Design of New Institutions for Environmental and Resource Management, With Application to Pollution Control

Think Globally, Act Locally

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Abstract

Considering the nature of conflicts over resource and environmental problems, a new approach is needed. Finding the common ground and collaboration hold promise as conflict resolution paradigms in such situations. Economists can help design institutions that would foster these paradigms.

For pollution control, the common ground paradigm suggests that polluters and sufferers together determine pollution emission, pollution reduction, and finance of pollution reduction.

For pollution management, this paper proposes a new policy instrument involving taxes, subsidies, and cost sharing. Using this instrument, a coordination process involving polluters' and sufferers' determines a consensus about emissions and pollution reduction. Incentives for cooperation are provided by a noncooperative threat point.

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Designing New Institutions
for Environmental and Resource Management,
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"Think globally, act locally"

There is growing concern about global scale environmental problems such as global warming, vegetative changes, extinction of species, deforestation, ozone depletion, disruption of water supplies, and desertification (Nisbet, 19991; Gore, 1990). Single media management, carried out by EPA and state agencies for air, water, and wastes, are being recognized as inadequate (Barlett, 1990). Similarly, single species management has not worked (Wilson, 1992): there is a high rate of species lost, and species are being lost even from national parks (Kane and Starke, 1992). For example, 25 percent of large animal species have been lost from Yosemite, and 36 percent have been lost from Bryce Canyon. Clearly, existing institutions are not being successful at proper resource management.

An evolutionary process is a gradual method of Institutional change. Another approach is a social engineering approach or conscious design of new institutions (Hurwicz, 1994; Schotter, 1995). Such an approach produces "punctuated evolutionary change" (Boulding, 1992) that is not gradual. This paper demonstrates the design approach for pollution management.

The purpose of this paper is three-fold:

1) to highlight the design of institutions and organizations as an appropriate activity for economists;

2) to propose a new paradigm (the common ground) for collective action problems;

3) for a particular setting, to demonstrate the design process and how an agreement about pollution control could be facilitated by economic coordination.

The setting is pollution management at a local level in the face of federal or state standards that provide an external threat point to propell the location of a common ground. Based on voluntary agreement, the stopping rule for the process is unanimity. In the Calculus of Consent. Buchanan and Tullock (1962) suggest that any collective decision rule other than unanimity will have coercive aspects.

Economists' Views about Institutions and Organization

The importance of institutions for environmental outcomes is recognized in the work of Bromley (1989, Ostrom (1990, 1994), North (1991). As North states (p.l, 1991):

"Institutions are the humanly devised constraints that structure political, economic, and social interaction. They consist of both informal constraints (sanctions, taboos, customs, traditions, and codes of conduct), and formal rules (constitutions, laws, property rights)... .Institutions provide the incentive structure of an economy... .it shapes the direction of economic change..."

Institution and organization are often confounded. Economists use the term institution to mean social rules, while organization refers to a coordination structure for information and decisions which may be constrained by social rules. The preferred structure of an organization can be based on economic rationale (Williamson, 1975; Radner, 1992; Reiter, 1995).

Decentralization and centralization are two contrasting types of organization of decisions. For resource management, decentralization implies that all decisions are made locally, whereas centralization can refer to all decisions being made at a federal level. However, the set of possible organization structures is larger than centralization and decentralization! For example, hierarchical and linked structures are more complex forms of organization.

Mechanism design literature (Hurwicz, 1973, 1987, 1995) has to do with the design of appropriate social rules. The emphasis of this literature has been on information and incentive compatibility. Incentive compatibility has to do with minimizing enforcement and information costs: if players makes decisions in a framework that is consistent with their own interests, enforcement and information costs will be minimized. Decentralization has been a focus of mechanism design because of favorable information and enforcement costs. Privacy about preferences is another rationale for decentralization.

Coordination refers to how information and decisions can be meshed in a complex organization. According to Reiter (1995), a mode of organization "consists of (i) an algorithm for computing the decision rule, and (ii) an assignment to indivdidual agents of the steps required to execute the algorithm. The problem of incentive compatibility addressed in principal-agent literature is that individual agents may have incentives to act on a different decision rule than the organization as a whole. The design of contracts or other policy instruments can bring about a closer correspondence of objectives within an organization.

Welfare economics theorems about market failure may be reinterpreted to be in terms of coordination: when there are shared social objectives such as public goods and externalities, some form of coordination is required. Theorems about the second best and separability may be reinterpreted to imply that - while coordination may be required for public and externality goods — private goods not involved in externalities need not be subject to coordination.

Coordination can facilitate agreement in collective action situations by reducing transactions costs and information costs and also by providing an environment for cooperation. Coordination systems may operate voluntarily. For example, Tullock (1994) discusses coordination in nonhuman societies such as ants in which decentralized actions such as road building are carried out in response to environmental signals. For such nonhuman species, compliance is voluntary because of common (survival) preferences. The coordination situation for humans may be more difficult because of differing preferences and complexity of a decision environment.

New Paradigms and Institutions for Environmental Management

The need for revising environmental and resource management is receiving increased attention by political scientists (Kraft and Vig, 1990; John, 1994; Naimann, 1995). Literature examining environmental policies discusses reorganization of government and policy, and, more basically, redefinition of the underlying philosophy of management.

Government Reorganization

Even for global problems such as global warming, resource management may not be implementable on a global scale because of information and enforcement problems. Local management has been a recurring theme. Garrett Harden (1987) gives the advice (p. 162), "Never globalize a problem if it can possibly be dealt with locally." That is, even though many environmental problems are experienced on a global scale, action to alleviate problems may be necessary at a local level. A related idea is grassroots globalism, or "trickle up globalism", proposed by Hazel Henderson (1995), which differs from globalism based on a planning (top-down) approach.

Concomitantly, government reorganization proposals include introducing ecosystem management approaches within each relevant government agency, better integration of agencies with overlapping jurisdictions, and decentralization of federal regulation in favor of state regulation (Bartlett, 1990).

There are recognized drawbacks to decentralization, with states and localities assuming roles previously at the federal level. States and localities may lack the expertise and funds available to a national government (Lester, 1990). States and localities may be more subject to pressures to reduce standards to lure or keep industry and jobs in their region. States may lack funding for adequate environmental and resource protection.

Reasons for continued federal involvement are discussed by Lester (1990). Environmental quality monitoring may be most appropriately administered by the federal government for reasons of uniformity and economies of scale. Grant funding of state programs from earmarked national tax revenues can help provide a basic minimum environmental quality. Equity is another reason for national minimum standards for health (both human and ecosystem). Minimum property rights to health and a sustainable future for all parties may be specified at the national level in the form of a bill of rights.

While monitoring, cost sharing, and setting minimum rights and standards may require continued federal involvement, environmental solutions can be tailored by local areas. There will then be a potential for greater innovation through local experiments (Hird, 1994). A networked structure has been proposed as an appropriate organization for resource problems when there are overlapping jurisdictions (Kraft, 1990).

New Resource Management Concepts

Stewardship is a concept of resource use based on Judeo-Christian ethics in which man's role is to be a caretaker of the earth (Gore, 1992). This concept may be most readily applied at a local level. A related concept of human-environment interactions is resource use within environmental carrying capacity constraints (Daly and Cobb, 1989). Applying the carrying capacity concept at a local level may be possible (Kumar, 1992), both in terms of implementation and information.

One emerging paradigm calls for defining the common good (Raskin, 1986) by communities, of communities, which may be defined otherwise than geographically (Daly and Cobb, 1989; Gillroy, 1993). In particular, the common good for environmental-economic interactions has been specified by the World Commission of Environment and Development (the Brundtland commission; 1987) in terms of establishment of sustainable patterns of resource use, minimization of disruption of ecosystems, and minimization of negative impacts on human health (Paehlke, 1990).

An alternative pardigm is based on the idea of common ground. This terminology derives from mediation literature. The concept differs from the common good, which requires agreement over values, in that multiple parties may have different values which are blended through a social decision process (Gray, 1989). The difference between the common good and common ground concepts has been expressed by Corbett (1995):

...An army, a land management agency, or any other corporate body needs a common cause and a plan for achieving it, but a society needs a common ground - an ethic - that allows its members to count on one another while pursing diverse and even incompatible objectives. A society need not pretend to know where it's going, as long as its members can agree about how to get there....

The process of finding agreement, called collaboration by Gray, is possible when there are shared values (eg. survival and a common future) that cut across all interests. In contrast to economists' focus on free-riding, Gray's hypothsis is that different behavior rules may apply when there is collaborative decisionmaking, with shared power, than when there is power politics in which interests are viewed as competing. Evidence for this view is provided by voluntary contribution both in real settings and in experimental tests (Dawes and Thaler, 1988; Foldvary, 1994).

Democratic institutions such as those involved in finding a common ground are more likely to bring about acceptable outcomes than authoritative frameworks (Paehlke, p. 385):

"Human experience suggests that open, democratic societies are more conducive to change than closed, authoritarian ones... Pluralism and flexibility in governance, as well as in economic activities, permit widespread experimentation and social change when challenges arise. Popular mobilization that results from voluntary cooperation tends to outlast coerced obedience...If we extend and deepen our democratic commitment to nature, we can create a better world in the next century."

Therefore, public participation should have a larger purpose than merely being a check on government agency actions: a consensus ensures that all parties voluntarily choose a proposed cooperative solution.

That a common ground type of resource management has succeeded historically is documented in the work of Ostrom and others who have studied the success stories of common property resource management (Bromley, 1992; White, 1994). As Olson's seminal work suggests (1965), a consentual process can be successful in a local setting, when the number of participants is relatively small, and individual actions are more easily observed.

Appendix B summarizes several successful examples of this type of management.
One example involves farmers and the city of New York collaborating to maintain water quality.
Another concerns U.S./Mexico agreements to solve waste problems along the border. Another is a community based effort to resolve land use conflicts within a national forest. Bureau of Land Management has also proposed a Coordinated Resource Management tool to bring about consensus on resource management in a river basin.

A Coordination Process for Pollution Control

The coordination process described below applies for the following situation. Suppose in a local community there are persons (to be called polluters) who get utility from consuming a good that produces an externality for others (to be called pollution sufferers). Of course, pollution sufferers desire a reduction of pollution. The type of process described in this section is designed to help polluters and sufferers together find a solution that makes both better off compared to an externally defined threat point. The solution involves cost sharing for pollution reduction.

The production frontier in this case consists of the efficient points for two goods: the pollution producing activity and the level of environmental quality. Pollution reduction can expand this production frontier, allowing both more of the activity that produces pollution and more environmental quality. The question is how this expansion can be financed. Polluters alone may not have sufficient capital to provide pollution reduction.

Bargaining following a definition of property rights has been one suggestion for solving pollution problems (associated with the Coase theorem). In a bargaining context, polluters and sufferers determine where to locate on the production frontier. Compared to a threat point, a bargaining solution can make each party better off.

With pollution reduction, the bargaining problem includes joint determination of the level of pollution emission, the level of pollution reduction, and the finance of pollution reduction costs. Property rights can be defined in terms of a standard giving the maximum allowable pollution level to be experienced by the sufferer. Such a standard may limit the polluting activity to be less than desired by the polluter. With pollution reduction, even with sharing the cost for pollution reduction, sufferers can be made better off because pollution is reduced compared to the standard. If the threat point is a tax that polluters have to pay per unit of emission, pollution reduction can also make polluters better off by reducing the tax paid. Thus, benefits for both polluters and sufferers depend on there being a noncooperative threat point (e.g. defined by the federal government in terms of a tax and/or standard).

Finding an agreement about cost shares, pollution control level, and emission level is complex because of differing incomes, preferences, and nonlinear costs (eg. economies of scale in some range of pollution reduction volume and exponential increases in cost as percent reduction increases; Knapp, 1978).

The complexity of finding a situation in which all are better off compared to a noncooperative reference was demonstrated in Loehman and Dinar (1994). In a hypothetical but realistic specification regarding birdwatchers and farmers in the San Joaquin Valley, it was demonstrated that a potential agreement could be located in which all are better off. There, for irrigation improvements, the potential agreement was located through iterative search over possible cost shares. Here, a more natural process involving willingness to pay bids and quantity proposals is described.

The purpose of a coordination process is to facilitate determination of a cooperative bargaining solution in a decentralized setting. The process is cooperative because of the cost sharing aspect. Design methodology involves defining a policy instrument and institutional and procedural rules (Loehman and Rassenti, 1995).

Institutional rules for the process are defined in terms of a message space, or language for communication (Hurwicz, 1972, 1973). Here, the message space is in terms of willingness to pay for pollution reduction and amount of emission desired for varying cost schedules. Allocation and adjustment rules determine how messages are related to outcomes (Hurwicz, 1994). Procedural rules specify the sequencing of message arrival and execution of allocation rules. Analogous to a market auctioneer, a coordinator is needed to collect messages from players and execute rules.

With cost sharing to cover costs of pollution reduction, the proposed policy instrument also includes: nonprofit production of pollution treatment; for the polluters, a tax on net pollution emissions and a subsidy on percent reduction. Similar to a Coase situation, the sufferers receive the taxes and pay the subsidies. (Loehman, 1995, compared alternative policy instruments; this one has advantages in terms of simplicity.) The theoretical basis for the policy instrument is described below. The theory demonstrates that a decentralized equilibrium obtains Pareto optimal resource use.

Design Procedures

The policy instrument consists of cost sharing together with taxes and subsidies. It is designed to satisfy Pareto optimality in an abstract setting, i.e. ignoring incentive problems.
Below, the design of the policy instrument and process is described.

Pareto Optimality Benchmark. The externality good is denoted by E (total emission); Q denotes the level of environmental quality after pollution. Private good consumption is denoted by x_i. Pollution reduction activities can reduce net pollution to E(1-r) for percent reduction r. The polluter can then experience the output E while producing a quality level of $Q = \underline{Q} - E(1-r)$. Engaging in pollution reduction has a cost which increases with E and r; cost of reduction is denoted by C(E,r). Cost of pollution control must be included in the resource constraint for the society of polluters and sufferers.

Pareto optimal pollution reduction is described by

$$\max_{r,E,x_i} \; \beta_1 u^1(x_1, E) + \beta_2 u^2(x_2, \underline{Q}-E(1-r))$$

$$\text{s.t.} \quad x_1 + x_2 + C(E,r) \leq M = M_1 + M_2$$

where β_i denote welfare weights. For the budget constraint, the tradeoff between private goods and pollution reduction cost here receives a value of one. Without pollution reduction, r equals zero, and there is no cost for pollution control (C(E,0)=0). The absence of pollution control is a feasible solution for the Pareto optimality problem but may not be optimal (assuming the welfare weight on the sufferer is positive). A positive level of pollution reduction r produces an outward shift of the production frontier (x, Q) compared to the no reduction case.

At a Pareto solution satisfying appropriate second order conditions:

$$u_E^1/u_x^1 - (1-r)\, u_Q^2/u_x^2 = C_E;$$
$$E\, u_Q^2/u_x^2 = C_r$$

Policy Instrument: the Balanced Cost Share Equilibrium. As a threat point, a bureaucratic tax on pollution may be set and collected by a government agency. If the tax is not used to compensate sufferers, such a tax could not produce a voluntary equilibrium, even if the Pareto optimal level of pollution results, because sufferers would not agree voluntarily to accept any pollution level without compensation.

In contrast, for cooperative pollution reduction, cost sharing for pollution reduction occurs between polluters and sufferers, and taxes are paid as compensation to sufferers who in turn subsidize pollution reduction. E and r are jointly agreed upon for given cost shares, taxes, and subsidies.

The balanced cost share equilibrium defined previously for public goods (see Mas-Colell and Silvestre, 1989, and Weber and Wiesmeth, 1991) provides the basis for the decentralized solution. It employs personalized prices as well as cost shares. The balanced cost share equilibrium can be viewed as a generalization of the Lindahl equilibrium that is relevant for both normal (increasing marginal cost) and decreasing marginal cost cases. It was shown by Mas-Colell and Silvestre to apply for multiple goods with a personalized price for each person for each good. Here, there is a mixture of goods and bads, and the personalized prices can be interpreted to be taxes and subsidies.

A balanced cost share equilibrium produces a set of personalized prices (here p_i, q_i), one for each participant and good (E and r), for a given set of cost shares (s_i). At the equilibrium prices and shares, each person voluntarily chooses the same level of the associated goods (here E and r).

The following equilibrium system involves separate choices by each participant for private consumption and E,r. The subscript "1" denotes a polluter and "2" denotes a sufferer:

$$\max_{x_1, E, r} \quad u^1(x_1, E)$$

$$\text{s.t.} \quad x_1 + p_1 E + q_1 r + s_1 C(E,r) \leq M_1$$

$$\max_{x_2, E, r} \quad u^2(x_2, \underline{Q} - E(1-r))$$

$$\text{s.t.} \quad x_2 + p_2 E + q_2 r + s_2 C(E,r) \leq M_2.$$

The sum of the shares must equal one to cover costs. For the equilibrium to be Pareto optimal, the sum of the prices must be zero. Therefore, the equilibrium conditions include the following balancing conditions, where i denotes members of the set of players:

$$\sum_i p_i = 0;$$
$$\sum_i q_i = 0;$$
$$\sum_i s_i = 1.$$

Necessary equilibrium conditions respectively for the polluter and sufferer are:

$$u_E^1/u_x^1 = s_1 C_E + p_1;$$
$$0 = s_1 C_r + q_1.$$

$$-(1-r)\, u_Q^2/u_x^2 = s_2 C_E + p_2;$$
$$E u_Q^2/u_x^2 = s_2 C_r + q_2.$$

Unlike the Coasian bargaining case in which either taxes or subsidies are equivalent in terms of Pareto optimality, here there is no ambiguity: the balanced cost share equilibrium must have a tax on pollution and a subsidy on pollution reduction. From the first order conditions, q_1 must be a subsidy on pollution reduction -- because the marginal cost of increasing reduction is positive. p_2 cannot be positive or zero; otherwise there is a contradiction of positive marginal cost of pollution reduction. Because prices sum to zero, p_1 must be positive. Therefore p_2 is compensation to the sufferer, equal in magnitude to p_1, the tax paid by the polluter per unit E.

Given a set of cost shares s_i, a solution of the system (if it exists) is a mapping from shares to prices and quantities:

$$\{s_i\} \rightarrow \{E, r, x_i, p_i, q_i\}.$$

Taking cost shares as given, the number of equations for the balanced cost share equilibrum system (first order conditions, plus price balance conditions, plus budget constraints defining private goods for each player) exactly equals the number of unknowns (private good consumption, prices on E and r, and E and r quantities). If the Jacobian of the system is not zero, a solution for prices and quantities can be found, given incomes and cost shares (see Diamantaras, 1992). Note that any set of cost shares can potentially result in an equilibrium solution, and multiple equilibria represent different Pareto optima.

The effect of varying shares in this context was explored in Loehman (1995); when equilibria are sparse, several sets of shares can result in nearly the same solution in terms of final welfare.

Message Space and Allocation Rules. The basic messages for the process will be willingness to pay and quantity proposals. For implementation purposes, first order conditions can be translated to be in terms of marginal willingness to pay.

Define marginal willingness to pay for an increase in pollution emission by the polluter as follows. $MWTP^1_E(x_1,E,r)$ is the maximum that the polluter would pay to increase E by one unit starting from E and private good level x_1:

$$u^1(x_1 - MWTP_E^1,\ (E+1)) = u^1(x_1,\ E)$$

Similarly, $MWTP^2_E$ is defined to be the maximum that the sufferer would pay to reduce E by one unit at E and x_2:

$$u^2(x_2 - MWTP_E^2, Q-(E-1)) = u^2(x_2, Q-E).$$

The willingness to pay functions are related to utility evaluated at the appropriate point as follows:

$$MWTP_E^1 = u_E^1 / u_x^1;$$
$$MWTP_E^2 = u_Q^2 / u_x^2.$$

That is, the marginal willingness to pay functions are like demand functions for E and Q respectively by the polluter and sufferer.

First order necessary conditions for the balanced cost share system can be rewritten in terms of willingness to pay as:

$$MWTP_E^1 = s_1 C_E + p_1;$$
$$0 = s_1 C_r + q_1;$$
$$-MWTP_E^2 * (1-r) = s_2 C_E + p_2;$$
$$MWTP_E^2 * E = s_2 C_r + q_2.$$

Note that the polluter only desires a reduction in pollution if it will improve the budget constraint, since r is not present in the polluter's objective function. The sufferer's willingness to pay for r is directly related to $MWTP^2_E$, the maximum the sufferer would pay to reduce E. With the balance restrictions on prices and shares, first order conditions in terms of willingness to pay collapse to:

$$MWTP_E^1 = MWTP_E^2 * (1-r) + C_E;$$
$$MWTP_E^2 * E = C_r.$$

First order conditions then have the interpretion that marginal willingness to pay by the polluter for an increase in E must equal the marginal treatment cost plus the marginal willingness to accept by the sufferer.

The process to find a consensus involves determining levels of E and r to satisfy these first order conditions for the appropriate prices. During the process, the conditions are inequalities:

1) the polluter'marginal willingness to pay to increase E must no less than marginal cost of treating E for the given r level, otherwise the proposed level of reduction is too high;

2) the sufferer's marginal willingness to pay for an emission reduction must be no less than the marginal cost of r per unit of E, otherwise r is too high or E is too low.

The pollution taxes and subsidies for each player are the differences between marginal willingness to pay and marginal cost shares for E or r:

$$p_1 = WTP_E^1 - s_1 C_E;$$
$$p_2 = -WTP_E^2 * (1-r) - s_2 C_E;$$
$$q_1 = -s_1 C_r;$$
$$q_2 = WTP_E^2 * E - s_2 C_r.$$

During the process, new taxes and subsidies are computed each round from willingness to pay messages according to the above rules. Out of equilibrium, they must be normalized to sum to zero. At the equilibrium, all conditions will be satisfied.

Procedural Rules for Finding Environmental Consensus. This section describes the procedural nature of a coordination process to implement the cost sharing equilibrium. The process for pollution reduction is similar to a process for public goods (Loehman and Rassenti, 1995a), except that it is more complicated because of the interaction between pollution emission E and percent reduction r in producing the net environmental quality.

A coordinator is required to execute the process, a role similar to that of an auctioneer but more complex. At each step of the process, the coordinator compares messages to cost information to compute taxes and subsidies. The coordinator computes taxes and subsidies based on rules corresponding to first order conditions. Although the process seems more complex than market price determination, the participants need not know the details of how the coordinator computes charges. They need only respond to suggested charges with their quantity demands.

The process has three essential elements: the use of price (here, taxes and subsidies) as an equilibrating tool, price-taking behavior on the part of polluters and sufferers, and consensus as a stopping rule. The language for reaching agreement involves messages regarding marginal willingness to pay and desired quantities of emission for given pollution reduction, given cost shares, taxes, and subsidies. The process is sequential search for equilibrium - or consensus — with private information about preferences. That is, although participants reveal willingness to pay information, the complete schedule of preference is not known to the coordinator.

Because each participant has only one bid message, but there are two goods (E and r) to be jointly determined, the coordinator is given the task of determining percent reduction. Each participant makes emission proposals taking the percent reduction proposed by the coordinator as given. The coordinator averages the participant emission proposals to find the current group proposal.

Briefly, the process sequence is as follows:

1. For the given percent emission reduction, the current group proposal for emission quantity, and a corresponding charge schedule, each participant is asked if they want to continue the proposal process.

2. On continuance:

(i) Each participant states the desired emission level for the given charge schedule.

(ii) Each polluter states marginal willingness to pay for an increase in emission from the current level; each sufferer states marginal willingness to pay for a reduction in emission from the current level.

(iii) Aggregate bids must exceed marginal treatment costs for emissions to be allowed to increase.

3. The coordinator computes the average of emission proposals. Based on bids, the coordinator proposes a new percent emission reduction (see Appendix B for details). The coordinator simultaneously computes new prices based on first order conditions, evaluated at for current bids, average emission demand, and percent reduction.

The process stops when all agree not to continue. Since the process may have intermediate steps that are not Pareto improving, a voting phase should be used to verify that an equilibrium solution is preferred to the noncooperative threat point. If no agreement is reached, the noncooperative situation is imposed.

Example. Table 1 demonstrates the process. Details of the underlying utility and cost functions are shown in Appendix B. The process starts with zero prices, initial shares proportional to endowment, and zero percent reduction. For the first round, the polluter wants 10 units while sufferers want zero units. Given a percent reduction of .49 and tax of $3.15 per unit of emission, the polluter then reduces demand for emission to 2.87 units while the compensated sufferers propose to increase allowable emission to about 2 or 3 units. Taxes and subsidies are adjusted for the new willingness to pay values, and so on.

For this example, after six interations, the process converged to consensus agreement of 2.56 units of emission and .60 percent reduction; the net pollution level is 1.03, lower than the external standard of 4 units. Even though sufferers are paying a share of the cost of pollution control (each has a cost share of .25) and are subsidizing the percent reduction, the net charges for sufferers are negative (implying a subsidy) because they receive compensation from the polluter for each unit of emission. The polluter pays less with a net charge of $6.11 than with the tax of $4.71 per unit of E for an emission level of 4 units (the external standard). Therefore, compared to the threat point, all are better off at the consensus.

Such a process would be carried out at a local or substate area with polluters and sufferers negotiating directly to find a consensus about pollution emission and reduction. Note the organizational structure implied by this process: there must be a threat point defined externally (eg., by a federal or state government based on health concerns, equity, etc.), a coordinator who is not one of the parties to the agreement, and the parties themselves who negotiate as equals in finding unanimity.

Conclusions

This paper has proposed **a Coordination** process that could be applied to find consensual agreement in a setting with differing objectives or preferences about pollution. Polluters and sufferers together decide the level of pollution emission and pollution deduction as an alternative to an external standard. In contrast to a Prisoners' Dilemma game that has no means of coordination, the coordination process provides a way to reach a preferred cooperative solution.

The design of the process draws on economic theories of equilibrium and search as related to underlying supply and demand schedules, here expressed in terms of willingness to pay.

The proposed process is consistent with the philosophies of decentralization, collaboration or cooperation, and conflict resolution through finding a common ground. However, its success depends on there being a noncooperative threat point which is worse than the cooperative solution found by the process. Thus, there is still a necessary role for an external government body to define the threat point.

To proceed toward implementation of such a process as a formal institution, testing and subsequent modification of the process based on possible incentive problems is required. As a precursor to social experiments to test new institutions, the experimental laboratory provides a method for testing the efficicacy of rules in a relatively low cost way.

(Testing of such a process in a public goods setting is currently under way at the Economics Science Laboratory, University of Arizona. Several similar processes are being compared in terms of message space and related incentives.)

Table 1. Simulation of the Cost Sharing Process for Pollution Control, for given shares (.5,.25,.25).

Round	1	2	3	4	5	6
E_{avg}	3.33	2.91	2.57	2.58	2.54	2.56
E_1 E_2 E_3	10.00 0.00 0.00	2.87 3.61 2.30	2.52 2.58 2.65	2.57 2.65 2.54	2.56 2.58 2.56	2.56 2.55 2.56
r	0.49	0.55	0.62	0.59	0.61	0.60
prices p	3.15 -2.04 -1.10	2.99 -1.75 -1.23	2.80 -1.63 -1.17	2.83 -1.64 -1.18	2.81 -1.63 -1.18	2.81 -1.63 -1.18
prices q	-13.75 11.45 2.29	-5.29 4.30 0.98	-4.90 3.99 0.91	-4.68 3.79 0.89	-4.69 3.80 0.88	-4.70 3.81 0.89
$charge_1$ $charge_2$ $charge_3$	-1.37 8.29 3.80	8.32 -2.58 -1.68	6.45 -1.12 -1.69	6.20 -1.08 -1.62	6.07 -0.98 -1.60	6.11 -1.00 -1.62
$utility_1$ $utility_2$ $utility_3$	2.52 -1.02 -0.23	1.53 0.86 0.47	1.58 0.81 0.50	1.59 0.80 0.49	1.59 0.80 0.49	1.59 0.80 0.49

Utility is gain measured relative to the threat point.

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Appendix A: Applications of the Common Ground Concept

Here, several examples are given to demonstrate the possibility of common ground decisionmaking for environmental problems.

Protection of Catskill and Croton Watersheds

Interested parties were the City of New York and 550 farmers in the two watersheds that provide drinking water for 9 million people each day (McGuire, 1994). To protect drinking water, the city was given two choices by the New York State Department of Health and federal Environmental Protection Agency: creation of a water filtration system at a high cost; or stringent controls on land use in the watershed areas. Initially, the city contemplated strict regulation of animal waste and grazing which would have affected almost all farms adversely. Instead, a collaborative solution was found with the following ingredients:

-- In place of the strict regulation, adoption of whole farm planning to implement best management practices unique for each farm.

-- City funding for implementation of whole farm planning beyond current cost-sharing programs.

-- Voluntary participation by farmers. But, unless there is at least 85 percent participation, the city can reinstate strict regulation (the noncooperative reference).

-- Establishment of an areawide council representing all interested parties to monitor and assist the program.

Cross-Border Environmental Management [from personal communication with David Fege, Interim Director, Border Liason, EPA San Diego Office, EPA Region 9]

There is local, state, and federal partnership evolving in two border areas for water quality improvement: between Nogales, Arizona and Sonora, Mexico; between San Diego and Tijuana, Mexico. The areas are similar in terms of the problem: rivers are flowing from south to north, and are contaminated in the process; waste water treatment is being strained by limited capacity and increasing population. In both cases, there has been much citizen involvement. The result is joint treatment plants being built at the border with cost sharing between the interested parties. The process is being helped with new funding available from NAD Bank (North American Development Bank) which will provide loans for waste water, drinking water, and landfills. Projects for NAD Bank will be reviewed by a new binational institution: BECC (Border Environmental Cooperation Commission) which includes representatives from federal, state, citizen, public interest groups, and the International Boundary Water Commission (a 100 year old institution). The impetus for new joint actions is the NAFTA agreement.

Negrito Watershed Community Project [from a proposal and letter to Maynard Rost, USDA Forest Supervisor from Ted Butchart, April 30, 1992]

From the proposal for a demonstration project for ecosystem management on a landscape scale:

"NARRATIVE: Timber sales on the Gila National Forest are wedged in a logjam of appeals and regulatory restrictions. Cattle compete with elk for limited forage. Riparian conditions continue to decline. Because traditional planning strategies do not seem likely to satisfactorily resolve all of these approaches, there now exists an opportunity to try another approach: New Perspectives.

ABSTRACT: A five-step demonstration project is proposed for managing natural resources on a specific landscape within the Gila National Forest. Planning strategies would integrate the management of individual resources on a long-term basis and according to thorough data inventories. Projecting desired future forest conditions, monitoring cumulative effects, and ensuring the sustained health of forest communities would serve as guiding principles.

LONG-TERM SOLUTION: New Perspectives and integrated resource management strategies may offer a genuine opportunity to resolve the problems that currently stymie plans to manage resources on the Gila National Forest effectively, productively and responsibly. These planning strategies address management problems of any individual resource in the large context of the entire ecosystem. In the case of timber harvests, for example, the allowable sale quantity would be a function of silvicultural activities planned to promote the health and diversity of the ecosystems.

...these kinds of policies can be implemented with little reduction to the production of commodities. Stewardship does replace production, however, as the guiding principle."

"Dear Maynard,

We would like to thank you for your support of the Negrito Creek Watershed Community Project. This is a community initiated attempt to find the common ground between people who have traditionally seen themselves as adversaries. Your willingness to work with all the parties and move toward a community-based, landscape-level management philosophy is greatly appreciated.

We believe that developing a rational and defensible basis for management, based on solid information at various ecological scales (which will help the group get at cumulative effects), and a complete consensual airing of concerns between all parties, will not only reduce the conflicts between user groups, but will significantly ease life within the Forest Service by solving conflicts outside the courts. In the end, the land and all of its inhabitants will benefit from this kind of cooperative, ecological approach."

<u>On Coordinated Resource Management (CRM)</u> [from "The Debate about BLM and Nature Conservancy Preservation Programs for the San Pedro Watershed, report by Jim Corbett to Saguaro-Juniper and El Potrero shareholders, 11-24-92]

..."The BLM [Bureau of Land Management] has proposed Coordinated Resource Management (CRM) as the tool for concerned citizens to use to come to a consensus on resource management of the San Pedro River Basin....CRM is operationally defined in a 1987 memorandum of understanding by the BLM, Soil Conservation Service, Forest Service, and Extension Service. It involves all affected interests using a team approach to arrive at agreement by consensus of the team....CRM is to be concerned with land conditions and uses and the corresponding needs for conservation activities and agreements throughout the watershed."

Appendix B: Simulation for Pollution Emission and Treatment

Simulation is based on a problem with one polluter (i=1) and two sufferers (i=2,3). Specifications for utilities are:

$$u_1 = \log(1+x_1) + \log(1+E);$$
$$u_2 = \log(1+x_2) + 2\log(1+Q-E(1-r));$$
$$u_3 = \log(1+x_3) + \log(1+Q-E(1-r)).$$

Incomes for the three participants are respectively \$20, \$10, and \$10; that is, the polluter has twice as much income as the sufferers. Initial values are $Q_o=10$ ad $E_o=4$.

For the noncooperative reference case, it is assumed that an external bureau will determine a tax based on marginal damage cost; this tax is not paid to the sufferers. The total marginal damage cost at E_o for the two sufferers is \$4.71 per unit E (\$3.14 and \$1.57 respectively for the two sufferers). Resulting base utility levels are $u^1_o= 2.38$; $u^2_o= 6.29$; $u^3_o=4.34$.

Cost of pollution reduction r for emission E is defined by

$$C(E,r)=.1E^2(10r-5r^2+5r^3).$$

that is, marginal costs of E and r are increasing, so that the polluter could make a profit by producing pollution reduction for a price.

The participants each maximize utility subject to a budget constraint with the individual nonlinear cost share function subtracted from income. The coordinator solves the following optimization problem:

$$\max_{p_i,q_i,l_i,r} \sum_i l_i^2 - r\sum_i q_i$$
$$s.t.$$
$$x_i=l_i+M_i-p_i*E-q_i*r-s_i*C(E,r),\ i=1,3;$$
$$q_1=-s_1*C_r;$$
$$q_2=MWTP_E^2*E-s_2*C_r;$$
$$q_3=MWTP_E^3*E-s_3*C_r;$$
$$p_1=MWTP_E^1-s_1C_E;$$
$$p_2=-MWTP_{E_2}*(1-r)-s_2C_E;$$
$$p_3=-MWTP_E^3*(1-r)-s_3C_E.$$

l_i are slack variables for the budget constraints (which must be known to the coordinator) and q_i serve as slack variables for the first order conditions. Prices are not constrained to sum to zero in the optimization but are afterwards normalized to sum to zero.

GAMS was used to simulate the process to solve the individual optimization problems and to compute resulting prices.