Point-Nonpoint Source Pollution Trading Using Collective Performance Incentives

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Tradable permit markets for point-nonpoint source pollution are being encouraged by the US Environmental Protection Agency for the regulation of water quality. Nonpoint source pollution is distinguishable from point source pollution in terms of its observability. Unlike point sources, the individual nonpoint source loadings and abatement cannot be observed by the regulator. At the aggregate level, both point and nonpoint source loadings and abatement are observable by the regulator. Therefore, traditional permit trading based on individual performance standards cannot be used with markets that include nonpoint sources. Instead, the regulator must choose to use an enforcement mechanism based on an observable proxy for individual nonpoint source abatement (Letson, 1992; Malik, et al, 1993: Malik, et al., 1994; Taff and Senjem, 1996), or one based on the observable collective level of nonpoint source pollution (Meran and Schwalbe, 1987; Segerson, 1988). The former, technology-based trading, has been the preferred approach in both the economic literature and in practice. This paper addresses the issues associated with trading using the latter, a collective performance-based approach. Using a principal-agent framework, this paper sketches both the potential benefits and obstacles associated with switching to a collective performance-based approach.

Although tradable permit markets can be constructed in a variety of institutional forms, they all share some common elements. First, overall environmental quality goals must be established. Within watershed-based trading markets, this can be established through analyses such as Total

Maximum Daily Load (TMDL). The TMDL allows regulators to learn the aggregate contributions to pollution from various types of polluters, such as the agricultural sector, development, and industrial point sources, and it can provide the baseline information from which performance goals for improving water quality can be developed. Changes in ambient water quality can also be measured. Second, the regulator must allocate the total allowable level of discharge among the regulated firms within the market. Regulated firms traditionally included only point source polluters. This is accomplished by assigning individual performance standards to the dischargers, where the sum of individual performance standards must equal the overall regulatory goal. Any discharge above permitted levels must be abated, but the choice of abatement method is left to the discharger.

Discharge permits can initially be distributed in a number of ways (i.e., free allocation or auction) without affecting the overall efficiency of the market, as long as individuals are allowed to subsequently trade the permits (Tietenberg, 1985). Trading can be implemented through various institutions. They may involve licensing a set of brokers to facilitate trades, developing an auction system, or allowing market exchange between individuals or groups of dischargers. Since discharge allowances can be traded, purchasing permits from other dischargers is a valid form of abatement. Firms with relatively high abatement costs may be willing to buy permits from firms with relatively low abatements costs. In exchange, the low cost firm takes on the lion's share of the abatement.

Traditionally, the key to the success of tradable permit markets has been that the overall standard of abatement is achieved regardless of which discharger is performing the abatement. The total number of permits in the market always remains equal to the total allowable level of discharge.

Although the exchange of permits affects the distribution of abatement, it does not affect the total level of abatement. Efficiency is achieved when each firm's marginal cost of abatement is the same, and, therefore, all benefits of trade have been exhausted.

Pollution is typically categorized as either point source or nonpoint source. The primary distinction between the two forms of pollution is based upon the ability to observe discharge at the point of origin. Discharge from a point source of pollution can be observed at both the point of origin (i.e., individual contribution level) and the point of accumulation (i.e., the aggregate contribution level). Nonpoint source pollution, on the other hand, can only be measured at the aggregate level. This is due to nonpoint source pollution's diffuse nature.

Point source pollution is often referred to as "end-of-pipe" pollution, because it has a distinct and observable point of origin such as a factory waste pipe. Nonpoint source pollution enters waterways not from a single location, but is carried over and through the soil. One example of nonpoint source pollution is the runoff of nitrogen and phosphorous from agricultural land use. Since the nonpoint source holds more information regarding its own discharge of pollutant than either the regulator or the point sources, trading must occur in an environment of asymmetric information. While the nonpoint source may or may not know its own discharge level with certainty, it can observe it to a greater degree than anyone else.

In the tradable permit market, point sources cannot attribute nonpoint source abatement to the responsible party and thus have difficulty in developing contracts that are both efficient and effective. Classic asymmetric information problems of hidden information and hidden action confound the ability of the point source to offer optimal contracts for the abatement of nonpoint source pollution. This results in the under provision of nonpoint source abatement at greater cost.

We can classify models of asymmetric information in many ways. Traditionally, if the informed party holds the information prior to contracting with the uninformed party we refer to the problem as one of hidden information. Models of hidden information are commonly referred to as adverse selection models since the uninformed party cannot observe important characteristics of the informed party prior to contracting. If the information held by the informed party regards decisions made after the signing of the contract we refer to the problem as one of hidden action. Models of hidden action are referred to as moral hazard models, as the informed agent can make unobservable decisions that may be detrimental to the contracted goal after the contract is signed.

Since the early 1970s, economists have used the principal-agent framework since to examine the efficiency of incentive contracts in an environment of asymmetric information. The principal-agent model allocates all of the bargaining power to one party, which allows the modeler to observe the set of constrained Pareto optima that can be obtained by maximizing the utility of one agent while the other is held to a given utility level (Macho-Stadler and Perez-Castrillo). This simplifies the bargaining game to a Stackelberg form in which the uninformed party (i.e., the principal) makes a "take it or leave it" contract offer to the informed party (i.e., the agent).

Nonpoint source pollution does not fit the traditional principal agent model, where it is assumed that the principal can observe individual output but is concerned with some unobserved characteristic of the agent, or some level of unobserved effort of the agent. As stated previously, the point source and regulator cannot observe the abatement output from any individual nonpoint source. However, this does not rule out the use of the principal-agent framework to develop incentive contracts for pollution trading.

Trading markets can deal with the asymmetry of information in either of two ways: (i) the technology-based approach, or (ii) the collective performance-based approach. Each uses a different observable and verifiable sets of information. The technology-based approach concentrates on the observable level of abatement technology being used. In the nonpoint source case, abatement technology takes the form of best management practices. Thus, trading is based on a proxy for individual abatement. The collective performance-based approach concentrates on the observable level of aggregate nonpoint source abatement. Point sources purchase an aggregate amount of abatement from a group of nonpoint sources.

<u>Technology-based Trading</u>

In both the economics literature and in practice, nonpoint sources have been incorporated in trading markets through the use of a technology-based trading approach. Observable units of abatement technologies, such as filter strips or animal waste storage lagoons, serve as a proxy for the unobservable level of abatement performed by individual nonpoint sources. In this setting, the point source is confronted with both hidden information and hidden action problems

The actual production of abatement through BMPs relies heavily on heterogeneous site characteristics that are most likely known to the nonpoint source but are unknown to the point source. Thus a hidden information problem exists prior to contracting. The point source would like to be able to sort high productivity BMPs from low productivity BMPs. In addition, the nonpoint source can exert different effort levels after the contract is initiated which may also affect BMP abatement performance.

The introduction of a proxy for individual nonpoint source abatement allows the regulator to observe inputs in the abatement process, and provides a verifiable basis for enforcing noncompliance in terms of failing to adopt those inputs. In the case of point sources, the regulator can observe the abatement of an individual firm and can shift the uncertainty associated with the performance of the chosen abatement technology back to the individual polluter. However, the nonpoint source abatement proxy cannot help the regulator with the identification of noncompliance due to variations in proxy accuracy. The regulator cannot shift the uncertainty associated with nonpoint source abatement technology back to the individual nonpoint source. Instead, the regulator shifts this risk to the point sources by requiring over-abatement through the trading ratio.

A trading ratio requires point sources to purchase additional units of new technology to protect against increases in overall loads. For example, if an acre of filter strip does not perform well in phosphorous abatement, then having additional acres will provide enough phosphorous abatement to help ensure that the overall regulatory goal will still be met. In a permit market with a trading ratio, the regulator holds a prior belief regarding the distribution of BMP productivity characteristics in the watershed and assumes minimum effort levels. Using this information, the amount of over abatement required to achieve an exogenously determined safety measure is set as the trading ratio.[1]

[1] Readers are directed to Malik, et al (1993) and Taylor, et al (2000) for detailed analysis of point-nonpoint source pollution trading and the optimal trading ratio.

Offsetting point source abatement with nonpoint source abatement is based on a technology standard, as opposed to a performance standard. Point sources receive a certain reduction in required abatement levels, in exchange for an uncertain level of abatement from nonpoint sources. Proxies are used to approximate nonpoint source abatement levels, and trading ratios are used to provide a safety margin, but the success of any offset remains uncertain. In addition, this approach is costly in the sense that it ignores valuable information that could reduce contracting costs. In addition, the technology-based trading approach limits the menu of abatement choices for the nonpoint source. It mimics command-and-control regulation in the sense that the point source dictates the observable abatement technology to be adopted. An approach that incorporates additional verifiable information and that allow flexibility in nonpoint source abatement decisions could prove to be more cost-effective.

Performance-based Trading

The only verifiable information the point source has on nonpoint source abatement directly is the aggregate level of nonpoint source abatement. The point source can contract for an aggregate level of abatement produced jointly by multiple agents, but cannot observe individual abatement once the contract is signed. There exists a rich literature on overcoming the moral hazard problem of nonpoint source pollution through collective performance based incentive contracts. It builds out of the research on the class of incentive contracts required in the case of joint production, where the final product depends on the collective work of a group of individuals. In cases of a group of individuals working to create a single product or project, the agents must combine their individual effort levels to produce the common good. The difficulty of structuring an efficient contract is similar to that of the free-rider problem in the provision of public goods. Since shirking in effort is only detected through the common final product, the effect of individual shirking is spread across all agents in the group. Thus any efficient contract must make each agent feel responsible for the whole of the final product in order to provide the appropriate incentive for overcoming the free-rider problem.

Holmstrom (1982) argues that when the principal cannot observe individual efforts that contribute to the production of a common output, budget balancing incentive contracts will not be efficient if agents are risk neutral. Budget balancing means that all of the revenue for the production of the common output is distributed among the agents in the team. To achieve efficiency in this case, when collective output is below the contracted level each member of the group receives a payment of zero. In such cases, Holmstrom suggests that an additional agent be contracted to manage the other agents. Compensation of a supervisory agent prevents all of the revenue from being distributed among the productive agents and also introduces an additional element of control. The introduction of a bureaucracy adds costs, but allows for efficient incentive contracts for production.

Since Holmstrom, a variety of collective-performance based incentive contracts have been proposed in the literature. Each has its own strengths and limitations for application to the point-nonpoint source trading market. In addition, assumptions regarding budget balancing and risk aversion vary between mechanisms.

Rasmussen (1987) shows that by employing a random penalty a budget balancing incentive contract can be efficient if agents are risk averse. Holmstrom's result is dependent upon the risk neutrality of the agents. When agents are risk averse the efficient outcome is possible with budget balancing and random penalties. When aggregate nonpoint source abatement is observed to be less than the contracted amount, a scapegoat contract will randomly select and fine one member of the group. The fine is then redistributed among all of the other agents in the group. A massacre contract selects a member of the group who will receive the sum of the fines imposed on all of the other members of the group, when aggregate abatement is observed to be lower than the agreed upon level. Both forms of random penalty can produce efficient outcomes, although the massacre contract is the most robust.

The general research on contracting for joint production was applied directly to the case of nonpoint source pollution by Segerson (1988) and Xepapadeas (1991), among others. Adopting frameworks similar to those of Holmstrom and Rasmussen, these models propose regulatory regimes for the optimal contracting of nonpoint source abatement as opposed to voluntary incentive contracts.

Segerson (1988) adapts Holmstrom's non-budget balancing joint production model in the nonpoint source case with risk neutral agents. When the group of nonpoint source dischargers provide more than the regulated level of aggregate nonpoint source abatement each agent receives a subsidy payment. The individual effort of the agent is aligned with the aggregate abatement output goal through the threat of a tax equal to the full marginal damage of violations from the contracted level of aggregate abatement. When aggregate abatement is less than the regulated level each agent is assessed a tax that is linear in the violation of the aggregate standard. Each abater will equate their own marginal cost to the marginal benefit of aggregate abatement, and the optimal level of abatement will be delivered by each agent.

Xepapadeas (1991) derives an optimal contract between the regulator and nonpoint sources using the budget-balancing approach with risk averse agents developed by Rasmussen. In this scheme subsidies are paid to all nonpoint sources in the group, in proportion to their declared abatement level. If the contracted level of aggregate abatement is not achieved, a fine is charged to a randomly chosen polluter. The fine must be high enough to prevent shirking and achieve the Pareto optimal abatement level. Kritikos (1993) shows a modification of the budget-balancing contract of Xepapadeas that allows for Pareto optimality.

Collective-Performance Incentives within a Trading Market

There has been substantial work on creating incentive contracts for joint production in general and for nonpoint source pollution in particular. This work sheds light on how a trading mechanism between a regulatory agency and nonpoint sources may work. However, in choosing an appropriate mechanism for trading pollution between point and nonpoint sources further research on collective performance contracts is needed. The importance of the voluntary participation aspect of trading programs, the ability to employ penalties, and the importance of budget balancing constraints within a pollution trading market will impact on the form of the optimal incentive contract.

Point-nonpoint source trading programs to date have been structured around the voluntary participation of nonpoint sources. Due to the political strength of the agricultural sector, the largest source of US nonpoint source pollution, this institutional structure is likely to remain in the future. Thus, collective performance incentive contracts will have to meet a participation constraint. This is something that is not an issue in the works of Segerson and Xepapadeas where it is assumed that an agency is directly regulating the nonpoint sources and thus participation is mandatory. The inclusion of a participation constraint may rule out various penalty mechanisms by requiring higher base subsidy payments or lower fines.

Severe penalties are not intended to be used in these principal-agent models. They are meant as background threats that encourage the optimal actions of the agents and thus attain the collective goal. However, in the presence of production uncertainty (i.e., as is the case with random weather shocks on nonpoint source abatement production) these penalties may become a major factor. Random penalties have a higher probability of penalizing non-shirking agents in the presence of production uncertainty and may become difficult to contract over time.

Traditionally, non-budget balancing contracts are seen as problematic because the group must discard its output if the aggregate level of output is not attained. When the output is a physical product that can be sold, the agents would prefer to void the contract with the principal and sell their individual output on the market. Thus, when budgets are not balanced an incentive to recontract with the principal develops. Non budget-balancing contracts can overcome the recontracting problem by creating a bureaucracy, such as Holmstrom's supervisory agent.

The Principal-agent framework is a model of non-cooperative behavior. When agents begin to cooperate or create coalitions they can undermine the goals of the principal's contract. All joint production incentive contracts share a concern for the effects of coalition building between productive agents and/or between productive agents and supervisory agents. In decentralized models, where an agent is contracted to act as supervisor, the principal cannot allow the contract incentive (whether a prize or a penalty) to be determined solely by the supervisor. The principal must complicate the traditional incentive contract to discourage any coalition building between agents. When coalitions are possible an efficiency loss will occur in operation of the organization contract.

Whether non-budget balancing is as much of a concern in the nonpoint source abatement context is not clear. The parties will not be able to sell their individual output elsewhere, as it is not a marketable good outside of the point source abatement market. Thus, a non budget-balancing contract may not require decentralized agents and may not need to incur the efficiency losses discussed above.

Conclusions and Scope of Future Research

Collective performance incentive contracts shift the burden of uncertainty from regulators to polluters who have access to information of various kinds that is unavailable to others. Under the current technology-based trading approaches society and/or the point sources bear all of the uncertainty about performance of BMPs. Under a collective performance-based system, however, the agents involved in the trade would be held liable for non-compliance with water quality standards, placing the burden of uncertainty on the agents best able to adapt to it. In addition, collective performance-based approaches may be able to reduce abatement costs because they allow the nonpoint sources a greater deal of flexibility in abatement choice. It also ties trades to the aggregate level of pollution in the watershed, which is the goal of the regulatory program.

Future research must be conducting in two areas. The first is the development of a collective performance incentive mechanism that fits the unique institutional setting of a point-nonpoint tradable permit market. The second is to develop models of trading using various classes of technology-based incentive contracts and collective performance incentive contracts. These models will allow researchers to evaluate permit market design and the conditions in which collective performance-based trading may be superior to technology-based approaches..

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