Transboundary Environmental Degradation and the Growing Demand for Institutional Innovation

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Abstract: Transboundary pollution constitutes an important component of environmental degradation in many countries. The demand for institutional changes that reduce transboundary pollution grows with increasing levels of economic development and accumulation of environmental degradation. Single countries, however, can set up such institutions only in cooperation with other countries. This paper analyzes the strategic game theoretic situation of countries concerned with transboundary pollution under alternative benefit-cost situations. The results suggest that a system of reciprocal obligations of countries can result in supranational agreements if the assurance problem of each signatory can be solved and the distribution of costs and benefits of such agreements are perceived as being fair.

Introduction

The problem of transboundary environmental degradation is global; many nations in Europe, the Americas, and elsewhere have been cited as emitters and/or receivers of polluted air or water (Hart, 1987). Economic analysis of transboundary pollution is in its infancy. Only a few avenues of study have been explored.

One of the aspects that has received little attention is game strategic dimensions of the problem and their implications for institutional innovation. The objective of this paper is to explore the implications of incentive structures associated with pollution of air resources and to discuss potential solutions to the problem.

Particular characteristics of international air resources and the conceptual underpinnings of a game theoretical approach are also be discussed. Under the incentive structures faced by many countries, demand for institutional innovation is growing. The paper concludes with the economic implications of a possible alternative institutional arrangement for dealing with the problem of transboundary pollution.

Incentive Structures Associated with Transboundary Pollution

Much semantic confusion exists among resource economists about the difference between common property, public goods, and externalities. Sketching the physical characteristics of resources and their economic consequences is useful to create meaningful distinctions. Market goods are exclusive, independent with respect to utility and production functions and mobile only with respect to money. In the case of transboundary pollution, none of these characteristics is met completely. Global resources are often nonexclusive, rife with externalities, and fugitive.

An efficient, competitive market in air resources will probably not develop via private contracting by households and firms due to the physical and economic characteristics of air resources. Optimal resource use will probably involve supranational institutional arrangements. Successful institutions must also take into account the specific physical attributes of global air resources and the incentive issues that result.

The incentive structure applicable to a particular transboundary pollution problem depends largely on the size and distribution of benefits and costs under alternative decisions by each country. They define the payoff matrix; i.e., the nature of the game. In the matrices presented here, net benefits are comprised of the profits attributable to production activities minus the external costs due to environmental degradation. The distribution of benefits and costs determines each individual country's incentives and thus the potential for negotiation. As with other externality problems, a separation of private and social costs is

crucial. The following paragraphs outline two games that are instructive as general examples of the different degrees of skewness in payoffs and their impact on incentive structures.

Case One

Let us assume that two countries, A and B, are identical with respect to production technology and the imposition of pollution on each other. The existence of transboundary pollution means that social costs exceed private costs. Hence, both countries overproduce from a social point of view. The payoff matrix (Table 1) assumes that at the privately optimal level of production (Q_p), profits (Π) are 90 and external costs (XC) are 60. However, the socially optimal level of production (Q_s) would yield profits of 60 and external costs of 10. For simplicity, let us assume further that the external costs generated by A accrue entirely to B and vice versa.

Table 1—Payoff Matrix

	Country B			
	Q_p	Q_s	Q_p	Q_s
Country A Q_p	(30, 30)	(80, 0)	(70, -30)	(73.5, -29.5)
Country A Q_s	(0, 80)	(50, 50)	(52.5, 7.5)	(56, 8)
	Case One		Case Two	

Case one represents a typical prisoners' dilemma game. If both countries pollute, each realizes benefits of 90 from domestic production but imposes a pollution cost of 60 on the other country. Hence, the net benefits in each country are 30. If only country A pollutes, the production benefits to A are 90 and external costs (imposed by B) are 10, yielding a net of 80. In country B, the benefits are 60 and the damage of transboundary pollution caused by A is 60. Therefore, country B's payoff is zero. The outcome of Q_p in country B and Q_s in country A is symmetric to the above case. Finally, if neither country pollutes, the benefits remain at 60 each but each country has external costs of 10. Hence, the net benefits for each country are 50.

Case Two

The scenario in case two assumes that 75 percent of the externality-producing activity is concentrated in country A. Again, for country A at Q_p, $\Pi = 90$ and $XC = 60$, whereas at Q_s, $\Pi = 60$ and $XC = 10$. However, let us assume that, in country B, Q_p yields profits of 30 and external costs equal to 20, while Q_s results in $\Pi = 20$ and $XC = 6$. This case also assumes that 75 percent of the total external costs generated are suffered by country B and 25 percent by country A. For example, when both countries pollute, total external costs are 80 (60 are generated by country A and 20 by country B). However the damage *accrues* to countries A and B in the amounts 20 and 60, respectively, due to the fugitive nature of the global air resource.

As may be expected, with a skewed incidence of benefits and costs, incentives are also lopsided. In this case, country A continues to pollute and country B has the incentive to abate. Outcome (73.5, -29.5) is the stable equilibrium. The global optimum (56, 8) is achievable only through compensation. Country B could compensate country A in the amount 17.5 and experience an overall gain of 20. However, equity concerns may prevent this solution regardless of its economic efficiency.

Demand for Institutional Change

This section discusses how alternative payoffs translate into a private demand for institutional change; i.e., the practical prospects for attaining an institutional solution in an international context. Categorically, the central determinants of the demand for institutional innovation are efficiency and equity.

Efficiency Considerations

Changing relative factor scarcities and product demands can render existing institutions inefficient. In terms of efficiency, the demand for institutional change results from constraints that inhibit a more profitable use of production factors (Ruttan and Hayami, 1984). In some cases, efficiency gains can be captured via voluntary transfers of existing property rights. In others, formal government changes in the conditions attached to rights may be necessary (Livingston, 1987).

In the case of transboundary pollution, efficiency gains stem from the net gains that can be realized by reducing environmental degradation. Conceptually, net benefits are equal to the reduction in external costs minus the reduction in profits/utility attributable to a change in the level of production and emission. Thus the efficiency demand for institutional change increases whenever the demand for environmental quality increases or supply decreases. As the external costs of pollution increase or abatement technology becomes less costly, the potential net benefits of institutional innovation increase. Many argue that global air quality is better today than it was a few decades ago. Nevertheless, perhaps due to income effects, public awareness of and attention to environmental issues has grown tremendously. The increase in demand for clean air seems to have outstripped the change in supply. The result is an increasing demand for institutional arrangements that effectively reduce pollution.

Equity Issues

When the distribution of costs and/or benefits of an existing institution are perceived as unfair, the impetus for institutional change emerges as well (Runge and von Witzke, 1987). One can reasonably expect that, as global integration continues, attention to international equity will increase. The equity concerns relating to transboundary environmental degradation derive from the skewedness of production benefits and external costs.

Baumol (1982) and others have developed utility-based fairness theory by introducing the notion of symmetry between parties. A fair allocation is defined as one in which neither party envies the other. Obviously egalitarian (strictly equal) allocations are fair. The possibility of unequal but fair allocations arises out of heterogeneous tastes. The possibility of fair distributions that do not actually derive from equal initial endowments rests on the concept of an egalitarian equivalent allocation, which is an allocation that could have, *in principle*, arisen from egalitarian resource endowment.

This is illustrated in Figure 1. This graph is plotted in commodity space where X = industrial production and Y = environmental quality. Assume that B is a lower income country that places a lower value on environmental quality. D_E (equidistant from the two origins) represents an equal and therefore fair allocation of goods, according to Baumol. If tastes were identical, one would expect U_A and U_B to be tangent at D_E. However, given the divergent tastes, other allocations (specifically on the contract curve between D_1 and D_2) are both fair and Pareto optimal. The range of fair, contracted allocations expands as taste diverges.

Unequal initial endowment D_3, although not equal, may yield a negotiated solution of D_2 (if country B captures all gains from trade) and therefore can be deemed fair via the egalitarian equivalence principle; i.e., although the outcome D_2 arose from an unequal initial endowment (D_3), it could have, in principle, arisen out of D_E and is thus fair. At some

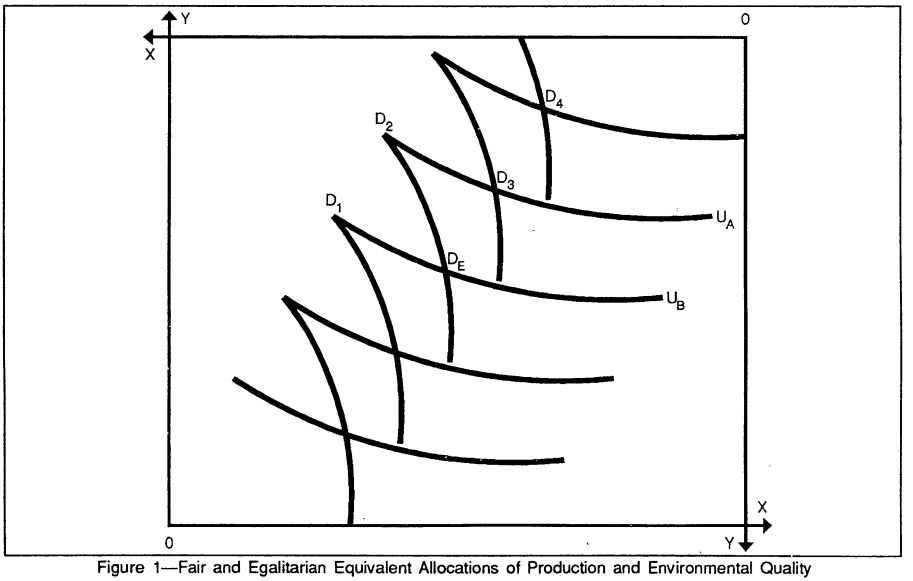

Figure 1—Fair and Egalitarian Equivalent Allocations of Production and Environmental Quality

point, however, the initial allocation is so skewed (like D_4) as to render a fair solution impossible.

The implication of Baumol's theory for the demand for institutional change is that where countries exhibit a very unequal distribution of initial endowments of production and environmental quality (i.e., where certain countries are particularly disadvantaged by virtue of initial conditions), private contracting within the existing institutional structure is unlikely to produce a fair outcome. In these cases, equity issues can be dealt with only through substantial institutional changes that, in effect, alter endowments.

Implications

To a large extent, the incidence of costs and benefits determines the prospects for an institutional solution. In general, the more homogeneous the countries involved in pollution, the greater the private impetus for an institutional solution. As income level and external costs incurred by a nation rise, so does the demand for institutional innovation. If the growing demand for institutional arrangements reduces the reelection chances of a government, policy makers have a growing incentive to seek international agreements over transboundary pollution.

Institutional arrangements are more likely to arise voluntarily when the countries involved are relatively homogeneous in regard to high income, environmental damage, and technology. International agreements on transboundary pollution are therefore more likely to emerge between countries of similar levels of economic development, such as in West Europe or North America. Low income countries, where the domestic political pressure for environmental quality is low, may not be willing to sign an agreement on transboundary pollution that bears the risk that the number of potential signataries is too low to create a critical mass (e.g., Hurwicz, 1951).

As the characteristics of nations diverge, either due to climatic circumstances or income differences, less efficiency and more equity motivation exists for voluntary institutional innovation. As specialization in externality-producing activities increases, one would expect the incidence of benefits and costs to become increasingly skewed. As Sugden (1984) has argued, with increasing heterogeneity of countries, solving the assurance problem becomes more and more difficult unless some outside enforcement mechanism exists.

Design Perspective on Institutional Innovation

The previous section discussed the factors that influence the demand for institutional innovation. The supply of innovation is an endogenous response to the demand for change. Economists can contribute to the debate by providing social science knowledge (Ruttan, 1984). In this section, the efficiency and equity issues that must be considered are discussed, and a potential solution is explored.

Efficiency: Institutional and Transaction Costs

The Coase theorem suggests that in a zero-transaction-costs world, negotiated outcomes will be invariant with respect to the structure of property rights. Let us consider the situation shown in Figure 2 where country A reaps all the benefits from production of acid rain and country B bears the entire cost. With no liability, Q_{NL} will initially be produced with B bribing A back to Q^* (as long as B's willingness to pay to avoid damage exceeds A's willingness to accept to forego production). Similarly, with full liability, Q_L is the initial position with A bribing B to Q^*.

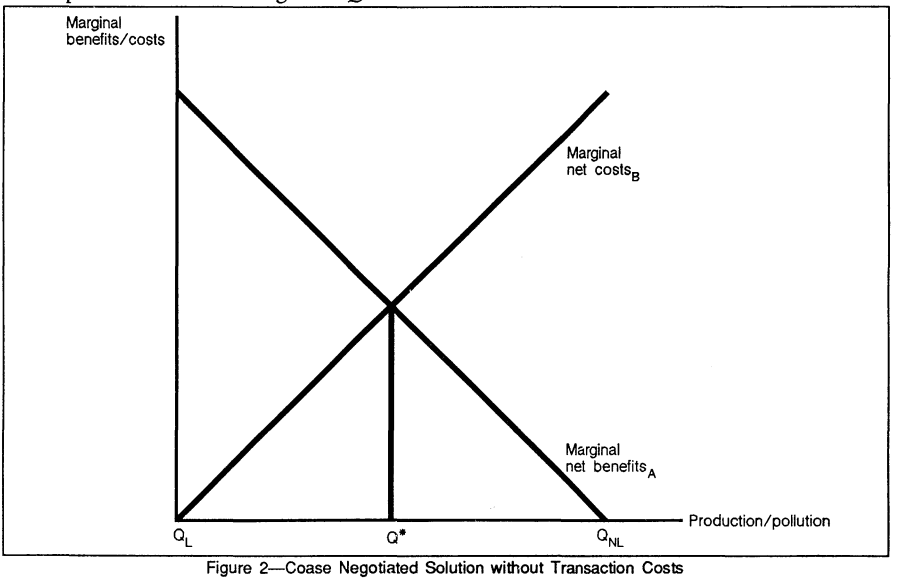

Figure 2—Coase Negotiated Solution without Transaction Costs

With the introduction of transaction costs or nonseparability, the Coase theorem breaks down; i.e., the negotiated outcome will be variant with respect to property rights (Bromley, 1986). In addition to other considerations, transaction costs rise with the number of parties involved (Olson, 1965). Assume that, with no liability, the costs of acid rain are dispersed widely among consumers in country B. The transaction costs associated with organization and negotiation would likely be large and reduce the amount available to bribe country A, as shown in Figure 3 as the net offer curve. Under these conditions, the negotiated solution would be Q_1^*. Alternatively, assume that, with liability, the burden of negotiation is concentrated on a small number of producers in country A. Transaction costs are expected to be relatively smaller, yielding a negotiated solution like Q_2^*. Thus the outcome is indeed variant with respect to the institutional arrangement in operations (Bromley, 1987).

Note that, at both Q_1^* and Q_2^*, the remaining externality is Pareto irrelevant in that no additional gains from trade can to be realized (Buchanan and Stubblebine, 1962). Certainly, the outcomes are not comparable in Pareto terms, where property rights are taken as given

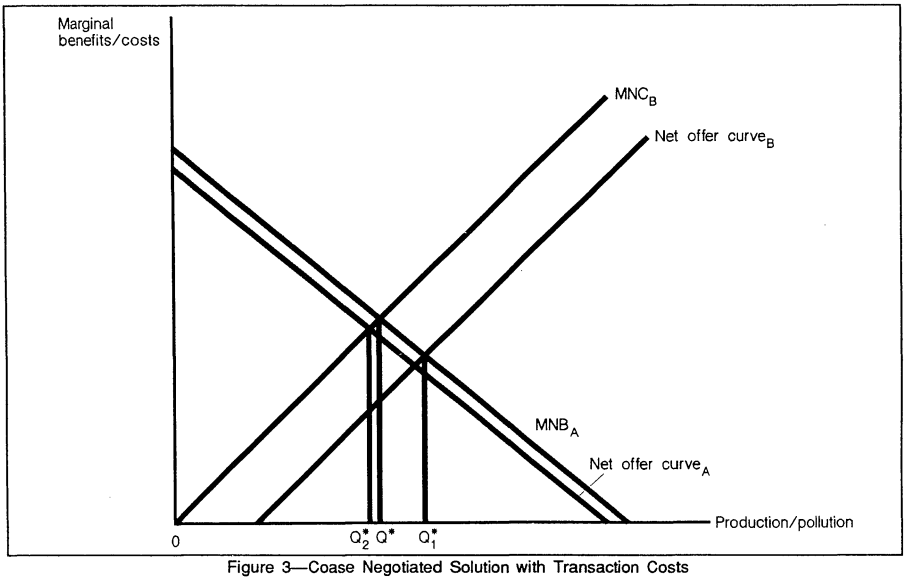

Figure 3—Coase Negotiated Solution with Transaction Costs

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Distributional Issues

Alternative institutional arrangements also vary in their equity implications. One alternative notion of equity relies on John Rawls' "veil of ignorance" (Rawls, 1971): assuming that individuals are ignorant as to where and/or when they were born, how would one structure the institutions governing pollution of international resources? By tackling the problem in this way, individuals are divested of personal interests and are free to focus on the viability of the whole. The following section suggests one institutional arrangement that may be equitable in the Rawls sense.

Potential Institutional Solution

Based on the efficiency and equity factors discussed above, cooperation among nations according to an institutional arrangement embodying reciprocity may be appropriate. A reciprocal institutional arrangement is a conditional cooperative commitment designed to overcome the "free-rider" problem. In this case, it implies that contributing to reducing a public ill is fair only if others contribute as well (Sugden, 1984). The contribution could be a reduction in domestic emissions proportional to the country's global share of production/pollution. The overall goal would be to meet an agreed "safe" global standard. The

to choose a noncooperative strategy because each agent is uncertain about the behaviour of the other. Assurance is necessary to achieve coordinated, optimal solutions. With a repeated prisoners' dilemma game, an incentive exists for all players to change the rules of the game and to agree on a system of conditional commitments (Snidal, 1985).

The advantages of the institutional arrangement set forth above include the following. First and foremost, it recognizes the interdependence between nations facing the global pollution by structuring a set of conditional commitments. Second, a physical standard, adjusted periodically, accommodates long-run concerns about the sustainability of ecological systems. Third, given the difficulty in obtaining accurate information about the source, conveyance, physical impacts, and economic value of international pollution, a proportional allocation of responsibility may be the least-cost approach. And, finally, the principle of reciprocity may be perceived as fair. Overall, such an institutional arrangement has the potential to be both equitable and more efficient.

Summary and Conclusions

This paper examines typical incentive structures associated with transboundary pollution and the resulting demand for institutional innovations. The problem is often one of coordination. In this regard, institutional innovations must reflect explicit recognition of international interdependencies. Thus, the design of efficient and equitable institutional arrangements becomes crucial (Hurwicz, 1987). In designing institutions, social science research and analytical skill are usually socially far less expensive than processes of learning by trial and error (Ruttan, 1984).

In pursuing this approach to understanding institutional design, this paper discusses reciprocity and its potential as a solution under different circumstances. Reciprocal agreements hold significant promise among countries that are homogeneous in terms of income, production, and environmental damage. As heterogeneity increases, institutional innovations may require wider scope for negotiation. Transboundary resource problems are likely to become increasingly important in the global economy. Game theoretical analysis of these problems provides a rich research topic for the future.

Note

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DISCUSSION OPENING—*Terence J. Centner* (Department of Agricultural Economics, University of Georgia)

Livingston and von Witzke advocate reciprocal agreements as a solution to the problem of transboundary air pollution. This conclusion implicates two underlying principles that must be reconciled in any transboundary agreement: territorial sovereignty and external responsibility. Under the first principle, a sovereign state is able to use its environment without interference from other states. However, most countries acknowledge that they do not possess an unqualified right to use their environment to cause harm to another state under the 1972 Declaration of the UN Conference on the Human Environment. Furthermore, the USA and many western European countries have signed the 1979 Convention on Long-Range Transboundary Air Pollution. External responsibilities are embedded in these agreements, but in the absence of effective enforcement mechanisms, countries have few remedies for actual transboundary pollution problems.

Continued acid rain pollution in North America and Europe shows that overcoming territorial sovereignty is difficult. Despite binding international conventions, Canada and the Scandinavian countries have experienced little success in being able to control external pollution. Control of air pollution needs to be founded on agreed rights and obligations that recognize territoriality and external responsibility. Although a clear way to harmonize these two principles may not be obvious, a starting point is to recognize both national and international institutions.

On the national level, centralized authority with enforcement provisions and private rights of action provide an administrative model with considerable merit. Two features of such a model deserve further comment. First, countries may assign property rights to resources, such as the right-to-farm legislation in the USA or legislation establishing standards. If countries are to internalize pollution costs, domestic legislation must refrain from adopting legal provisions that privatize limited aspects of pollution. Second, the right of private citizens to sue polluters for violation of statutes, as is available under numerous federal laws in the USA but is less common in Europe, may diminish the need for alternative transboundary pollution controls.

On the international level, relaxation of jurisdictional prerequisites, diplomacy, and economic and legal sanctions compelling polluters to internalize costs of transboundary pollution may provide for greater pollution control. The impact of the principle of territorial sovereignty on these factors means that pollution controls should be easier in

cases where the nations are developed and relatively homogeneous. Such nations would have the financial ability to pay for pollution costs and would be expected to have similar notions of fairness and equity and similar property rights in air resources.

The limited success of past pollution agreements suggests that more than one institution might be pursued simultaneously to maximize pollution control. First, reciprocal agreements may assist in fostering mechanisms to encourage the reduction of pollution activities. Second, various public remedies, such as arbitration, an international environmental protection authority, or commissions to deal with pollution problems may help compel polluting states to take responsibility for external damages caused by internal polluters. Third, private remedies that provide access to foreigners in judicial proceedings and domestic tort doctrines that force polluters to internalize the extraterritorial costs of air pollution are possible additional means of enforcing external responsibility for transboundary pollution.

GENERAL DISCUSSION—*Bill R. Miller, Rapporteur* (Department of Agricultural Economics, University of Georgia)

One participant asked if enough scientific knowledge existed to allow economists to apply the kinds of theoretical devices described by Livingston. Livingston replied that data are not available to estimate loss functions as a basis for taxation. Therefore, developing reciprocal standards seems most appropriate. Reciprocity is the key to the interdependent nature of the problem.

Livingston replied to the discussion opener that the principles of territory and responsible behaviour must be enforceable to ensure fairness. Mutual monitoring and enforcement are important parts of reciprocal agreements.

Participants in the discussion included G.H. Peters.