The Feasibility of Cost Sharing in Nonpoint Source Pollution Control

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Problem and Research Objectives

Both the Rhode Island State and municipal governments are looking for an abatement policy which is both cost-effective and accepted by the public. Cooperative policies involving cost sharing have been used to encourage the adoption of best management practices to control nonpoint source (NPS) pollution.

Cooperative programs involving cost sharing can make cost minimizing programs more acceptable to the public. Alternative solutions to NPS pollution may be less efficient programs which require significant amounts of enforcement or expensive community wide sewer.

A game-theoretic framework, incorporating a bargaining process between subpopulations within a watershed, can be used to determine acceptable cost allocations (e.g., cost share ratios) for NPS pollution control. A game-theoretic framework involving joint social cost or social welfare functions can be used to model cost sharing agreements and cooperative solutions to environmental protection. A new framework is used in this study which acknowledges water quality benefits indirectly through empirical public preference models. The framework also acknowledges the potential for cooperation towards NPS pollution control between neighborhoods within a wastershed which also is a tool for designing optimal cost sharing programs.

The objectives of this study are (1) to provide an analytical and empirical framework for comparing the acceptability of cooperative and noncooperative programs for mitigating NPS pollution, and (2) to test the hypothesis that publicly acceptable cost share programs for NPS pollution control can be designed which minimize NPS pollution abatement costs.

Methodology

An analytical framework for determining the feasibility of cooperative (e.g., cost sharing) water quality protection programs involving septic systems improvements has been specified. The framework relies on calculating "values" for players involved in cooperative games in characteristic function form (e.g., Shapley values) and partition function form. Values determine benefit and cost allocations for property owners within watersheds. Games in partition function form are able to better characterize games involving public goods and behavior such as free-riding. Values for games in partition function form are theoretically more applicable to situations involving water quality improvements and nonpoint source pollution control, while values for games in characteristic function form have traditionally been used in wastewater management.

To test the existence of an acceptable cost share solution which minimizes the cost of controlling nonpoint source pollution, cooperative games values have been used to allocate septic system management costs among three areas of Potowomut, RI (e.g., players): (1) a wellhead protection district, (2) a riparian zone, and (3) an area with no abatement requirements. The framework is also being used to demonstrate the applicability to other communities or watersheds where environmental conditions may differ. Issues such as the need for weighting factors to adjust for population size and the impact of assumptions about player threats are being evaluated using different Wastewater Management District Plans in Potowomut, RI.

Principal Findings and Significance

In 1996, the City of Warwick proposed an ordinance requiring specific septic system management measures for a wellhead protection district to protect drinking water from sewage in Potowomut. Some homeowners resisted the ordinance at the meeting and no further action has been taken to protect drinking water from sewage. The situation in Potowomut is characterized by two conditions: (1) the city decides abatement levels or action to be taken by individual homeowners, and (2) program approval must be unanimous. If cost sharing is implemented through the use of homeowner fees, the process for defining homeowner fees is a cooperative game and cooperative game values are suitable focal points for arbitration. The cooperative game consists the three players representing the wellhead protection district(player W), the Greenwich Bay shoreline area (player G), and the non-abatement or non-sensitive area where septic systems are assumed to have no effect on water quality (player N).

Cooperative game values in this study are weighted to insure that no homeowners are being paid to participate in programs, and, in the case of the Shapley value, to insure that the results for the three-player game (where players are assumed to represent a partnership of identical homes) are equal to the results for a complex game between the individual homes in Potowomut (e.g., insure that the partnership axiom is met). The weighting scheme applied to the Shapley value is applied to the incomplete cooperation (IC) value, but the partnership axiom is not guaranteed to be satisfied for the weighted IC value. An alternative system for weighting IC values for three-player games is developed and appears to satisfy the partnership axiom.

To demonstrate cost allocation procedures, homeowner fees are determined for a program requiring 50 connections in the Greenwich Bay Shoreline area and 50 connections in the wellhead protection district. Homeowner fees are derived by (1) specifying non-cooperative payoffs to all coalitions using empirical models of program preferences, (2) Solving for equilibrium conditions in non-cooperative games, (3) defining characteristic function and partition function values based on non-cooperative equilibrium payoffs, (4) calculating Shapley values and IC values from characteristic and partition functions, and (5) allocating costs based on Shapley and IC values.

Grants are available to reduce the cost of new septic systems in Potowomut, and cost allocations are calculated for a range of grant levels. The results indicate that when weighted Shapley values are used, homeowner fees exceed WTP values for player G at grant levels between 10% and 20% under rational threats and at grant levels between 5% and 15% under Nash solutions. When partially weighted IC values are used, fees for player G again exceed WTP values under Nash solution but to a lesser extent, but never exceed WTP under rational threats. The use of fully weighted IC values decreases the expected benefits of free-riding, and fees are noticeably larger under fully weighted IC values for players with the greatest expectations about free-riding.

Homeowner fees are a discontinuous function of grant levels due to discrete changes in characteristic and partition function values and threat conditions. Discontinuities are more frequent and of greater magnitude when Nash solutions to non-cooperative games are assumed. The size of benefits from free-riding also increases the magnitude of discontinuities.

In cases of water quality and other public goods, optimal levels of provision occur when the sum of marginal benefits is equal to the marginal cost of public good provision. However, actual situations where optimal levels of abatement are defined and implemented are rarely encountered. A more common situation involves government assurances that water quality will be protected if certain abatement plans are implemented. Water quality benefits are commonly defined in terms of numerical criteria that must be met, and the existence of discrete or binary water quality protection goals guarantees positive net benefits to be allocated among players in most situations.

The cooperative game solutions used to allocate costs in this study are expected to be useful in other situations involving nonpoint source pollution control where the perceived benefits of water quality protection are discrete. These procedures are also applicable to games with more than three players, but determination of characteristic and partition function values requires solutions to more complex non-cooperative payoff matrices.

The first draft of the project report is near completion. The outline of the report is shown in Figure 1.

Figure 1. Outline of Project Report

I. INTRODUCTION

II. A COOPERATIVE GAME FRAMEWORK FOR COST ALLOCATION

- Optimal Public Good Provision
- Solutions for Two-player Cooperative Games
- Solutions for N-player cooperative Games
    - Solution values for games in characteristic function form
    - Values for games in partition function form
- Modeling Cooperative Agreements for Wastewater Management Districts
- Estimating Cost Allocations Using Cooperative Game Values

III. COST ALLOCATION FOR SEPTIC SYSTEM IMPROVEMENTS IN A COASTAL COMMUNITY

- Description of the Cooperative Game and the Players
    - Characteristic Functions
    - Partition Functions
- Cooperative Games Solutions and Net Benefit Allocations
    - Shapley Values
    - Incomplete Cooperation Values
- Cost Allocation and Homeowner Fees
- A Comparison of the Applicability of Shapley and IC Values
    - The impact of grants on cooperative agreements

IV. GENERAL APPLICABILITY AND SENSITIVITY OF THE COST ALLOCATION

MODELING FRAMEWORK

- The Impact of Free-riding
- Limitations of Modeling Assumptions
- Other Institutional Considerations

V. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK

Sections four and five of the report discuss relevant issues such as (1)how do the allocation procedures discussed in this study compare to allocation procedures used in the past by federal agencies, (2)what institutional characteristics (e.g., political representation and voting rules) must be considered when assessing the applicability of different cost allocation methods, and (3)what recommendations can be given to managers and planners based on the results of this study. It should be noted that the US Environmental Protection Agency is expected to provide guidance to states about efficient and acceptable methods for allocating waste treatment responsibilities across point and nonpoint source dischargers within watersheds not currently meeting water quality standards (i.e., TMDL program). The cooperative game methods and results discussed in the project report outlined above can be compared to the allocation methods currently referenced by EPA and may help predict stakeholder behavior in watershed management.

Following completion of the project report, a significantly condensed version of the report will serve as draft of a paper for publication in a peer reviewed journal (e.g., Journal of Environmental Economics and Management, Journal of Public Policy, Water Resources Research, etc.). The anticipated title is "Free riding and Cost Allocation Solutions in Nonpoint Source Pollution Control".

Descriptors

Economics, Policy analysis, Nonpoint pollution, Cost sharing, individual Sewage Disposal System.

Articles in Refereed Scientific Journals

Miller, Christopher, Cost Sharing and the Benefits of Integrated Water Quality Protection Goals, in preparation, journal to be determined.

Miller, Christopher, Free-riding and Cost Allocation Solutions in Non-point Pollution Control, in preparation, journal to be determined.

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications