between the market or the consumer's price and the producer's price (net of the price for emissions) represents an incentive to demand and produce less of the pollution-intensively produced good. Output of the pollution-intensively produced good will fall and output of the environmentally friendly good will increase. Sectoral reallocation is accompanied not only by the increase in the relative market or consumer's price but also by the price of emissions rising relative to the price of other factors of production. All this confirms the role of endowments in the Heckscher-Ohlin approach. Technically, some details vary with the modeling of the generation of pollution, which may be treated explicitly, beside a production function [Siebert, 1974a; 1978], or which may be collapsed into a production function with the environment as an input. In this case the mass balance concept requires limiting the input space [Pethig, 1976].

Whereas in the previous argument we started from an autarky situation (for which comparative advantage is defined), all the results from traditional trade theory also carry through if we reduce environmental endowment in a trading equilibrium. Consider the small-country case for which the relative price of the two goods is determined by the world market. In a two-factor model, relative factor prices are fixed as well. In such a Rybczynski context, the output of the pollution-intensively produced good will be reduced if environmental scarcity increases. The output of the less pollution-intensively produced good will increase.

If three factors of production are considered, i.e., capital and labor in addition to environmental endowment, and if the relative price of the two goods produced is given in the small-country case, relative factor prices vary, and environmental scarcity can be substituted by capital and labor. With respect to the change in the comparative advantage, the results depend on the type of pollution intensity. The usual results carry through for the case of a strong emission intensity [Siebert et al., 1980, p. 171].

Nevertheless, the manner in which environmental policy affects competitiveness is of interest in determining optimal environmental quality. Since pollution-intensively producing sectors will be negatively affected, the country will experience a loss of comparative advantage in these products, and its sectoral structure will have to change. The loss of competitiveness may be one argument in determining the optimal environmental quality; this loss of competitiveness may be interpreted as an opportunity cost of environmental policy that must be taken into account in determining the environmental target. At the same time, environmental policy may establish incentives for adjusting abatement technology and creating new technical knowledge. The other side of the coin is that the environmental

problem requires a redefinition of the gains from trade by taking into account the loss in environmental quality if a country specializes in the export of pollution-intensively produced goods [Siebert, 1977]. By internalizing an externality, environmental policy eliminates a distortion that favors the pollution-intensively producing sector.

3. International Repercussions of National Environmental Policy

Even in a scenario in which environmental media are purely national, there are international repercussions between national environmental policies if the small-country assumption is given up. In that case, national environmental policy has an impact on the terms of trade, the gains from trade as well as environmental quality in the other country.

If the country undertaking environmental policy is large and can influence the relative product price in the world market, environmental policy has a terms-of-trade effect. Environmental policy makes the pollution-intensively produced good more expensive. If this good happens to be the export good, the country's terms of trade will improve. The other country will import less of the pollution-intensively produced good. This is in contrast to the small-country case, in which the loss of competitiveness will occur when the given world market price is reached. In the large-country case, the large country can use environmental policy like an optimal tariff. Thus, the country can behave strategically, at least in theory. The other country may retaliate. However, it is difficult to evaluate the empirical relevance of the optimal tariff analogy for the area of environmental policy.

Factor prices of immobile factors of endowment differ before the factor price equalization theorem has fully worked (which it never may do in practice). Moreover, only specific configurations of factor endowments with immobile factors allow factor price equalization in theory, as we know from the cones of endowment [Helpman, Krugman, 1985]. It is quite normal for prices for an immobile factor such as land and immobile labor to differ among countries. And it is normal for environmental endowment or environmental scarcity to influence competitiveness and for pollution-intensively producing sectors to be negatively affected by environmental policy. It would not be correct to require the same prices for immobile factors everywhere.

Like other traditionally recognized factors, such as resources, technical know-how, and so on, environmental abundance or scarcity is a factor in trade that should be included in determining comparative advantage. It would not make sense that pressure groups with strong interests (export and import industries, unions) induce policymakers to compensate for the environmental advantages of other countries through trade policy measures. In such a setting, a country poorly endowed with

labor will protect itself against labor-intensive imports; a country poorly endowed with capital will protect itself against capital-intensive imports; a country poorly endowed with technical knowledge will protect itself against technology-intensive imports; and a country poorly endowed with environmental services will protect itself against pollution-intensive goods. In such a setting, the idea of the advantages of international specialization is dead. Consequently, the argument to level the playing field is a fallacy.

National environmental policy also affects environmental quality in the other country. Consider a country that undertakes environmental policy and increases its emission taxes. Consequently, the price of the taxed good rises, and the comparative advantage in trade is reduced. Exports fall, and the production of the pollution-intensive good decreases. Resources are reallocated from the pollution-intensive sector to others, and the production in the environmentally sound sector might increase. As a result, environmental quality improves. On the other hand, the measure can have negative effects on the countries with which this country trades. When the comparative advantage of one country falls, the comparative advantage of the other countries trading in the good in question rises. Production of the pollution-intensive commodity therefore increases in other countries. This causes a reallocation of the factors of production in favor of the pollution-intensive good; emissions increase, and the environmental quality of these countries worsens. In short, the environmental policy of a country affects the quality of the environment in other countries through increased specialization in trade.

Does this pollute-thy-neighbor thesis mean that a country can force a degraded environment on another nation? The answer is no, for the following reasons. It is true that the industrialized nations can export pollution via trade. But environmental policy in the industrialized nations involves costs, both in terms of resources and foregone goal attainment (full employment, comparative advantage, etc.). This limits a country's willingness to implement these measures. More specifically, the costs of pollution abatement rise progressively, putting severe limits on environmental policy. A second argument is that the environmentally rich country, i.e., the developing country, can protect itself by also introducing environmental policy measures. By imposing such measures as emission charges, it will reduce its comparative advantage in pollution-intensive goods for international trade and thereby avoid specializing in the production of these products. In this way, the environmentally rich country can maintain or improve the quality of its environment.

Another aspect is that industry may relocate to the country with the low environmental standard. In that case, the repercussions of the environmental policy of one country on the environmental quality of other countries occur through the link of factor mobility. Again, the country negatively affected can protect itself by introducing a stricter environmental policy.

Ecologists are not afraid that a country undertaking environmental policy at home will negatively affect environmental quality abroad by the mechanisms of relocation and trade; their concern is that international competition will induce countries to become more lenient in their environmental policy. Institutional competition — ecologists fear — will lead to zero regulation. This argument is wrong, because not taking into account the loss of environmental quality in determining the target of environmental policy would represent a misallocation of resources. The definition of the gains from trade must include environmental quality as one argument. Thus, when a loss in environmental quality is adequately reflected in the decision-making process, ecological dumping will not occur. Apparently, the fear of ecological dumping is as unfounded as the political demand to level the playing field.

Nevertheless, the case of purely national environmental media may require some commitments to international rules. An important aspect of the problem is the casuistry of the environmental problem where we must distinguish between pollutants arising from production and pollutants contained in goods (or released when using goods). With pollution arising in production, the arguments presented above apply. With respect to pollutants contained in export goods or released in their use, an ethical problem arises: should nations apply the environmental standard they use at home to their exports? Here the answer in the Kantian tradition, or according to other ethical positions is quite clear: Do unto others as you would have them do unto you. In a way, this is the ecological analogue of the most favored nation clause in multilateral trade. Here, the rules at home — the country of origin principle — represent the terms of reference.

Such an approach also has important implications for the exports of wastes. Wastes should only be exported if the environmental standards of the exporting country were applied. This does not prevent the export of wastes if other countries had better deposit conditions, for instance, in geological terms. In any case, a country negatively affected by imports containing pollution or releasing pollutants when used may protect itself by taxing pollutants, taxing the imports or applying product norms.

A second aspect of a commitment to rules is that environmental policy may be used as a protectionist pretext. Again, this is not relevant when pollutants arise continuously in production; trade distortions arise if tradeables have a high pollution content and if product norms or licensing are used as environmental policy instruments. An example is the introduction of catalytic converters for cars in Germany and the potential trade barriers deriving therefrom in the European Common Market. Other examples are allowable amounts of pesticides in consumption goods or emission norms for machinery. The barriers to trade caused by product standards become more impenetrable if one discriminates between product standards for domestic and foreign goods. GATT regulations do not permit discrimination, and

product standards should be applied to imported goods as well as to import substitutes. In reality, however, product standards can be formulated in such a way as to permit domestic industries to meet the standards more easily than their foreign competitors.

4. Transfrontier Pollution

The environmental policy of a country may have repercussions on the environmental quality of another country via the international division of labor. But countries are also interlinked more directly via environmental media, for instance, via river systems or atmospheric media. In this case, the question arises as to how the economic decisions in one country affect environmental quality in the other country.

Transfrontier pollution has a common feature with global pollution: in both cases countries are directly linked to each other via environmental media. For analytical purposes it is worthwhile, however, to distinguish between transfrontier pollution and global pollution [Siebert, 1985, p. 132]. In contrast to a national environmental system

$$[1] \quad U^j = G(E^j),$$

where U^j denotes environmental quality and E^j emissions in country j (G is a damage function), an environmental system with transfrontier pollution is characterized by a diffusion function, T , with environmental quality in the region j being determined by the emissions not only of region j , but — via the diffusion function T — also by the emissions of region i :

$$[2] \quad U^j = G(E^j, T(E^i)).$$

T may be unidirectional, or pollutants may flow in both directions. Transfrontier pollution represents an externality between countries and implies a distortion. The upstream, or upwind, country sends pollutants via the environmental media to the downstream, or downwind, country. The polluting country reduces its level of pollution by sending pollutants abroad, thus lowering the opportunity costs of environmental policy and increasing its comparative advantage for pollution-intensive activities. In the pollution-receiving country, the level of pollution is increased and comparative advantage of pollution-intensive goods is reduced. Thus, the distortion refers to environmental allocation as well as to sectoral structure.

Without a solution to transfrontier environmental problems, national environmental policy operates under the conditions of an international distortion. This has

several implications. The opportunity costs of protecting the environment in the downstream, or downwind, country are too high. This limits the scope of environmental policy and reduces the optimal environmental quality strived for in the downstream (downwind) country. Moreover, the obstacles to environmental policy may be increased by pointing to transfrontier pollution; environmental policy has to find its reason in being the forerunner for other countries, as in the German case, in the hope that there will be an international demonstration effect and that other countries will follow.

In the bargaining process between autonomous countries we meet all the problems of environmental policy "in nuce." The environmental media of the downstream (downwind) country are used as common property resources with free access. The downstream (downwind) country has no property title with which to enforce abatement in the polluting country; it is not possible to forbid the polluting country to use the environment in the downstream (downwind) country as a receptacle for wastes. The polluting country can behave as a free rider. Without clearly defined property rights, both countries have to determine the tolerable level of pollution in a bargaining process.

In a scenario with a unidirectional spillover and in which the upstream (upwind) country uses the environment of the downstream (downwind) country as a free good, bargaining implies that both countries can only benefit if the polluter compensates the polluter for reducing pollution in the upstream (upwind) country (victim-pays principle). Thus, a side payment is necessary. Unilateral action on the part of the downstream (downwind) country cannot improve efficiency. When bargaining costs are neglected, a solution to the game is found in which the marginal damage prevented (in the downstream/downwind country) equals marginal costs of abatement (in the upstream/upwind country). This bargaining result is a Coase solution [1960] and a Nash equilibrium in a cooperative game. A noncooperative solution does not exist.

The solution to the transfrontier pollution problem requires some sort of commitment by national governments to an international agreement. This commitment may include ceding national sovereignty in specific areas of environmental policy to an international agency, developing cost-sharing rules, or agreeing on diffusion norms or uniform reductions in national emissions. In the sense of a causal therapy, a solution should explicitly address the quantities transmitted, i.e., $T(E^i)$ in equation [2].

In a cost-sharing arrangement, the costs of attaining and maintaining an acceptable level of quality in the transfrontier environmental medium would be distributed among the countries according to a set rate. Many problems arise with this proposal. Since costs are determined by the desired level of environmental quality, how much environmental quality should be strived for? By what criteria can abatement costs

be attributed to different countries? As a rule, countries are not prepared to cede authority to an international organization.

In the bargaining process, the polluter will exaggerate the costs of pollution abatement in order to reduce the demands of the other country. Similarly, it is to be expected that the victim will exaggerate the extent of the incurred damages in order to maximize the assessment of the corrective measures needed. In order to avoid this deliberate falsification of information about the damages and costs of the respective abatement, it has been suggested by the reciprocal compensation principle [OECD, 1973] that an international fund be established to which the polluting country would pay according to its assessment of the damages and to which the victimized country would pay according to its assessment of the costs of abatement. The funds collected from the two parties would then be redistributed to them for the implementation of the environmental protection measures. It is essential that the countries should not know the rate at which the tax receipts will be redistributed because this information would distort their estimates of the costs and damages.

An interesting approach to transfrontier diffusion is to define the ambient level of pollution of an environmental medium at the border, for instance, of a tributary to a river or of air quality. A transfrontier diffusion norm allows a decentralized approach to environmental policy in the countries involved. The upstream (upwind) country, having agreed on a diffusion norm, probably not without a side payment, will internalize the costs of transfrontier pollution to the individual polluters. In such an approach, it can be left to the individual countries to decide which policy instruments to use to make sure that the diffusion norm is not violated, and emission tax sales may very well differ between countries. Transfrontier diffusion norms could be instrumental in implementing the polluter-pays principle for the individual polluter, albeit not for the polluting country possibly receiving a side payment.

Another proposal is to reduce emissions uniformly in both countries by x percent, thus alleviating the transfrontier pollution problem. In this approach, transfrontier pollution is only indirectly addressed. Solving transfrontier polluting by uniform reductions in both countries apparently does not represent a causal therapy, but instead would require the unnecessarily high abatement of pollutants or imply a too low environmental quality. Consequently, such an approach is inefficient.

Whereas in the case of transfrontier pollution we have negative externalities between countries, there are also positive spillovers. A case in point is the equatorial rain forest. The equatorial rain forest in Brazil and in other countries has a positive value for absorbing CO_2 , producing oxygen and ensuring biodiversity. Maintaining the rain forest would represent a positive externality to other countries.

Similarly, as side payments are required in a solution that would reduce transfrontier pollution, one can argue that side payments should be made to the countries with a rain forest in order to induce them not to destroy it. As regards the bargaining for side payments, however, there is one difference between the transfrontier

pollution case and the rain forest problem which must be stressed. It might very well be that it is in the long-run interest of the rain forest country itself to maintain the forest for its own advantages, including tourism in the future. Therefore, noncooperative solutions may exist. Of course, monitoring such agreements raises problems, which can be analyzed in a principal-agent context.

5. Global Environmental Media

In the case of global environmental media, two or more countries jointly use the environmental system as a public good, and diffusion processes are not too important. Examples of global systems are the ozone layer and the global warming of the atmosphere.

The international public good (U^k) is used in equal amounts by all countries; it extends over an area comprising two spatial subsets (countries i and j) in which pollutants are generated. We have

$$[3] \quad U^k = G(E^j, E^i).$$

Apparently, the international public good can be interpreted as a special case of transfrontier pollution in which the diffusion function T of equation [2] is not explicitly considered. For analytical reasons as well as for policy solutions, it is worthwhile to explicitly distinguish between the cases of transfrontier pollution and global environmental media.

In principle, each country can assume the free-rider position, hoping that the other countries will care and pay for the public good. In addition to this policy, solutions are complicated by the following:

- Countries, or their people, may have different preferences with respect to which global environmental media to pollute and they may have different risk attitudes.
- Even assuming identical preferences and identical risk attitudes, the income per capita varies considerably among the countries of the world; this implies different constraints for the individual countries, which leads to a different evaluation of the global environment.
- Although global environmental systems can be interpreted as a public good for the world as a whole, countries may be affected differently if the public good is not of equal importance to all countries. This means that in contrast to Samuelson's definition [1954], according to which the public good "is used in equal amounts by all," the user intensity varies for countries. For instance, global warming and the resulting melting of the ice caps would negatively

affect low-lying countries, such as Bangladesh and the Netherlands. This means that the willingness to pay will differ among countries.

In contrast to the transfrontier pollution problem, we have to take into account that each polluter hurts himself if the global environmental medium deteriorates. Consequently, in contrast to transfrontier pollution, unilateral action may improve the welfare of one player. This affects the reaction function of each country in the bargaining approach. But each country does less than is optimal, since its own contribution is small.

Allocating the tolerable quantity of worldwide emissions by means of a uniform reduction rate of x percent in each country is not efficient. Some countries may be able to reduce emissions at much lower costs. Moreover, uniform reduction rates do not protect against renegeing and thus endanger the stability of the institutional arrangement. Countries with a low initial emission level (for instance, China, with 12.2 percent of worldwide CO₂ emissions and coal reserves for several hundred years) will have an incentive not to stick to the contract.

A solution to global environmental problems may consist in agreeing on a lid for the total quantity of emissions and then allocating the tolerable level of emissions to the individual countries [Grubb, 1989]. In contrast to the transfrontier pollution problem, the total quantity of emissions is the decisive variable in a causal therapy of global environmental problems.

Transferable discharge permits prevent the inefficiency of uniform reduction schemes. They ensure that the reduction of emissions occurs in the most efficient country. This means that the costs of environmental protection are minimized for a target level of environmental protection. Moreover, transferable discharge permits are especially suited to the solution of the global environmental problem because diffusion problems ("hot spots") are not relevant.

One possibility of introducing such a system of transferable discharge permits is to allocate them on a per capita basis of the world population. This would imply that a country like China, with a low level of pollution, but a large population, would receive more permits than it actually needed. Countries with high emissions and a small population would not receive enough permits to cover their actual level of emissions. The trading of permits becomes necessary. The stability of these institutional arrangements might be enhanced if permits were not sold, but were leased instead.

6. An International Order for the Environment

When international public goods are involved and when countries can behave as free riders, and thus strategically, an institutional arrangement is called for. Such an

order defines the rules for the behavior of individual countries. Each country has to commit itself to these rules. In analytical structure, the problem is similar to the rules for multilateral trade which are intended to prevent strategic behavior of individual countries in order to improve their terms of trade. The world as a whole can benefit from a cooperative solution, both in the trade policy case and in the environmental case. Some impetus is necessary to break the deadlock of a prisoner's dilemma, for instance, a hegemony or a coalition of major players in the trade case or, possibly, a country that sets the pace by moving first in environmental policy. Over time, the national interest of a country may vary; it may renege on the institutional arrangement that becomes unstable. Thus, the stability of the institutional arrangement poses a problem that is similar for trade policy and environmental policy.

An international order in environmental policy relates to global environmental goods, to an institutional arrangement by which the optimal environmental quality is agreed upon and to an institutional arrangement for implementing the target. In a second area, rules for solving transfrontier pollution problems have to be established. Conceivably, Europe may go ahead in solving the transfrontier pollution issue with the European Court of Justice developing some guidelines. Finally, some rules for trade in products with a high pollution content and for trade in wastes are needed, but, at the same time, these rules should not create trade barriers.

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