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On the Economics of Transnational Environmental Externalities

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As man socialized and the human population clustered into geographically, culturally, and politically defined nation states, reaping the material benefits of specialization and efficiency, human interaction increased both within and among these states. However, because of the sheer magnitude of the environment and its assimilative capacity in relation to human populations and industrial production, in the historical past there was little, if any, interaction between states that involved a purely nonhuman or environmental element. A nation's waterborne wastes were easily assimilated by river, estuary, and coastal waters before such wastes could interfere with other nations' activities. No state produced and consumed chemical compounds that were not easily neutralized by a seemingly infinite natural environment. In the past few decades, such a perception of the natural environment has increasingly changed to the realization that the planet's environmental assimilative capacity, even augmented by substantial investment, cannot sustain an endlessly growing population or material consumption per capita. Nations are coming to realize that not only are they economically and politically interdependent but also environmentally dependent with no well-defined international markets or political mechanisms for efficient regulation.

Economic science has analyzed problems of nonmarket interdependence for a very long time, applying the concept of externalities since Pigou. In essence, externalities are social interdependencies not taken into account

NOTE: I have benefited from the comments of A. V. Kneese, W. J. Baumol, and L. Westphal on an earlier draft.

by formal markets or by agreements between the affected individuals or nations. Thus, externalities embrace a spectrum of problems from the neighbor's noisy and disturbing stereo to the commitment of all nations today toward rapid economic development which may preclude choices between material consumption and aesthetic enjoyment of future nations. In either case, the affected party's, i.e. the disturbed neighbor's or future generations', preferences are not adequately being considered when a decision is made.

The classical economic solution to such externality problems was to "internalize" them by either developing a well-defined market for the "spillovers" or controlling them through collective provision of regulations. Neither of these possibilities appears easily amenable to the problem of transfrontier externalities in general, and environmental externalities in particular. First, environmental externalities have arisen because most dimensions of the natural environment on a regional or global scale are resources without rigidly defined or enforceable ownership rights. The oceans, stratosphere, and electromagnetic spectrum are typical examples. These resources are viewed as being commonly owned or not owned at all. A nation which agreed to a particular pattern of ownership of these resources could potentially lose some of its implicitly controlled resources and thereby national wealth.[1] As long as international entitlements are obscure, any nation can lay implicit claim to the common property resource exceeding any equitable share it may presume to receive if entitlement were made explicit. This is not to say that once some other nation impinges on a nation's perceived implicit entitlement, that it will not find a negotiated settlement and thereby explicit entitlement to be superior to an implicit one. However, the impinging nation, in negotiating, must revise downward its own perceived ownership of the common property resource. In consequence, proceeding from a situation of implicit entitlements of common property resources to explicit regulation and thereby ownership means that some (or all) nations must revise their expectations of national wealth, stemming from the resources that each implicitly believes it controls.

A second aspect of major importance arises from the concept of na-

1. Christy draws a very useful distinction between the production of wealth and distribution or ownership of wealth with regard to ocean fisheries. The first concept involves issues of access and free use while the second involves specification of shares. The discussion in this paper will be centered on distributional as opposed to use issues. See F. T. Christy, Jr., "Fisheries: Common Property, Open Access, and the Common Heritage," *Pacem in Maribus*, edited by Elizabeth M. Borghese (New York: Dodd, Mead & Company, 1972), Ch. 6.

tional sovereignty. Not unlike consumer sovereignty as conceptualized by economists, national sovereignty implies the idea that governments, acting in their own interest will, omitting deviations in power or information implying political or economic monopoly, achieve the greatest welfare for all by independently pursuing autonomous goals and interacting competitively through international markets. The belief in national sovereignty as an ideal is so imbedded that it is impractical to presume it will be easily given up.

Coupling the concepts of national sovereignty in decisions and the idea that implicit, as opposed to explicit, entitlement of international common property resources yields a greater perceived wealth for nations, is suggestive that resolution of transnational externality problems will generally need to be embedded within the following restrictions:

1. No nation will easily accept international agreement on entitlement of significant common property resources without compensating payments to retain its perception of national wealth. In consequence, the classical answer to externality problems of internalizing the decision-making process for the resource is not easily transferable to transnational problems. A new overriding element of distributional gains and losses must be simultaneously included in efficiency consideration.

2. Undirectional transnational externalities, if they are of substantial importance to the emitter country as a method of waste disposal, will in general be resolved by some form of a compensation system where compensation flows *from* the receptor country. The nonliability case (or "victims must pay" principle) will generally be dominant.[2] This is to be contrasted with the reciprocal environmental externality case where compensation may flow in either or both directions.

3. International court settlements of transnational externalities are not likely to yield satisfactory results. There appear to be three almost insurmountable problems. First, how are damages to be measured and damage payments assessed? The receptor country's social values may be strikingly different than the emitter country's. In consequence, there may not be a social welfare index that is applicable or acceptable by both. If the damage is entirely confined to hindering production in the receptor country, then international trading prices, at least at the margin, offer a measure of welfare loss. However, if the impact is on individual citizens with no market prices representing their losses, then a measure of welfare loss is not available

2. The appearance of reciprocity may negate this statement, particularly in those cases where an external diseconomy in one direction between countries is offset by an external economy in the opposite direction.

except through direct examination and questioning. A very striking example of this is the preservation of Nubian monuments behind the Aswan Dam where the value is *only* to "all of humanity." In addition, there may be uncertainty as to the magnitude of loss unless the externality is allowed to continue to the point of maximum damages, i.e., threshold levels of fish populations. And, with irreversible biological or other processes, this becomes a dangerous, if not intolerable, experiment. Second, given the sovereign rights of nations, no nation can be forced to pay environmental damages. The trade-off here is in terms of loss of international prestige and goodwill or increasing the possibility of conflict versus monetary payments based on possibly misrepresented public preferences of the receptor nation. Third, there is basically the "chicken and egg" problem of historical precedent most dramatized by airports and noise pollution. An airport is built drawing in people that then are affected by airport noise. As Coase cogently stated the problem, who is responsible? Who is the polluter in the "polluter must pay principle"? As environmental problems increase in severity and potential damages induced among countries rise, it seems that assigning responsibility will become increasingly difficult. In this context, there is also the problem of assigning damages when more than one nation's waste residuals contribute to total damages. If the different nations' residuals are synergistic or if damages are nonlinear relationships of waste intensity, then there is no easy method of determining how much responsibility each nation should take even with the "polluter must pay all costs and remaining damages" principle. Thus, it can be anticipated that international courts or international commissions will have difficulty in arbitration even if such institutions were given partial regulatory powers.

To conclude this rather negative introduction, transfrontier environmental externalities are not likely to be resolved by international organizations without some form of compensation to both countries—an unlikely case unless a transnational external economy can be discovered to offset the inherent costs of a transnational external diseconomy.[3] In this paper, I attempt to develop a rather abbreviated taxonomic discussion of models on transnational environmental externalities and analyze them in the context of bilateral and multilateral negotiation. The role of international tribunals, courts, or management commissions is not analyzed

3. It should be recognized that a great many offsetting negotiations which are indirect, i.e. without direct monetary compensation, occur currently. The rule is preferential nation status, military gifts, U. N. vote commitments, economic aid unrelated to the conflict "a priori," often are a form of compensation. Direct monetary compensation is only one form of retribution within the context of intergovernmental arbitrage and agreement.

explicitly except as an occasional point of reference for "ideal" efficient utilization and distribution of global environmental resources.

Wealth Effects of Transnational Externalities in Production

In order to clarify taxonomically transnational externalities, we shall employ the traditional concepts of production and utility relationships in economics. In so doing, externalities will be divided into four categories.

1. The first category is externalities generated in production processes that affect production costs and processes in other nations. Examples include industrial water pollution that requires treatment before industrial use in a downriver nation or the salt pollution of the Colorado River by U. S. agricultural tailings' water that reduces farm productivity in Mexico.
2. The second category is externalities generated in production in one country that do not affect production but degrade the environment of citizens in other countries. An example might be the acid rains in Scandinavia emanating from the Ruhr industrial complex.
3. The third category is externalities generated by acts of consumption or final use of goods which affect production costs, i.e. rude tourists.
4. The fourth category is externalities generated by acts of consumption which influence environmental quality in other countries, i.e. municipal wastes affecting recreational use of Lake Erie. It appears relevant that for transfrontier environmental externalities the first two cases could be considered the dominant ones currently. However, as urban sprawl continues and populations centralize and enlarge, pollution from acts of consumption might become increasingly relevant as a transnational problem. Municipal wastes in the Great Lakes and elsewhere offer support for this allegation.

In addition to classifying externalities on the basis of source such as production processes or acts of consumption, they can also be usefully classified by how each enters utility and production relationships of citizens in nations. Definitionally, a truly global externality problem is one in which the externality enters some production function, utility function, or both in every nation. Alternatively, a regional externality problem connotes that the externality only enters a prescribed subset of all nations' utility and or production functions.

Using the neoclassical concept of utility and production function, the various types of transnational environmental externalities can be catalogued. Let $F^i(x, k, y)$ denote the production function for country i where x denotes a vector of outputs, k a vector of resource inputs, and y a vector

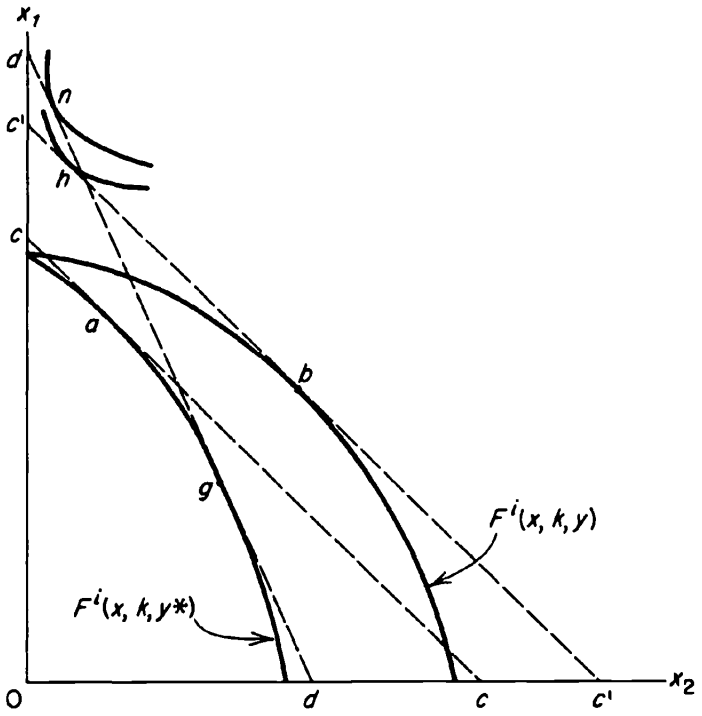
of environmental externalities that influence production, but cannot be controlled by autonomous decisions of firms in nation i. The vector y may include such components as water quality in a river, lake, or estuary jointly used by several nations, or a common airshed. Thus, $F^i(x, k, y)$ represents the traditional economic concept of a production frontier for country i, where given its domestic resources k, externality components y which, prior to regulation, it does not control, and levels of production for $N-1$ of the N products it produces, the function yields the maximum of the Nth product the country can produce. Omitting considerations of environmental externalities within a nation for the moment, i.e. presuming all y's are externally determined for the nation, then F^i can be viewed as a wealth measure for the ith country. As some or all of the components of y are changed, then so must the actual (and perceived) wealth of the ith country. In figure 1, a simple diagram is given where the country produces two goods, and a component of y is changed which influences the production of one of those goods, x_2. Note that y^* represents an external diseconomy since maximum production of x_2 is reduced for any predetermined production level of x_1. If both products of country i are affected by the transnational external diseconomy, then the curve in figure 1 would move more uniformly inward.[4]

A glance at figure 1 easily confirms several expectations on international trade patterns. Countries affected by uncompensated transnational externalities in production will tend to produce more of those commodities less influenced by external diseconomies if firms in these countries respond to international prices. If a country is relatively small and the transnational externality is also relatively small so that compensation that

4. In the international trade literature, resource endowments traditionally are not presumed to move internationally. Thus, with this assumption transnational environmental externalities will shift the production curve inward, but generally not alter its convexity properties regardless of how pervasive the external diseconomy. This can be easily demonstrated. Since an external diseconomy in production may reduce the productivity of inputs, as output shifts from one commodity to another, one can expect diminishing marginal productivities of inputs to continue at an accelerated rate, as production of the second commodity is increased. Consequently, convexity will generally be retained. Recently, Baumol, Starrett, and others have pointed out that the highly pervasive externalities in production may destroy the convexity of production curve for commodities if resources are *transferable* in production. Transnational externalities do not present this problem so long as resources are immobile. This is suggestive that multinational corporations that contribute to international resource mobility may at some point contribute to nonconvexity, making it more difficult to identify efficient intracountry environmental control strategies. See W. J. Baumol and David Bradford, "Detrimental Externalities and Non-Convexity of the Production Set," *Economica* (May 1972); and D. Starrett, "On a Fundamental Non-Convexity in the Theory of Externalities," Harvard Institute of Economic Research, *Discussion Paper 115,* 1970.

Figure 1

Effect of Transnational Externality on a Country's Production Possibilities



adjusts trade patterns has no perceptible influence on international trade prices, then a clear measure of loss in wealth of the country can be obtained. If the country produced at point b prior to the transnational externality or in its absence, but with the externality it produces at a, then income loss measured by international prices equals the distance between c and c'. However, if compensation or removal of the externality changes international prices, then the direct linkage between measured income losses and welfare losses is obviously broken. As an extreme example, let us presume that compensation or payments for resolving the transnational externality in production of commodity x_2 shifts international prices from dd to $c'c'$ in figure 1. The country thereby shifts its production from g to b. But now it shifts its consumption point from n to h, thus exporting more x_2 for less x_1. The country has been made *worse off* from

the removal of or compensation for the transnational externality because of international price effects. This is again obviously an extreme case, but it demonstrates the problem of determining welfare loss when international prices are affected by the compensation adjustment for external diseconomies. It also underscores the point that even a receptor country may lose by making a commitment to international arbitration of transfrontier externalities unless international trade effects are given adequate consideration. Normally, however, we should expect that with good information, bilateral negotiation would lead to a net welfare gain for both emitter and receptor countries.

A second aspect of consideration regarding wealth effects of transnational externalities in production is how the externality enters production functions in both emitter and receptor nations. Obvious alternatives in the receptor case include:

1. effects on all or some resource inputs, either through reducing their marginal productivity, total productivity, or both;
2. the choice of processes and techniques or factor proportions separable from impacts on the productivity of inputs;
3. adjustment in qualitative aspects of the product which influences its value;
4. the need for additional technology or other inputs to alter inputs before they can be used, such as water purification.

Note that 1 and 4 relate explicitly to particular factors of production, while 2 affects the production process directly. Finally, under 3, not only must one consider cost-minimizing control strategies, but also market demand considerations to measure welfare losses. In terms of the functional relationship F^i discussed earlier, the four impacts can be translated as follows.

Table 1 contains a symbolic categorization of the various impacts of external diseconomies on production. For any particular transnational environmental externality, each impact in isolation or any combination may be operative. However, the policy implications for each in measuring wealth or income losses can be substantially different. For example, in assessing the extent of receptor costs of the externality, if the only impact is a shift downward in productivity of all inputs, then costs are easily measured applying international prices. This is also the case when all that is required is some additional residuals processing. Alternatively, in the case of product change, costs must be determined as the difference in net rent between production of the qualitatively different commodities,

TABLE 1

Impact of External Diseconomies on Production Processes

Impact of Externality	*Symbolic Representation*	*Comments*
Productivity of inputs	$F_{y^*k} < 0$[a]	Marginal productivity of selected inputs decreased
	$F_{y^*x} < 0$	Total productivity of all inputs decreased uniformly
Process or technique substitution	F replaced by F′	Transformation process of inputs to outputs altered separable of effects on input productivity
Change in qualitative aspects of output	$F(x^*, k, y^*)$ with $x^* \neq x$	New vector of outputs x with different qualitative characteristics or dimensions
Additional technological adjustment of other inputs	$F(x, k^*, y^*)$ with $L^* = F(x, k, y^*)$	Production function is altered to embody additional processes

a. F_{y^*k} represents the derivative of the production function with respect to externality y^* divided by the derivative of the production function with respect to input k.

i.e. beer produced in Olympia, Washington, or in St. Louis with variations due to water quality. Such an assessment requires explicit knowledge of consumer preferences in the receptor country and countries it exports to. Likewise, unless there are accurate measures of the cost of process change or change in technique, it will be most difficult to assess receptor nation costs from this source of impact. A simple dynamic example with technological change will suffice to illustrate complexities here. A nation downstream is affected by increasing deterioration in water quality. In consequence, firms there respond by selecting a less water-intensive production process. Embodied technical change in this process leads to greater efficiency in production and efficiencies in production compensate partially or offset completely inefficiencies due to water quality deterioration. Where is the loss to the nation? It surely includes technology conversion costs, but an unanticipated external economy has otherwise offset external diseconomies associated with poorer water quality. This example is cited only to point out the difficulties inherent in measuring the wealth or income loss of the receptor nation. Conceptually, the rule to follow would be the so-called "with and without" principle encountered in

benefit-cost analysis. Thus, an appropriate static measuring device of wealth-income loss is output valued at international prices with and without the transnational externality. However, if there are underlying dynamic processes such as learning embodied in external diseconomies, such static measurements will be disputed in bilateral negotiation, particularly with the adoption of the "polluter must pay" or absolute liability principles.

In the emitter country, the same four cases of impacts on imputs (in a positive sense) and shifts in processes are possible because of the country's ability to use environmental assimilative capacity and cause downstream damages without compensation. When the transnational externality is strictly related to production sectors in the several countries, it is significant to ask whether the impact on factor use will be completely symmetrical. In other words, if the marginal productivity of a factor is reduced downstream, is it carried upstream for the same factor or is the upstream country's outward shift in $F^i(x, k, y^*)$ induced by different causes? If, for example, the upstream country uses the river for upstream dumping rather than incurring process changes (while the downstream effect is to reduce the marginal productivity of a single factor downstream), then assessment of damages is relatively straightforward with international prices constant. However, if there are qualitative changes in the upstream countries' product (which is competitive or complementary with the downstream countries' product that also undergoes qualitative changes), then again demand conditions must be understood to assess damages and measure the involuntary transfer in wealth.

Take two countries with equal factor endowments and resource size facing competitive international prices that are constant, i.e. each country is small in relation to global or regional markets. The upstream country increases factor productivity per se by dispersing waste heat into the streams rather than using cooling towers requiring 10 per cent of its productive factors, while the downstream country experiences the need for cooling towers in order to use river water for production of commodities which requires, by assumption, 8 per cent of its factors of production. Since in neither case do productivity of individual factors or international prices shift, the composition of output in the two countries would not change. All that occurs, is that the emitter country receives a 10 per cent increase in factor income and the receptor an 8 per cent decrease in factor income while the world as a whole undergoes a net 2 per cent rise in the amount of commodities produced by the two countries. If the externality can only be corrected by stopping the heat emission upriver, then it should not be. Allowing the externality to continue is economically

efficient, but distributionally adverse to the receptor country. Since there generally will be no mechanism to require the emitter to provide compensation, i.e. except by threat of receptor country or altruistic goals of the emitter country, no transfer payment will occur. A "polluter pays" principle similar to the one adopted by Organization for Economic Cooperation and Development (OECD) member countries where the polluter must pay for controls and not pay compensation for damages would lead to an inefficient allocation of resources in this case.

What is important to note is that transnational production externalities which are uncompensated induce distortions of production relationships in *both* emitter and receptor countries. Perceived wealth of both change as a result of the involuntary character of externalities. However, it is very likely that the impact downstream, because of different factor endowments, production technologies, factor mixes, and comparative advantage in commodities, will be different than the upstream country's impact. A guess might be that in most cases, the emitter country's firms save in costs of additional technology, i.e. recycling and in-factor productivity per se, while the receptor country firms tend to lose in terms of required process or technical changes in production and qualitative aspects of the commodities produced. In consequence, the usual implicit assumption that upstream and downstream control costs are similar in magnitude is not likely to be valid.

To summarize this rather scattered discussion on the wealth effects of transnational externalities in production: (1) these types of externalities can be viewed as involuntary transfers of a nation's wealth; (2) if the externality influences competitive international prices, then its resolution by the OECD "polluter pays" principle may economically harm the receptor country as well as the emitter country. Likewise, the "victim must pay" principle may economically harm both emitter and receptor countries. However, transnational externalities in production generally yield a potential rise in income in one country and a fall in income in the other. In certain instances, where control costs or efficiencies are different between countries, it may pay to retain the externality and, if necessary, use lump-sum transfers to achieve equity.

Wealth Effects from Transnational Externalities on Consumers

Thus far, the discussion has been developed from a perspective of externalities in production, but a few words are added here to describe the impact of externalities in final use or consumption as distinct from produc-

tion. In order to develop the idea of a wealth transfer resulting from transnational externalities in consumption, I apply a simple graphical technique first used by Dolbear.[5] Let there be two countries with collective utility functions as follows:

$$\begin{aligned} &U^1(x_1, y_2), \\ &U^2(x_2, y_2), \end{aligned} \tag{1}$$

where x_1 and x_2 are the quantities of a private good consumed in countries 1 and 2, and y_2 is the quantity of a private good consumed by 2, but yielding an external diseconomy to 1.

With first and second derivatives denoted by subscript, we assume:

$$\begin{array}{llll} U_x{}^1 > 0, & U_y{}^1 < 0, & & \\ U_{xx}{}^1 < 0, & U_{yy}{}^1 < 0, & U_{xx}{}^1 U_{yy}{}^1 > (U_{xy}{}^1)^2; & \\ U_x{}^2 > 0, & U_y{}^2 > 0, & & \\ U_{xx}{}^2 < 0, & U_{yy}{}^2 < 0, & U_{xx}{}^2 U_{yy}{}^2 > (U_{xy}{}^2)^2. & \end{array}$$

Note that the usual strict concavity assumptions are specified for preferences toward the two private goods, x and y. The significant difference, however, is that individuals in country 1 are presumed to undergo increasing marginal disutility if the externality is intensified.

Next, a budget constraint for both countries is postulated:

$$\begin{aligned} px_1 &= M_1 + B, \\ px_2 + ry_2 &= M_2 - B; \end{aligned} \tag{2}$$

or

$$p(x_1 + x_2) + ry_2 = M_1 + M_2; \tag{2'}$$

where p and r are the given international prices for private goods x and y, and M_1 denotes the initial income of country 1. Negotiation for external effects between 1 and 2 is allowed through payment of a bribe, B with $B \gtreqless 0$, which cancels out of equation 2′. For simplicity, we shall assume $p = 1$ by suitable redefinition of quantity units of x, and that the externality and consumption of y_2 are strictly joint products.

In figure 2, indifference maps are depicted along with initial (before

5. F. T. Dolbear, Jr., "On the Theory of Optimum Externality," *American Economic Review* (March 1967).

the externality appears) endowments.[6] Country 2's indifference map is identified with the origin 0. However, country 1's indifference map is not. Since 1 cannot exchange y_2 in an international market, its budget constraint would be a sloped line commencing from point *a*, i.e. the country's exchange price for y_2 is initially zero; and the country will, given a choice, be at a corner solution. As point *a* moves to the left, country 1 has a higher budget. But, in order to represent 1 and 2's combined budget in x–y space, the budget line and indifference map of 1 must be rotated in order to be parallel with the slope of the combined budget line such that the sum of 1 and 2's budget does not exceed their combined budget. Thus, the indifference map for country 1 is rotated in x–y space so that x_1 is always measured from the aggregate budget line from right to left in figure 2.

Initial consumption is at point *a* where both 1 and 2 are consuming x but neither is "consuming" y_2. Next, country 2 "purchases" the externality yielding commodity and moves to point *b* where the budget line *aa'* is tangent to the indifference curve 22. Clearly, this point is not Pareto optimal in a global sense, since residents of country 1 suffer a loss of utility and are moved *involuntarily* from indifference curve 1'1' to 11. By negotiation, they could achieve the contract curve *cc*, which implies a reduction in intensity of the externality. It should be reemphasized that country 1 has control only over consumption of product x and cannot either purchase or sell y_2, except by negotiating with 2, thereby ruling out the development of a competitive market for the externality. Also, the contract curve defined as *cc* is *not* one where marginal rates of substitution for x and y are equated with relative prices defined as $1/r$, although the budget line of country 2, *adjusted* for fees or payments, must pass through this tangency.

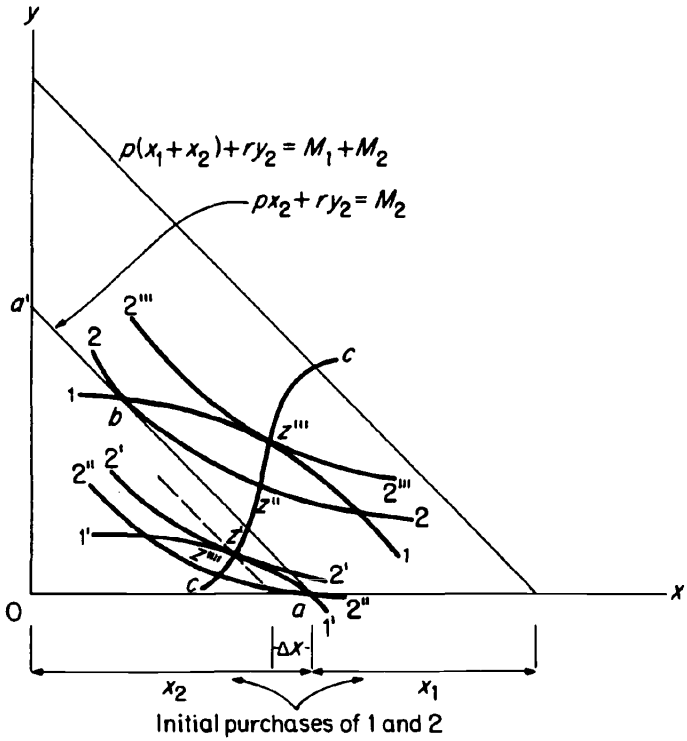
What we now wish to introduce are simplified versions of the "third party liability" (TP) and "victim must pay" (VP) principles. First, the TP rule is presumed to require that country 2 compensate country 1 for all disutilities caused by the externality.[7] With negotiation and the TP

6. Collective indifference maps for each country are presumed to exist which effectively assumes away difficulties of interpersonal comparisons within countries.

7. Note that country 2 by assumption can only regulate the externality's impact by reducing consumption of y_2 or paying country 1 some x to tolerate the external diseconomy. Thus, country 2 cannot provide controls and country 1 implicitly cannot undertake defensive expenditures internally to reduce the intensity of the externality. Recently, the OECD member countries agreed to implement a "polluter pays" principle which in effect requires the polluting firm to pay all control costs and the receptor firm or consumer to pay all residual damages. Also, transfrontier pollution was explicitly excluded from this agreement. For clarity, we adopt the following terminology: polluter being responsible for all control costs and residual damages is denoted as the

Figure 2

Initial Purchases of 1 and 2



rule specified, the point z' on the contract curve in figure 2 is achieved. Note that if the TP rule is specified, damages cannot occur or must be paid in kind, i.e. reduced noise only, then point a will be achieved once again but at a loss to at least one, if not both countries. Also, a TP rule which specified that the damaged country must be made better off while the liable country cannot be better off, will result in negotiation to the contract curve. The ultimate point achieved on the contract curve in this

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"third party principle" where third party connotes the implicit need for an outside enforcement body or court in order to establish exclusive right for the receptor nation; polluter pays only the control costs and no residual damages is referred to as the "polluter pays" principle. See Organization for Economic Cooperation and Development, *Recommendation of the Council Concerning International Economic Aspects of Environmental Policies,* Paris (May 26, 1972).

case will be to the left of point z' in figure 2 at point z'''', i.e. x_1 will be higher while y and x_2 will be lower than for the first PP rule.

We next turn to the case of VP rule. By VP rule, we mean that there is a rule which specifies that country 2 by inadvertently creating an external diseconomy is not required to compensate country 1 for damages. Also, there are assumed to be no provisions contained in this rule which would impede private negotiation between affected countries. Clearly, in this case a negotiated settlement would involve a payment from country 1 to country 2. Costless negotiation would result in a distribution of x and y on the contract curve between z' and z''' in figure 2. Between z' and z''' on the contract curve, both countries 2 and 1 are made no worse off and perhaps better off than at point b.

A TP rule, as specified here leads to a negotiated settlement on the contract curve cc on or to the left of point z', while a VP rule leads to a negotiated settlement on or to the right of point z''. Thus, the distribution of wealth between countries is altered by adoption of a TP or VP rule which changes the consumption patterns for x and y. Since negotiation leads to attainment of the contract curve regardless of rules, Coase is correct in asserting short-run efficiency.[8] The above derivation can be taken as a proof of the "Coase proposition" amended as follows: regardless of whether a TP or VP rule is adopted, "perturbations" arising from nonmarket forces can be resolved through negotiations of the countries affected, and provided transactions costs are zero *after* perturbation, Pareto efficiency is attained in the short run and in the long run if consumers and factors of production are immobile internationally.[9] In Appendix I, a simple model of international production is analyzed which demonstrates that under several rather general assumptions neither the TP nor VP rules will achieve global production efficiency without other internationally agreed upon secondary controls. The assumptions include certain types of positive transactions costs and that countries are essentially price takers. A second assertion which becomes obvious in the diagrammatic analysis is that with more or less continuous perturbations and negotiation, a VP rule will have "wealth" effects toward making some countries worse off, that is, if one assumes that, ordinarily, the emitter country is made better off by "creating" external diseconomies. Not unlike gambling, there will be some countries that emerge as winners and others as

8. R. Coase, "The Problem of Social Cost," *Journal of Law and Economics* (August 1960).

9. See Appendix I for a discussion of the possibilities when transaction costs are positive.

losers. Since the perturbations are unforeseen in this world, it would appear Paretian in spirit to adopt a TP rule.

Some Brief Notes on Bilateral Negotiation and Game Theory

Whether the "third party must pay," "victim must pay," or some intermediate principle is implicitly or explicitly adopted, there are potential gains from trade via bilateral negotiation. Both the emitter and receptor have incentives to undertake negotiation.[10] Thus, in terms of game analysis, unadjusted externalities without threats of conflict are essentially the form of cooperative or Nash types of games. Both countries can potentially gain by cooperation although each may decide that it is in its best interest not to cooperate, or pretend not to and thereby possibly achieve a greater expected threat payoff or value. With externalities generally, it can be expected that *side payments* will be made in order to achieve cooperation. Thus, the classical Nash cooperative solution without side payments appears to be inappropriate. Side payments might enter, for example, if the upstream and downstream control costs were different.

In order to illustrate some basic problems involved in negotiation for transnational externalities, we shall resort to a simple example. Let it be assumed that there are two countries 1 and 2 where 2 is the emitter and 1 the receptor. Downstream damages are 10 prior to control and 2 with control, with upstream gains due to savings in pollution control of 4. Downstream control costs are assumed to be 6. There are two decisions for each country that are not mutually exclusive, namely whether to join the coalition and at what level to participate, i.e., how much control to provide. We shall concentrate on the decision whether to cooperate or not presuming there is *no* double layered process of irrevocable agreement to negotiate which is followed by negotiations. Also, it is assumed for the moment that both announce their intention to negotiate simultaneously with offers. Finally, neither country is assumed to know precisely the other's control costs and the emitter country does not accurately know the level of downstream damages.

Given the previous assumptions and a set of expectational values of each country, the maximum bid and expected bid of the receptor country and minimum acceptable offer and expected offer for the emitter country

10. That is, assuming the externality is continuous over time, has inadvertently arisen, and the emitter, if he does not pay, must cease the activity-generating externalities under the "third party must pay" rule.

can be established. To make things simple, we shall set the following probabilities.

1. Country 2's government believes the probability of downstream damages being avoided by control of 10 is .2 and the probability of damages being avoided of 2 is .8. Thus the expected value of damages avoided by controls is simply: $E = .2(10) + .8(2)$.
2. Country 2's government believes the probability of the downstream country's control costs being 4 is .5, and the probability of these costs being being 6 is .5.
3. Country 1's government believes the probability of the upstream country's control costs being 4 is .5, and the probability of them being 6 is .5.

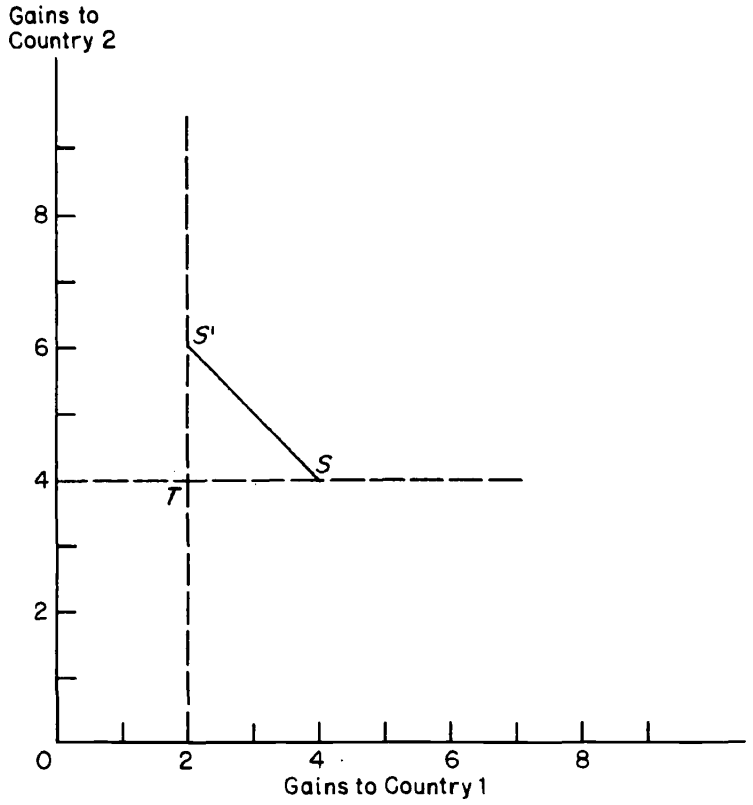
Presuming the "victim must pay" principle is in effect, the maximum bid that 1 would make to 2 would be initial damages less damages after control which is 8. The minimum acceptable offer for country 2, of course, is 4. These amounts are in effect the "threat payoffs" of the Nash type of game for coalitions. Thus, there are clearly gains from negotiation if negotiation can be *initiated.* However, note that "expected rent" beyond payment for control by country 2 from country 1 *prior* to negotiation is negative, i.e. rent defined as 2's expected value of downstream damages reduced is $.2(10) + .8(2)$ less 2's expected value of 1's control costs $.5(6) + .5(4)$. Thus, 2 may not undertake negotiations due to the fact that it expects 1's offer will be less than its control costs.[11] Alternatively, 1 will decide to attempt negotiation with 2 because its expectation of gain would be $8 - .5(4) - .5(6)$ which exceeds its gain of 2 from instituting control unilaterally.

In figure 3, the possible bargaining positions and "threat payoffs" for this problem are depicted. Any point on SS' is Pareto efficient in that all gains from negotiations on the transfrontier diseconomy between countries 1 and 2 are exhausted. Which point on SS' is ultimately selected via negotiation depends on the rules established for negotiation, i.e., once-and-for-all bid by the receptor, a sequence of simultaneous bids and demands, or sequential bids and demands. Also, the point depends on the exact specifications of the VP or TP rules. For example, if a TP principle is adopted which specifies the emitter country cannot be any better off than before the emergence of the transfrontier externality, point S will

11. It should be pointed out that this grossly simplifies expectation problems in that we omit consideration of country 2 calculating country 1's expectations and likewise country 1 calculating country 2's expectations on country 1, *ad infinitum.* Here we only consider country 1 and 2's expectations directly.

Figure 3

Efficiency Locus for Transfrontier Externality Between Two Countries



be the negotiated solution. Alternatively, if under the VP principle the receptor country cannot be made better off, then S' will be selected. Finally, if transactions-negotiation costs are introduced, then it is conceptually possible for country 2 to decide not to negotiate under either the TP or VP principles, since the country *a priori* perceives that it would be better off without it. (See Appendix I for an elaboration on this point.)

This most simple example of a cooperative game between two countries on transfrontier externalities underscores several points. First, the bidding process itself, i.e. who bids first and how binding is the bid, may sig-

nificantly alter the outcome. In the example above, country 2 will not establish negotiations or make the first bid because expected gains are negative. Second, precise information on damages and control costs by both countries will reduce the risk associated with bidding too high or setting payments too low. Under the TP principle, this risk factor is intensified since the emitter country now confronts uncertainty with respect to both receptor damages and downstream control costs. Alternatively, under the VP principle, the country making the payment, i.e. receptor, confronts uncertainty only with regard to the emitter's control costs. Such a reduction of uncertainty on information does not occur in OECDs "polluter pays" principle where the emitter is uncertain on damages *and* downstream control costs and the receptor is uncertain as to upstream control costs.

Conclusions

The major conclusions of this paper are as follows.

1. Transnational externalities in production or consumption are involuntary transfers of perceived wealth among emitter and receptor countries. Given the general acceptance of the national sovereignty principle, such externalities of a significant magnitude will in general only be resolvable via bilateral negotiation with side payments, usually from receptor to emitter.
2. Unadjusted transnational externalities, if their resolution through compensation or other means, shifts international prices, may make a single emitter *or receptor* nation better *or worse* off. Thus, the link between wealth-income and welfare of a country is broken. In order for the receptor nation to be made worse off, international prices must be markedly affected and willingness to pay for the commodity, influenced by the externality, must be strong if its relative price increases as a result of compensation or weak if its relative price decreases resulting from compensation.
3. Transnational externalities, unlike domestic externalities in production, will generally not cause a shift from concavity to convexity of domestic production functions. This is due to the usual underlying assumption in the classical trade literature that resources are mobile nationally but not internationally.
4. A "victim must pay" principle or a "third party" principle will lead to an inefficient long-run allocation of resources between countries,

provided resources are mobile between them and certain assumptions on positive transaction costs are valid.[12] These assumptions are that firms only respond to realized profits in international location decisions and are price takers. To achieve global efficiency in resource allocation, some other types of controls need to be implemented such as restrictions on international location. The same inefficiencies might arise for transnational consumption externalities unless consumers are not internationally mobile.

5. Transactions costs in negotiating for externalities are shown to markedly affect the expected outcomes of bilateral negotiation. If such costs are high, countries are generally risk averters, and these costs must be borne by the receptor country under the "third party" principle, then it can be expected that pollution will be greater than is desirable from a global viewpoint. There appears to be a basic asymmetry in incentives for negotiation of externalities between the "victim must pay" and "third party" principles, when transactions costs are positive. Under the VP rule, both emitter and receptor have incentives to negotiate and thereby incur transactions costs. Alternatively, with the TP rule, only the receptor has such incentives since the emitter is always better off by not negotiating.[13]
6. Unidirectional transnational externalities were shown to be as conceptualizable as a special case of cooperative games under the "victim must pay" principle. It was argued that rules on negotiation may substantially alter gains between countries undertaking bilateral negotiation for transfrontier externalities and thereby influence international efficiency in the utilization of resources.

12. See Appendix I for a semi-rigorous proof.
13. See Appendix I.