Market Mechanisms and Incentives: Applications to Environmental Policy

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October 17th – 18th, 2006

October 17, 2006: Market Mechanisms in Environmental Policy

8:00 a.m. – 8:45 a.m.	**Registration**	
8:45 a.m. – 11:45 a.m.	**Session I: Brownfields and Land Issues** Session Moderator: **Robin Jenkins**, EPA, National Center for Environmental Economics	
	8:45 a.m. – 9:00 a.m.	Introductory Remarks: **Sven-Erik Kaiser**, EPA, Office of Brownfields Cleanup and Redevelopment
	9:00 a.m. – 9:30 a.m.	Environmental Liability and Redevelopment of Old Industrial Land **Hilary Sigman**, Rutgers University
	9:30 a.m. – 10:00 a.m.	Incentives for Brownfield Redevelopment: Model and Simulation **Peter Schwarz** and **Alex Hanning**, University of North Carolina at Charlotte
10:00 a.m. – 10:15 a.m.	**Break**	
	10:15 a.m. – 10:45 a.m.	Brownfield Redevelopment Under the Threat of Bankruptcy **Joel Corona**, EPA, Office of Water, and **Kathleen Segerson**, University of Connecticut
	10:45 a.m. – 11:00 a.m.	Discussant: **David Simpson**, EPA, National Center for Environmental Economics
	11:00 a.m. – 11:15 a.m.	Discussant: **Anna Alberini**, University of Maryland
	11:15 a.m. – 11:45 a.m.	Questions and Discussion
11:45 a.m. – 12:45 p.m.	**Lunch**	
12:45 p.m. – 2:45 p.m.	**Session II: New Designs for Incentive-Based Mechanisms for Controlling Air Pollution** Session Moderator: **Will Wheeler**, EPA, National Center for Economic Research	
	12:45 p.m. – 1:15 p.m.	Dynamic Adjustment to Incentive-Based Environmental Policy To Improve Efficiency and Performance **Dallas Burtraw, Danny Kahn,** and Karen Palmer, Resources for the Future

	1:15 p.m. – 1:45 p.m.	Output-Based Allocation of Emissions Permits for Mitigating Tax and Trade Interactions **Carolyn Fischer**, Resources for the Future
	1:45 p.m. – 2:00 p.m.	Discussant: **Ann Wolverton**, EPA, National Center for Environmental Economics
	2:00 p.m. – 2:15 p.m.	Discussant: **Arik Levinson**, Georgetown University
	2:15 p.m. – 2:45 p.m.	Questions and Discussion
2:45 p.m. – 3:00 p.m.	**Break**	
3:00 p.m. – 5:30 p.m.	**Session III: Mobile Sources** Session Moderator: **Elizabeth Kopits**, EPA, National Center for Environmental Economics	
	3:00 p.m. – 3:30 p.m.	Tradable Fuel Economy Credits: Competition and Oligopoly **Jonathan Rubin**, University of Maine; **Paul Leiby**, Environmental Sciences Division, Oak Ridge National Laboratory; and **David Greene**, Oak Ridge National Laboratory
	3:30 p.m. – 4:00 p.m.	Do Eco-Communication Strategies Reduce Energy Use and Emissions from Light Duty Vehicles? **Mario Teisl**, **Jonathan Rubin**, and **Caroline L. Noblet**, University of Maine
	4:00 p.m. – 4:30 p.m.	Vehicle Choices, Miles Driven, and Pollution Policies **Don Fullerton**, **Ye Feng**, and **Li Gan**, University of Texas at Austin
	4:30 p.m. – 4:45 p.m.	Discussant: **Ed Coe**, EPA, Office of Transportation and Air Quality
	4:45 p.m. – 5:00 p.m.	Discussant: **Winston Harrington**, Resources for the Future
	5:00 p.m. – 5:30 p.m.	Questions and Discussion
5:30 p.m.	**Adjournment**	

October 18, 2006:

8:45 a.m. – 9:15 a.m.	**Registration**	
9:15 a.m. – 12:20 p.m.	**Session IV: Air Issues** Session Moderator: **Elaine Frey**, EPA, National Center for Environmental Economics	
	9:15 a.m. – 9:45 a.m.	Testing for Dynamic Efficiency of the Sulfur Dioxide Allowance Market **Gloria Helfand**, **Michael Moore**, and **Yimin Liu**, University of Michigan
	9:45 a.m. – 10:05 a.m.	When To Pollute, When To Abate: Evidence on Intertemporal Use of Pollution Permits in the Los Angeles NOx Market **Michael Moore** and **Stephen P. Holland**, University of Michigan

10:05 a.m. – 10:20 a.m.	**Break**	
	10:20 a.m. – 10:50 a.m.	A Spatial Analysis of the Consequences of the SO_2 Trading Program **Ron Shadbegian**, University of Massachusetts at Dartmouth; Wayne Gray, Clark University; and Cynthia Morgan, EPA
	10:50 a.m. – 11:20 a.m.	Emissions Trading, Electricity Industry Restructuring, and Investment in Pollution Abatement **Meredith Fowlie**, University of Michigan
	11:20 a.m. – 11:35 a.m.	Discussant: **Sam Napolitano**, EPA, Clean Air Markets Division
	11:35 a.m. – 11:50 a.m.	Discussant: **Nat Keohane**, Yale University
	11:50 a.m. – 12:20 p.m.	Questions and Discussion
12:20 p.m. – 1:30 p.m.	**Lunch**	
1:30 p.m. – 4:35 p.m.	**Session V: Water Issues** Session Moderator: **Cynthia Morgan**, EPA, National Center for Environmental Economics	
	1:30 p.m. – 2:00 p.m.	An Experimental Exploration of Voluntary Mechanisms to Reduce Non-Point Source Water Pollution With a Background Threat of Regulation Jordan Suter, Cornell University, Kathleen Segerson, University of Connecticut, Christian Vossler, University of Tennessee, and Greg Poe, Cornell University
	2:00 p.m. – 2:30 p.m.	Choice Experiments to Assess Farmers' Willingness to Participate in a Water Quality Trading Market **Jeff Peterson**, Washington State University, and Sean Fox, John Leatherman, and Craig Smith, Kansas State University
2:30 p.m. – 2:45 p.m.	**Break**	
	2:45 p.m. – 3:15 p.m.	Incorporating Wetlands in Water Quality Trading Programs: Economic and Ecological Considerations **Hale Thurston** and Matthew Heberling, EPA, National Risk Management Research Laboratory, Cincinnati, Ohio
	3:15 p.m. – 3:35 p.m.	Designing Incentives for Private Maintenance and Restoration of Coastal Wetlands **Richard Kazmierczak** and **Walter Keithly**, Louisiana State University at Baton Rouge
	3:35 p.m. – 3:50 p.m.	Discussant: **Marc Ribaudo**, USDA, Economic Research Service
	3:50 p.m. – 4:05 p.m.	Discussant: **Jim Shortle**, Pennsylvania State University
	4:05 p.m. – 4:35 p.m.	Questions and Discussions
4:35 p.m. – 4:45 p.m.	**Final Remarks**	

4:45 p.m. **Adjournment**

Voluntary-Threat Mechanisms to Reduce Ambient Water Pollution

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Voluntary-Threat Mechanisms to Reduce Ambient Water Pollution

Abstract: Given the political and economic attractiveness of addressing nonpoint source water pollution through a voluntary mechanism that carries with it a background threat of a mandatory policy (e.g. an ambient tax), this paper expands on recent theoretical work by Segerson and Wu (*Journal of Environmental Economics and Management*, 2006) in two important ways. First, we suggest a modification of the theory that generates optimal, voluntary abatement as part of a subgame perfect Nash equilibrium without the necessity for applying taxes retroactively. Second, we use laboratory economic experiments to test the voluntary/threat policy suggested by Segerson and Wu as well as the policy that we introduce, and compare them to a pure ambient tax policy. Our experimental results indicate that the voluntary/threat policy behaves as well or better than the pure tax policy, though these outcomes are highly dependent on the form and parameters of the mechanism.

Keywords: voluntary mechanisms; ambient-based tax; nonpoint source pollution; laboratory experiments

I. Introduction

Improvements in surface water quality since the passage of the Federal Clean Water Act Amendments of 1972 have come primarily as a result of reductions in emissions from point sources, such as wastewater treatment plants and factories. While opportunities for further reduce emissions from point sources remain, it is nonpoint source pollution that presently represents the greatest share of surface water impairment in the United States (Ribaudo 2003). Agricultural production, which occurs on approximately 60% of nonfederal land in the US (NRI 2002), is the largest component of nonpoint source water pollution and represents the leading source of water quality impairments among the rivers and lakes surveyed in the 2000 *National Water Quality Inventory* (US EPA 2002).

Given the role of nonpoint sources in influencing water quality, economic theorists have devised a number of mandatory approaches designed to reduce surface water pollution stemming from agricultural production. These approaches can be roughly broken into performance-based policies, which base regulation on measurable outcomes, and design-based policies, which are predicated on input and land management decisions (Ribaudo 1999). Since nonpoint source emissions are characterized as prohibitively costly to monitor on a firm-level basis, performance-based policies have been directed towards ambient environmental conditions. Beginning with the seminal work of Segerson (1988), numerous mandatory approaches that provide incentives to

nonpoint source polluters based on ambient pollution levels have been proposed (e.g., Xepapadeas 1991; Cabe and Herriges 1992; Hansen 1998; Horan et al. 1998; Karp 2004).

One main criticism of mandatory approaches, in particular policies that involve taxing nonpoint polluters based on ambient pollution, is political feasibility. Policy makers have historically addressed nonpoint source pollution almost exclusively through voluntary measures[1]. While voluntary programs have been widely accepted by agricultural producers, there is little evidence that they have delivered outcomes, in terms of improved water quality, that would warrant declaring them a success (Shortle, Abler and Ribaudo 2001). A recent study by the US Environmental Protection Agency (EPA) finds that almost 35 years after the passage of the Clean Water Act Amendments, nearly 70% of all stream miles in the United States can be classified as being in "fair" or "poor" condition (US EPA 2006).

In an effort to wed the political palatability of a voluntary policy with the theoretical attractiveness of an appropriately designed mandatory policy, Segerson and Wu (2006) introduce a policy that uses voluntary and mandatory programs as complementary instruments. The proposed policy allows firms in a watershed to voluntarily meet an ambient pollution standard. As long as the ambient standard is achieved, no regulatory fees are charged. If, however, the standard is not met voluntarily, then a mandatory instrument is put in place, in particular an ambient tax policy. The threatened tax policy is structured in such a way that firms are induced to meet the ambient pollution standard voluntarily.

The proposed voluntary/threat policy has some clear advantages over a strictly mandatory or strictly voluntary approach. From a producer's standpoint the policy is attractive because it allows for flexibility in meeting pollution standards without explicit regulation. From the regulator's standpoint the policy's attractiveness comes from avoiding the potentially large costs associated with administering the tax and incurring the information costs necessary to appropriately set the tax rate. Finally, the instrument is attractive from the social planner's perspective, as it offers the potential to cost effectively address the nonpoint source pollution problem.

[1] Common voluntary policies include land retirement programs, such as the Conservation Reserve Program, as well as working land programs, that provide incentives to agricultural landowners for developing best management practices (BMPs) and implementing pollution prevention and control measures. Annual federal expenditures for voluntary conservation programs are projected to be nearly $5 billion by 2011 (ERS 2002)

A shortcoming of the Segerson and Wu framework is a coordination problem in the voluntary setting resulting from the existence of multiple Nash Equilibria, including a possible equilibrium where no firm engages in pollution control. To eliminate the multiplicity of Nash Equilibria, we modify the threatened tax mechanism such that, if a violation occurs, expected tax payments under the subsequent tax policy are a function of the extent of the voluntary period violation. The threat mechanism can be parameterized in ways that leave optimal abatement in the voluntary setting the unique equilibrium.

Due to the novelty of a voluntary/threat policy, empirical program evaluation using naturally occurring data is difficult[2] since no such program is presently being implemented. The potential social gains from firms voluntary achieving a pollution standard at least-cost, together with the theoretic potential for socially suboptimal behavior imply that the experimental economics laboratory is an important alternative testing ground for gaining a comparative perspective of how the proposed policies will work in practice.

In recent years a burgeoning set of studies have complemented the theoretical literature by testing many of the proposed regulatory policies in an experimental economics laboratory setting (Spraggon 2002, 2004; Alpizar et al. 2004; Poe et al. 2004, Cochard et al. 2005, Suter et al. 2006, Vossler et al. 2006). The results from these experimental studies show that a subset of the proposed theoretical policies, including a tax policy similar to the threatened policy of Segerson and Wu, engenders outcomes that are highly efficient.

In the next section of the paper we provide a theoretical background for the policy introduced by Segerson and Wu and the endogenous policy that we propose. In Section III we explain the experimental design and outline five hypotheses to be tested. In Section IV we present and analyze the experimental results and then conclude the paper in Section V with a summary of our findings and a discussion of their policy relevance.

[2] Compliance mechanisms require farmers to undertake conservation measures to be eligible for some Federal aid programs. For example farmers that fail to reduce soil erosion on highly erodible land may be ineligible for some Federal benefits (USDA 2004). While this is similar to a voluntary/threat policy, the threat is based more on input decisions than on the actual effluent generated.

II. Theoretical Background

Our model follows that of Segerson and Wu closely.[3] Suppose there are n firms, denoted by i, in a given watershed. Let a_i denote abatement, and $C_i = C(a_i, \theta_i)$ the abatement cost function where θ_i is an index that represents characteristics specific to the firm.. We assume that the cost function is strictly convex, with $C'(a_i, \theta_i) > 0, C''(a_i, \theta_i) > 0$ and $C(0, \theta_i) = 0$. Ambient pollution at a monitoring point, denoted by x, is a function of the abatement decisions of all firms, with $x = x(a_1, \ldots a_n; \theta_1, \ldots, \theta_n)$, with $x'(a_i, \theta_i) < 0$ and $x''(a_i, \theta_i) \geq 0$. Given that abatement is costly, in the absence of any policy intervention we expect $a_i = 0$.

Now suppose that a social planner is interested in reducing ambient pollution to an exogenously determined water quality standard, which we denote x^s. The standard could be based on a Total Maximum Daily Load (TMDL) requirement or simply be a product of political bargaining. The social planner's problem and corresponding Lagrangian, assuming an interior solution, can then be written as [4]

$$\underset{a_i}{Min} \sum_{i=1}^{n} C(a_i, \theta_i) \quad s.t. \; x(a_1, \ldots, a_n; \theta_1, \ldots, \theta_n) \leq x^s, \; a_i \geq 0 \tag{1}$$

$$L = -\sum_{i=1}^{n} C(a_i, \theta_i) + \lambda(x^s - x(\cdot)). \tag{2}$$

The strict monotinicity and convexity of the firm cost functions imply that the first-order conditions are solved with $\lambda^* = -C'(a_i^*) / x'(a_i^*)$ for all i. The λ term can be interpreted as the marginal benefit to firms of increasing the ambient standard by one unit. Since $\lambda^* > 0$, the constraint is binding and therefore ambient pollution is exactly equal to the standard.

In the following subsections we detail the theoretical basis for three policies that seek to induce polluters in a watershed to achieve the ambient pollution standard at least cost. The first case, a pure ambient tax policy, and the second case, a voluntary policy with a threat of an exogenously determined tax, are very similar to those described by Segerson and Wu and therefore we do not provide formal proofs. We treat the third case, a voluntary policy with a

[3] In particular, we make the assumptions that abatement and firm characteristics can each be represented by a scalar, and that the policy goal is one of meeting an ambient water quality standard on average such that stochastic factors (e.g. weather) can presumably be suppressed.

[4] An interior solution implies that the relevant case has $a_i^* > 0$ for all i. If this were not true, then the regulator would be unnecessarily exposing one or more firms to potential tax liabilities when the firm(s) should clearly not be regulated.

threat of an endogenously determined tax, more rigorously and provide several proofs to establish the policy's theoretical properties.

IIa. Tax Policy

Suppose that the social planner is attempting to reach the ambient standard at least cost through the use of a policy that charges all firms in the watershed a marginal tax, τ, on units of ambient pollution above an ambient standard. Defining the tax rate $\tau = \lambda^*$, and using the superscript t to indicate abatement under the tax policy, the cost minimization problem for firm *i* is

$$\underset{a_i^t}{Min} \quad C\left(a_i^t, \theta_i\right) + max\left(0, \tau \cdot \left(x\left(a_1, \ldots a_n; \theta_i, \ldots \theta_n\right) - x^s\right)\right) \tag{3}$$

Under the tax policy $\boldsymbol{a}^t = \boldsymbol{a}^*$ is a Nash Equilibrium[5] (NE), where a_i^* is the cost minimizing abatement level for firm *i* as defined previously. To show this, suppose the $n - 1$ firms choose abatement level $a_i^t = a_i^*$. Recalling that $\tau = \lambda^*$, every unit of abatement by firm *i* that is less than a_i^* will cost the firm $-C'\left(a_i^*\right)/x'\left(a_i^*\right)$ in terms of tax payments, while the per unit abatement costs avoided will be less than $-C'\left(a_i^*\right)/x'\left(a_i^*\right)$, since $C''\left(a_i\right) < 0$ and $x''\left(a_i\right) \geq 0$. Therefore firm *i* will be strictly worse off by choosing $a_i^t < a_i^*$ as opposed to $a_i^t = a_i^*$. Firm *i* will also be strictly worse off by choosing $a_i^t > a_i^*$, since abating to the point where ambient pollution is below the ambient standard is more costly to the firm than meeting the standard with equality and there is no benefit in terms of additional tax penalties avoided.

Further, $\boldsymbol{a}^t = \boldsymbol{a}^*$ is a unique NE since a firm choosing $a_i^t > a_i^*$ would incur per unit abatement costs in excess of the tax rate, τ, and could therefore never be optimal. Given that none of the *n* firms choose $a_i^t > a_i^*$, no firm will rationally choose $a_i^t < a_i^*$, since this would result in pollution in excess of the ambient standard.

An important feature of the tax policy is that X^s in equation (3) can be replaced with a tax threshold, $\bar{x} \leq x^s$ such that the unique NE $\boldsymbol{a}^t = \boldsymbol{a}^*$ is maintained. Therefore $\bar{x}$ is a choice variable and setting $\bar{x}$ below x^s has the effect of increasing tax payments, while $a_i^t = a_i^*$ remains

[5] ***Bold*** typeface is used to signify a vector.

an optimal choice for each of the n firms. We can therefore define the cost to each firm of one period of the tax policy as

$$C\left(a_i^*, \theta_i\right) + \tau\left(x^s - \bar{x}\right). \tag{4}$$

IIb. Voluntary Policy with Exogenous Threat Mechanism

If the policy maker allows firms to meet the pollution standard voluntarily without incentives, we expect firms to expend zero abatement effort, since abatement is expensive. However, now suppose that the policy maker allows firms to respond to the pollution standard voluntary, but includes a threat of a tax policy if the standard is not achieved. Specifically, if ambient pollution is above the standard then the tax policy described above is put into place for $K \leq \infty$ periods.[6] The key parameter in the voluntary-threat mechanism is the pollution threshold, as the incentive to meet the standard voluntarily is provided by employing a tax threshold that is significantly less than the standard, which makes the tax payments – even under optimal abatement in the tax stage game – strictly positive for each firm. We label this as an "exogenous" threat mechanism as the pollution threshold is exogenous in the sense that it does not depend on behavior in the voluntary period in which a violation occurred.

Incorporating the superscript v to indicate outcomes in the voluntary stage, the amount of voluntary abatement chosen by firm i is denoted a_i^v. We further define $a_i^{v(s)}$ as the amount of voluntary abatement necessary by firm i to ensure that the ambient standard is exactly met, given the abatement activities of the other firms in the watershed, such that $x\left(a_i^{v(s)}, a_{-i}^v; \theta_i, \theta_{-i}\right) = x^s$. For the ambient standard to be met voluntarily, the threatened tax policy must be sufficiently costly so that the standard is met in the voluntary stage. We have already shown that in every period of the tax stage firms will choose a_i^* as part of a unique NE when $\tau = -C'\left(a_i^*\right) / x'\left(a_i^*\right)$. Next we show that if the costs imposed by the tax policy are sufficiently high, then each firm will choose $a_i^v = a_i^{v(s)}$ in the voluntary stage game as part of a subgame perfect NE (SPNE).

[6] Allowing the possibility that K is finite is a trivial variation on Segerson and Wu, who assume that the tax policy is imposed in perpetuity. Considering the finite case is important for purposes of experimental testing. In particular, it allows us to end and re-start the game in experimental sessions where a violation occurs, akin to a situation where the regulator gives firms a second chance to comply voluntarily.

It must be the case that firm *i* will optimally choose either $a_i^v = a_i^{v(s)}$ or $a_i^v = 0$ in the voluntary stage. It is never optimal for a firm to choose $a_i^v > a_i^{v(s)}$ since this results in ambient pollution that is strictly less than the standard and firm *i* would be better off choosing $a_i^v = a_i^{v(s)}$ so that the standard is achieved with equality. It is also never optimal for firm *i* to choose $0 < a_i^v < a_i^{v(s)}$. If $a_i^v < a_i^{v(s)}$ then the ambient standard will not be met, the tax policy will be imposed and firm *i* should not choose a positive level of abatement, since abatement is costly.

In the voluntary period the firm therefore has a choice between abating so that the ambient standard is achieved or not abating at all and paying the tax over the next *K* periods. Assuming a discount factor 0 < δ < 1, the cost of voluntary abatement sufficient to meet the standard across *K*+1 periods is given by $\sum_{k=0}^{K} \delta^k C\left(a_i^{v(s)}, \theta_i\right)$. The cost of abating zero in the voluntary period and facing *K* periods of the tax policy, is given by $\sum_{k=1}^{K} \delta^k \left(C\left(a_i^*, \theta_i\right) + \tau\left(x^s - \bar{x}\right)\right)$. Therefore a firm will abate voluntarily, and the standard will be achieved, if

$$\sum_{k=0}^{K} \delta^k C\left(a_i^{v(s)}, \theta_i\right) \leq \sum_{k=1}^{K} \delta^k \left(C\left(a_i^*, \theta_i\right) + \tau\left(x^s - \bar{x}\right)\right). \tag{5}$$

When $\bar{x} = x^s$, the expected liabilities are zero under the tax policy. In this case, no firm would ever choose $a_i^v \geq a_i^*$, since $\mathrm{C}\left(\mathrm{a}_\mathrm{i}^\mathrm{v}, \theta_i\right) \geq \mathrm{C}\left(\mathrm{a}_\mathrm{i}^*, \theta_i\right)$. Therefore the standard will not be achieved voluntarily and each firm is strictly better off by choosing $a_i^v = 0$.

When $\bar{x}$ is sufficiently below x^s, there is a SPNE whereby each firm chooses abatement strategy $a_i^v = a_i^{v(s)} = a_i^*$ in the voluntary stage and $a_i^v = a_i^*$ in the tax stage. To see this, suppose $\boldsymbol{a}_{-i}^v = \boldsymbol{a}_{-i}^*$ so that $a_i^{v(s)} = a_i^*$ for firm *i*. Recall that firm *i* will either choose $a_i^v = a_i^{v(s)}$ or $a_i^v = 0$. Choosing $a_i^v = 0$ will result in the standard not being met and the imposition of the tax policy. Therefore if $C\left(a_i^*, \theta_i\right) \leq \sum_{k=1}^{K} \delta^k \tau\left(x^s - \bar{x}\right)$ then firm *i* will optimally choose $a_i^v = a_i^{v(s)} = a_i^*$. Note that in order for $\boldsymbol{a}^v = \boldsymbol{a}^*$ to be part of a SPNE, $\bar{x}$ must be chosen so that $C\left(a_i^*, \theta_i\right) \leq \sum_{k=1}^{K} \delta^k \tau\left(x^s - \bar{x}\right)$ for each firm.

Under the voluntary-threat policy introduced by Segerson and Wu there will also exist SPNE whereby the ambient standard is achieved at greater than least cost unless

$C\left(a_i^*,\theta_i\right)=\sum_{k=1}^{K}\delta^k\tau\left(x^s-\bar{x}\right)$ for each of the n firms. If not, then firms for which this holds with inequality would have an incentive to overabate as they strictly prefer the voluntary policy to the tax policy. For this condition to hold with equality would require that all firms have identical abatement costs at the optimum and that $\bar{x}=x^s-\left(C\left(a_i^*,\theta_i\right)\Big/\sum_{k=1}^{K}\delta^k\tau\right)$. As an example of a SPNE whereby the ambient standard is achieved voluntarily at greater than least cost, suppose that $\boldsymbol{a}_{-i}^v<\boldsymbol{a}_{-i}^*$ so that in order for the standard to be met, firm i must choose $a_i^v=a_i^{v(s)}=a_i^*+\varepsilon$. This will be an optimal choice for firm i if $\sum_{k=0}^{K}\delta^k C\left(a_i^*+\varepsilon,\theta_i\right)<\sum_{k=1}^{K}\delta^k\left[C\left(a_i^*,\theta_i\right)+\tau\left(x^s-\bar{x}\right)\right]$ and otherwise it will optimally choose $a_i^v=0$. Therefore, for all values of

$$\bar{x}<x^s-\frac{C\left(a_i^*+\varepsilon,\theta_i\right)+\sum_{k=1}^{K}\delta^k\left[C\left(a_i^*+\varepsilon,\theta_i\right)-C\left(a_i^*,\theta_i\right)\right]}{\sum_{k=1}^{K}\delta^k\tau}$$

firm i will optimally choose $a_i^v=a_i^{v(s)}=a_i^*+\varepsilon$ and the ambient standard will be met voluntarily. None of the other firms have an incentive to deviate from their strategy since any increase in abatement effort will impose costs without a reduction in liabilities and any decrease in abatement effort will result in the standard not being met and the consequent costs of the tax policy being greater than the savings in abatement costs.

When $a_i^{v(s)}\neq a_i^*$ for at least one of the firms in the watershed, the costs of meeting the ambient standard are not minimized. As $\bar{x}$ diverges from x^s the range of optimal voluntary abatement levels expands and the potential for free riding increases. This implies a tradeoff in the choice of the tax threshold. Setting $\bar{x}$ low relative to x^s generates a more draconian incentive for firms to meet the standard voluntarily, but opens the door to greater disparities between optimal and realized abatement choices.

In addition to multiple SPNE where the ambient standard is achieved voluntarily, there also is a SPNE whereby all firms choose zero abatement in the voluntary period. If $\boldsymbol{a}_{-i}^v=\mathbf{0}$, firm i will also choose to abate zero units since abating to the point where the ambient standard is met

is excessively costly or not feasible[7]. In past experimental analyses of ambient regulatory policies with a zero abatement NE, in addition to the pareto optimal NE, groups achieved significantly lower levels of social efficiency than under the ambient policies that did not have a zero abatement NE (Spraggon 2002, Vossler et al. 2006). Unfortunately, in the case of the voluntary policy with the exogenous threat the choice of $\bar{x}$ alone cannot eliminate the zero abatement NE.

IIc. Voluntary Policy with Endogenous Threat Mechanism

To eliminate the existence of the suboptimal equilibria in the voluntary stage, Segerson and Wu suggest the threat of a retroactive tax policy. Under this policy, if the ambient standard is violated in the voluntarily stage, firms pay taxes for the violation in the voluntary stage, in addition to facing the tax policy in future periods The tax paid on ambient pollution in excess of the standard in the voluntary stage would be collected prior to the first round of the tax stage. While this does eliminate the zero abatement outcome in the voluntary stage, it seems to negate much of the political attractiveness associated with the voluntary policy. The voluntary policy with a retroactive tax distinguishes itself from a pure tax policy only in the sense that rather than being collected at the end of the period, taxes in the voluntary stage are collected at the beginning of the next period.

Retaining the flavor of the retroactive tax, we introduce a new policy instrument where the tax threshold is endogenously determined. In particular, the threshold in the tax stage is determined by the level of noncompliance in the voluntary stage. Therefore under voluntary noncompliance, this instrument makes the amount of future tax bills conditional on voluntary period behavior. This implies that even if all other firms undertake zero abatement, for example, firm *i* has an incentive to abate to reduce future tax payments. Formally, if the ambient standard is exceeded in the voluntary stage, then the tax payment due in each round of the tax stage is defined as

$$\text{Tax Payment} = \tau\left[x^t - \tilde{x}\right] \;\; where\, \tilde{x} = x^s - \varphi\left(x^v - x^s\right) \; and \;\; \varphi > 0. \qquad (6)$$

[7] There is a potential that the best response for firm *i* would be to meet the standard voluntarily even if all other firms chose zero abatement, however this would require that the standard be relatively close to the baseline level of ambient pollution and is therefore not of particular interest.

The scaling parameter, φ, is freely chosen by the regulator. Increasing φ lowers the tax threshold for all levels of $x^v > x^s$, where x^v denotes realized pollution in the voluntary stage, and therefore increases the severity of the threatened tax policy. The crux of the mechanism is that the tax threshold decreases as the level of pollution in excess of the standard in the voluntary stage increases, thus making the consequent tax policy more costly to firms. The tax payment in each period of the tax stage can then be written as $\tau\left[x^t + \varphi x^v - (1+\varphi)x^s\right]$ for pollution levels greater than $\tilde{x}$. From this representation, it is apparent that in the tax stage of the endogenous mechanism, firms pay a tax based on the pollution levels in that period as well as a scaled tax on the pollution that occurred in the voluntary stage.

We have shown that in the tax stage any threshold, $\bar{x} \leq x^s$ will induce a unique NE $\boldsymbol{a}^t = \boldsymbol{a}^*$, which implies that the standard is met at least cost. Simplifying equation (6) and multiplying it by the discount rate yields the tax penalty over *K* rounds from voluntary noncompliance under the endogenous threat mechanism

$$\sum_{k=1}^{K} \delta^k \tau\varphi\left(x^v - x^s\right). \tag{7}$$

In the voluntary stage, each firm compares the cost of abatement against the discounted stream of future tax payments, however the severity of the penalty is now a function of each firms' voluntary abatement decision. The result is the potential elimination of suboptimal equilibria. The equilibrium conditions generated by the endogenous tax threat are derived in Propositions 1 and 2 below.

Proposition 1: *If* $\tau = \lambda^*$ *then* $\left\{\boldsymbol{a}^v, \boldsymbol{a}^t\right\} = \left\{\boldsymbol{a}^*, \boldsymbol{a}^*\right\}$ *is a unique SPNE if and only if* $\varphi \geq \left(\sum_{k=1}^{K} \delta^k\right)^{-1}$.

Proof of Proposition 1: We have already shown that in the tax stage the strategy $\boldsymbol{a}^t = \boldsymbol{a}^*$ is a unique NE. In proving Proposition 1 we start by showing that when $\varphi \geq \left(\sum_{k=1}^{K} \delta^k\right)^{-1}$ and $\boldsymbol{a}_{-i}^v = \boldsymbol{a}_{-i}^*$ then firm *i*'s best response is to choose $a_i^v = a_i^*$. In the second part of the proof we show that when $\varphi < \left(\sum_{k=1}^{K} \delta^k\right)^{-1}$ and $\boldsymbol{a}_{-i}^v = \boldsymbol{a}_{-i}^*$, then it is not a best response for firm *i* to choose $a_i^v = a_i^*$.

Finally in the third part, we show that as long as $\varphi \geq \left(\sum_{k=1}^{K}\delta^k\right)^{-1}$ then $\boldsymbol{a}^v = \boldsymbol{a}^*$ can be the only SPNE.

When $\boldsymbol{a}_{-i}^v = \boldsymbol{a}_{-i}^*$, then the standard will be achieved exactly if firm *i* chooses $a_i^v = a_i^*$. In this case the tax policy will not be imposed and the cost to the firm over *K*+1 periods will be $\sum_{k=0}^{K}\delta^k C\left(a_i^*, \theta_i\right)$. If firm *i* chooses $a_i^v > a_i^*$ then ambient pollution will be below the standard and the tax policy will again not be imposed. The cost of choosing $a_i^v > a_i^*$ is greater than the cost of choosing $a_i^v = a_i^*$, however, which implies that this is not a best response. This result does not depend on the choice of φ.

If firm *i* chooses $a_i^v < a_i^*$ then ambient pollution will exceed the standard and the tax policy will be put into place. The cost of the tax policy will depend on the firm's voluntary abatement decision. Firm *i's* optimal choice of voluntary abatement at or below a_i^* can be represented by the minimization problem

$$\underset{a_i^v}{Min} \quad C\left(a_i^v, \theta_i\right) + \sum_{k=1}^{K}\delta^k\left[C\left(a_i^*, \theta_i\right) + \tau\varphi\left(x\left(a_i^v, \theta_i\right) - x\left(a_i^*, \theta_i\right)\right)\right] \quad \text{s.t. } a_i^v \leq a_i^*. \tag{8}$$

The Kuhn-Tucker conditions associated with equation (8) are

$$C'\left(a_i^v\right) + \tau\varphi\sum_{k=1}^{K}\delta^k x'\left(a_i^v\right) + \mu = 0 \tag{8a}$$

$$\mu\left(a_i^* - a_i^v\right) = 0 \tag{8b}$$

$$\mu \geq 0. \tag{8c}$$

We have to consider two possible solutions, one with $\mu \geq 0$ and $a_i^v = a_i^*$ and the other with $a_i^v < a_i^*$ and $\mu = 0$. Recall that $\tau = -C'\left(a_i^*\right)/x'\left(a_i^*\right)$ so that when $\varphi \geq \left(\sum_{k=1}^{K}\delta^k\right)^{-1}$ then condition (8a) implies $C'\left(a_i^v\right) + \mu \geq C'\left(a_i^*\right)\cdot\frac{x'\left(a_i^v\right)}{x'\left(a_i^*\right)}$. Clearly, the former solution will hold, since $x''\left(a_i\right) \geq 0$ and therefore it follows that $C'\left(a_i^v\right) + \mu \geq C'\left(a_i^*\right)$ for all values of $\mu \geq 0$. The latter solution, however, implies $C'\left(a_i^v\right) \geq C'\left(a_i^*\right)$, which cannot be true given the strict convexity of the cost function. So firm *i* minimizes costs given that the tax policy will be put in place by choosing

$a_i^v = a_i^*$, however, this represents the situation whereby the standard is met. The costs of choosing $a_i^v < a_i^*$ are therefore always greater than the cost of $a_i^v = a_i^*$, thus when $\varphi \geq \left(\sum_{k=1}^{K} \delta^k\right)^{-1}$ and $\boldsymbol{a}_{-i}^v = \boldsymbol{a}_{-i}^*$, the unique best response for firm *i* is to choose $a_i^v = a_i^*$.

When $\varphi < \left(\sum_{k=1}^{K} \delta^k\right)^{-1}$, then $C'\left(a_i^v\right) + \mu < C'\left(a_i^*\right) \cdot \frac{x'\left(a_i^v\right)}{x'\left(a_i^*\right)}$, in which case the K-T conditions (8a)-(8c) are solved only with $a_i^v < a_i^*$ and $\mu = 0$. To see this, define $\hat{a}_i^v$ to be the level of voluntary abatement that solves the K-T condition (8a), which implies that $-C'\left(\hat{a}_i^v\right) / x'\left(\hat{a}_i^v\right) = \tau\varphi \sum_{k=1}^{K} \delta^k$. The cost to firm *i* of choosing $\hat{a}_i^v$ and then facing the tax policy is $C\left(\hat{a}_i^v, \theta_i\right) + \sum_{k=1}^{K} \delta^k \left[C\left(a_i^*, \theta_i\right) + \tau\varphi\left(x(\hat{a}_i^v, \theta_i) - x(a_i^*, \theta_i)\right)\right]$. We showed earlier that the cost of $a_i^v = a_i^*$ is $\sum_{k=0}^{K} \delta^k C\left(a_i^*, \theta_i\right)$. Thus the cost of $a_i^v = \hat{a}_i^v < a_i^*$ is lower than the cost of $a_i^v = a_i^*$ if $C\left(\hat{a}_i^v, \theta_i\right) + \sum_{k=1}^{K} \delta^k \tau\varphi\left(x(\hat{a}_i^v, \theta_i) - x(a_i^*, \theta_i)\right) < C\left(a_i^*, \theta_i\right)$. Substituting $-C'\left(\hat{a}_i^v\right) / x'\left(\hat{a}_i^v\right) = \tau\varphi \sum_{k=1}^{K} \delta^k$, rearranging terms and dividing each side by $a_i^* - \hat{a}_i^v$, the inequality becomes $\left[\frac{\left(x\left(a_i^*, \theta_i\right) - x\left(\hat{a}_i^v, \theta_i\right)\right)}{a_i^* - \hat{a}_i^v}\right] \Big/ x'\left(\hat{a}_i^v\right) < \left[\frac{\left(C\left(a_i^*, \theta_i\right) - C\left(\hat{a}_i^v, \theta_i\right)\right)}{a_i^* - \hat{a}_i^v}\right] \Big/ C'\left(\hat{a}_i^v\right)$, which must hold because of the assumed curvature of the cost and pollution functions. Therefore $a_i^v = a_i^*$ is not a best response for firm *i* when $\varphi < \left(\sum_{k=1}^{K} \delta^k\right)^{-1}$. Thus, $\varphi \geq \left(\sum_{k=1}^{K} \delta^k\right)^{-1}$ is necessary to induce optimal compliance in the voluntary stage game.

We have now shown that $\boldsymbol{a}^v = \boldsymbol{a}^*$ is part of a SPNE only when $\varphi \geq \left(\sum_{k=1}^{K} \delta^k\right)^{-1}$. Next, we show that when $\varphi \geq \left(\sum_{k=1}^{K} \delta^k\right)^{-1}$ then $\boldsymbol{a}^v = \boldsymbol{a}^*$ is the only possible NE in the voluntary stage. To see this, suppose that $\boldsymbol{a}_{-i}^v \leq \boldsymbol{a}_{-i}^*$, such that at least one firm is abating less than the socially optimal amount and firm *i* must overabate in order to meet the standard. Let ε > 0 denote the amount of

overabatement needed by firm *i* to ensure that the standard is met so that $a_i^v = a_i^* + \varepsilon$ with an associated cost to firm *i* over *K*+1 periods of $\sum_{k=0}^{K} \delta^k C\left(a_i^* + \varepsilon, \theta_i\right)$. Firm *i* would never choose $a_i^v > a_i^* + \varepsilon$ since this would imply higher abatement costs without a reduction in tax burden. If firm *i* chooses $a_i^v < a_i^* + \varepsilon$ then the tax policy will be imposed. The optimal choice of voluntary abatement given that the tax policy will be imposed is determined by the cost minimization problem

$$\underset{a_i^v}{Min}\ C\left(a_i^v, \theta_i\right) + \sum_{k=1}^{K} \delta^k \left[C\left(a_i^*, \theta_i\right) + \tau\varphi\left(x(a_i^v, \theta_i) - x(a_i^* + \varepsilon, \theta_i)\right)\right] \quad s.t.\ a_i^v \le a_i^* + \varepsilon\,. \tag{9}$$

With corresponding K-T conditions

$$C'\left(a_i^v\right) + \tau\varphi \sum_{k=1}^{K} \delta^k x'\left(a_i^v\right) + \mu = 0 \tag{9a}$$

$$\mu\left(a_i^* + \varepsilon - a_i^v\right) = 0 \tag{9b}$$

$$\mu \ge 0\,. \tag{9c}$$

We must consider solutions with either $\mu > 0$ and $a_i^v = a_i^* + \varepsilon$ or $\mu = 0$ and $a_i^v \le a_i^* + \varepsilon$. Substituting $\tau = -C'\left(a_i^*\right) / x'\left(a_i^*\right)$ condition (9a) implies that $C'\left(a_i^v\right) + \mu = \varphi \sum_{k=1}^{K} \delta^k C'\left(a_i^*\right) \cdot \frac{x'\left(a_i^v\right)}{x'\left(a_i^*\right)}$. Further, since $\frac{x'\left(a_i^v\right)}{x'\left(a_i^*\right)} \ge 1$ we know that $C'\left(a_i^v\right) + \mu \ge \varphi \sum_{k=1}^{K} \delta^k C'\left(a_i^*\right)$. Therefore when $\varphi = \left(\sum_{k=1}^{K} \delta^k\right)^{-1}$ then the only possible solution has $\mu = 0$ and $\hat{a}_i^v = a_i^*$, and when $\varphi > \left(\sum_{k=1}^{K} \delta^k\right)^{-1}$ then solutions with $\mu > 0$ and $a_i^v = a_i^* + \varepsilon$ or $\mu = 0$ and $a_i^v \le a_i^* + \varepsilon$ will always be possible.

Since $a_i^v < a_i^*$ will never be optimal, we restrict our focus to comparing the cost of choosing the optimal $a_i^* \le \hat{a}_i^v < a_i^* + \varepsilon$ given that the tax will be imposed, to the cost of choosing $a_i^v = a_i^* + \varepsilon$ and thus avoiding the tax. The cost over *K*+1 rounds, associated with choosing $\hat{a}_i^v < a_i^* + \varepsilon$ is $C\left(\hat{a}_i^v, \theta_i\right) + \sum_{k=1}^{K} \delta^k \left[C\left(a_i^*, \theta_i\right) + \tau\varphi\left(x(\hat{a}_i^v, \theta_i) - x(a_i^* + \varepsilon, \theta_i)\right)\right]$ while the cost of choosing $a_i^v = a_i^* + \varepsilon$ and avoiding the tax policy is $\sum_{k=0}^{K} \delta^k C\left(a_i^* + \varepsilon, \theta_i\right)$. Substituting

$\tau \sum_{k=1}^{K} \delta^k \varphi = -C'\left(\hat{a}_i^v\right) / x'\left(\hat{a}_i^v\right)$ from the K-T conditions and rearranging, we have that the cost of choosing $\hat{a}_i^v$ is less than the cost of avoiding the tax if

$$-C'\left(\hat{a}_i^v\right) / x'\left(\hat{a}_i^v\right) < \frac{C\left(a_i^* + \varepsilon\right) - C\left(a_i^*\right)}{x\left(\hat{a}_i^v\right) - x\left(a_i^* + \varepsilon\right)} + \sum_{k=1}^{K} \delta^k \frac{\left[C\left(a_i^* + \varepsilon\right) - C\left(\hat{a}_i^v\right)\right]}{x\left(\hat{a}_i^v\right) - x\left(a_i^* + \varepsilon\right)}. \tag{10}$$

Multiplying the right hand side of equation (10) by $(\varepsilon/\varepsilon)$, the curvature of the cost and pollution functions imply that $C'\left(a_i^*\right) < \frac{C\left(a_i^* + \varepsilon\right) - C\left(a_i^*\right)}{\varepsilon} < \frac{C\left(a_i^* + \varepsilon\right) - C\left(\hat{a}_i^v\right)}{\varepsilon}$ and $-x'\left(a_i^*\right) \geq \frac{x\left(\hat{a}_i^v\right) - x\left(a_i^* + \varepsilon\right)}{\varepsilon}$. Since $\sum_{k=1}^{K} \delta^k > 0$ then equation (10) must hold and choosing $a_i^* \leq \hat{a}_i^v < a_i^* + \varepsilon$ is the minimum cost response for all values of ε. Therefore given that $\varphi \geq \left(\sum_{k=1}^{K} \delta^k\right)^{-1}$, it is never a best response for a firm to overabate so that the standard is achieved. Given that other firms will not abate sufficiently to achieve the standard, it is therefore never in the best interest of any firm to underabate. The cost of abatement below a_i^* is lower than the cost of the tax, by definition, which implies that a firm that is currently underabating would always prefer increasing abatement rather than facing the tax. When $\varphi \geq \left(\sum_{k=1}^{K} \delta^k\right)^{-1}$ we can never have an equilibrium in which one firm chooses $a_i^v < a_i^*$ and another firm chooses $a_i^v > a_i^*$ and therefore $\boldsymbol{a}^v = \boldsymbol{a}^*$ is part of a unique SPNE when $\varphi \geq \left(\sum_{k=1}^{K} \delta^k\right)^{-1}$.■

Proposition 2: *If $\tau = \lambda^*$ then $\left\{\boldsymbol{a}_i^v, \boldsymbol{a}_i^t\right\} = \left\{\boldsymbol{0}, \boldsymbol{a}_i^*\right\}$ is never a SPNE when $\varphi > 0$.*

Proof of Proposition 2: Suppose that $a_{-i}^v = 0$. Firm *i* would then make its abatement decision based on the minimization problem in equation (9). Condition (9a), implies that $C'\left(a_i^v\right) + \tau\varphi \sum_{k=1}^{K} \delta^k x'\left(a_i^v\right) + \mu = 0$. Since $\tau > 0$ and $x'\left(a_i^v\right) < 0$ it follows that either $\mu > 0$, $C'\left(a_i^v\right) > 0$ or both. When $\mu > 0$ this requires that $a_i^v = a_i^* + \varepsilon > 0$ and when $C'\left(a_i^v\right) > 0$ this requires

that $a_i^v > 0$. Therefore when all other firms choose zero abatement, firm *i* will optimally choose a positive level of abatement so that we can never have a zero abatement equilibrium. ■

III. Experimental Design

To test the relative performance of the voluntary/threat policies, a series of economics experiments were conducted at the Cornell Lab for Experimental Economics and Decision Research in the spring semester of 2006. Participants had taken at least one class in economics and the majority had participated in at least one prior (but unrelated) economics experiment. Experiment instructions were presented in writing, and orally with aid of PowerPoint slides. The experimental sessions lasted approximately one hour and participants earned experimental tokens during each decision round, which were exchanged for dollars at the end of the experiment at the announced rate of 70,000 tokens per $1US. Overall, there were 144 participants and average participant earnings were $20.

The experiment hierarchy is illustrated in Figure 1. There were six experimental treatments and each treatment was comprised of four separate experimental groups made up of six participants. The participants made decisions analogous to abatement decisions over 23 rounds[8] and the rounds were split up into Part A (rounds 1-5) and Part B (rounds 6-23). Part A was intended to establish a regulation-free baseline. Part B represented regulation under a voluntary-threat policy, whereby subjects faced one of the six policies listed in Table 1.

In each treatment, all participants faced the identical abatement cost function $C(a_i, \theta_i) = \delta a_i^{\alpha}$. As the term abatement implies reducing emissions relative to some benchmark, we instead framed the participants' decision as one of choosing a level of emissions. Specifically, emissions were related to abatement through the function $y_i = \gamma - a_i$. In addition, the abatement was related to ambient pollution through the linear function $x_i = \sum_{i=1}^{n}(\gamma - a_i)$.

Each participant was given an *"Emissions Decision Sheet"* that listed the "firm earnings" associated with all possible levels of emissions. To give policy relevance to the experimental parameters, the baseline ($a_i = 0$) firm earnings were chosen to proximate the net farm income of

[8] The actual number of rounds was random, however each group completed at least 23 rounds.

a medium sized dairy farm in New York State, operating with a herd size of 200 cows[9]. Table 2 lists the specific values for the experiment parameters, which conforms to the underlying assumptions of the theoretical model.

In Part B, each of the policy instruments were designed to induce a 40% reduction in ambient pollution levels, from an unconstrained profit-maximizing pollution level of 120 to an ambient standard, x^s, of 72. The 40% level was chosen so as to mirror the 40% nutrient reduction goals called for in the original Chesapeake Bay Agreement (CBP 2005). Reaching the ambient standard of 72 at least cost required each of the six participants to reduce their emissions to 12 units, from the unconstrained optimum of 20. This implies an optimal abatement amount, a_i^*, of 8 for each participant.

Under the tax policy, each participant pays a marginal tax, τ, of 2,500 tokens for every unit of ambient pollution, x^t, above the tax threshold, $\bar{x}$. Given that the marginal cost of reducing emissions beyond 12 is greater than 2,500 tokens and the marginal cost of emissions reductions by 12 units or less is less than 2,500, optimal abatement for each firm is exactly 12 units such that the ambient standard of 72 is exactly met.

In Treatment 1, the tax threshold is set equal to the ambient standard of 72. This duplicates the policy shown to be highly efficient in the experimental studies of Spraggon (2002), Poe et al. (2004), Cochard et al. (2004) and Suter et al. (2006) and serves as the baseline for evaluating the results of the voluntary/threat policy.

When τ =2,500, emitting exactly 12 units is a unique NE for any tax threshold at or below 72. However, when the tax threshold is strictly lower than 72 the *group* can maximize its payoff when participants emit fewer than 12 units. While collusive outcomes are not seen in recent experimental results when ambient pollution is a stochastic function of firm emissions (Suter et al. 2006), it is an open question whether participants behave in a more collusive manor in the non-stochastic environment presented in this study. Evidence from the closely related nonpoint pollution experiments of Spraggon (2002) suggests that, at least on average, decisions do not pivot on the presence/absence of uncertainty. In Treatment 2, the tax threshold is 50. which allows us to compare the results of the pure tax policy with the threatened tax policy of Treatment 4, which also has a tax threshold of 50.

[9] The average herd size and farm income amounts were determined based on the *New York State Dairy Farm Summary* reports produced by Cornell University for the years 1999-2003.

In Treatments 3 through 6 we evaluate the voluntary/threat policy with an ambient standard equal to 72 units. In each of these treatments, the threatened regulatory regime consists of three rounds (K=3). Three rounds were selected to allow for multiple observations of the voluntary scenario while still capturing the essence of a threat where participants pay a penalty over time for not meeting the standard, as suggested by Segerson and Wu. Given the short time frame over which the decision rounds occur, we assume that the discount factor, δ, is equal to 1.

In Treatments 3 and 4, the threatened regulatory policy has tax thresholds of 66 and 50 respectively. The threshold of 66 is low enough to provide the necessary incentives theoretically for voluntarily compliance. The threshold of 50 provides a stronger incentive for voluntary abatement, since the costs of the tax stage were higher, but also introduced the potential for a wider range of possible equilibria. By varying the tax threshold we gained some insight into the tradeoff between a tax threshold that is relatively close to the ambient standard and a lower tax threshold, which increases the incentive to abate voluntarily but also increases the potential for meeting the voluntary standard at higher than minimum cost.

Meeting the ambient standard voluntarily at least cost requires a great deal of coordination, since all participants must choose to emit exactly 12 units. In Treatment 5, we increase the potential for coordination by allowing groups to engage in costless, nonbinding communication (referred to in the experimental economics literature as "cheap talk"). In particular, each group is allowed up to five minutes of cheap talk before rounds 6, 11, 16 and 21. Participants are allowed to discuss any aspect of the experiment, but are not allowed to make threats or arrange for side payments. Cheap talk has been shown to greatly improve efficiency outcomes in earlier studies of the pure tax instrument (Suter et al. 2006).

In Treatment 6, we test the voluntary/threat policy with the endogenous threshold, whereby the zero abatement NE is eliminated. Recall from Section II that the choice of the scale parameter, φ, is in effect a choice of the magnitude of the incentive for voluntary compliance. To help engender transparency, we chose $\varphi = 1$, such that every unit of pollution above 72 in the voluntary stage results in the tax threshold being set an equal number of units below 72 in the tax stage.

IIIa. Testable Hypotheses

Although the pure tax, voluntary/threat with exogenous threshold, and voluntary/threat with endogenous threshold policies all theoretically induce outcomes whereby the ambient pollution standard is met at least cost, the relative empirical performance of the three mechanisms is an open question. While the pure tax policy with a constant marginal ambient tax has proven to generate highly efficient outcomes in several past experimental studies (Poe et. al. 2004, Spraggon 2002, Cochard et. al. 2004; Suter et. al. 2006), a voluntary policy with a threat of regulation has not been participant to experimental examination. By evaluating the experimental results from the voluntary/threat policy we endeavor to test the following three hypotheses.

(1) In the voluntary/threat policy treatments, firms abate voluntarily such that the ambient pollution standard is met.

(2) Firms are more likely to abate voluntarily with a lower threatened tax threshold, $\bar{x}$, and when the threshold is endogenous.

(3) The instances of participants choosing zero abatement are lower in the voluntary policy with an endogenous as opposed to an exogenous threshold.

Comparing the results from the pure tax treatments to the results in the voluntary/threat treatments, we then test two additional hypotheses:

(4) The average emissions decision in each of the policy settings is identical to the NE predictions.

(5) The voluntary/threat policies generate social efficiency outcomes identical to the outcomes under the tax only policy.[10]

IV. Results

In this section we present three sets of results. We begin with a simple presentation of the outcomes from the four voluntary/threat treatments. This presentation includes the number of rounds that each group met the ambient pollution standard voluntarily as well as evidence on how individual behavior differs across treatments. Based on these results, we draw conclusions regarding the first three hypotheses above. The second set of results relies on an econometric model to estimate the mean participant-level emissions decision in each of the policy scenario. This enables us to draw conclusions regarding Hypothesis 4. In the final set of results, we present

[10] The notion of efficiency is odd here given that we are in a cost-effectiveness framework. However, the efficiency calculations do allow for more delicate comparisons both across treatments and with related studies.

social efficiency outcomes for the six treatments. The efficiency results allow for a general comparison across all six treatments and specifically allow us to compare the outcomes of the tax only treatments relative to the voluntary/threat treatments.

For all of the results presented below, our analysis covers the decisions made up to round 23. This implies that for each participant we have 5 observations from Part A and 18 Part B observations. In addition to the summary results presented below, we also include a round by round graphical depiction of the group emissions for all treatments as an Appendix.

Result 1: In the absence of communication, participants generally do not meet the ambient standard voluntarily. With communication, we fail to reject the null hypothesis that groups comply voluntarily.

Inspection of Table 3 reveals that when groups are not allowed to communicate they have a very difficult time meeting the ambient pollution standard in the voluntary stage. When groups are allowed to communicate in Treatment 6, however, they are able to reach the ambient standard voluntarily with great regularity [11].

Result 2: Decreasing the threshold in the exogenous threat mechanism setting and implementing an endogenous threshold increase the likelihood the ambient standard is met voluntarily. Further, there is no strong evidence of free-riding.

While lowering the tax threshold from 66 to 50 increases the probability of voluntary compliance, groups still violate the standard more often than not. Even making the threshold endogenous, a case where voluntary compliance is the unique SPNE, only one of the four groups meet the standard in a voluntary round. Interestingly, the endogenous threat policy is the only scenario where a group exceeded the standard in the first voluntary round, but then met the standard voluntarily after experiencing the tax policy.

Measuring the degree of free riding when the standard was met is challenging, primarily because groups generally do not achieve the standard voluntarily. From the limited evidence available, it appears that free riding is not an issue. We expect the greatest potential for free

[11] Although group 2 did fail to meet the standard voluntarily in one of the rounds (and subsequently had to go through three rounds of the regulatory policy), this was a result of a mistake made by one of the participants. In the cheap-talk session that occurred after the mistake was made, the participant was apologetic to the other group members and stated that the wrong number was accidentally typed into the computer.

riding to occur with the voluntary policy and the exogenous threat mechanism with a threshold of 50, however we observe only one round where one participant overabated and one participant underabated (out of 23 rounds where the standard was met voluntarily). In the group that met the standard under the voluntary policy with the endogenous threat, we observe one participant that was consistently one or two units below the optimal emissions and one consistently one or two units above. This limited evidence does not indicate the prevalence of the more drastic types of free riding that are theoretically possible.

Result 3: The endogenous threshold mechanism does reduce the incidence of choosing the zero abatement strategy. Lowering the tax threshold of the exogenous threat mechanism also reduces the frequency at which firms choose zero abatement.

To arrive at Result 3 we measure the frequency at which the zero abatement strategy is chosen (i.e. when a participant chooses to emit 20 or more units). In the voluntary treatment with the exogenous threshold of 66, participants play the zero abatement strategy an average of 15 times per group over the 18 observed Part B rounds (s.e.=4.5). The per group frequency dropped to 5.3 (s.e.=2.3) in the case of the threatened exogenous threshold of 50. Finally, in the voluntary with endogenous threshold treatments the average number of times the zero abatement strategy was played dips to 4.5 times per group (s.e.=2.3). Note that only when the threshold is endogenous is the average number of participants in a group that violates the voluntary standard not significantly different from zero.

In addition to looking at the number of instances where participants chose not to abate in the voluntary rounds of the experiment, it is also interesting to look at the decisions participants made in the first round in which the voluntary/threat policy is in effect (round 6). In this round each participant has to make a decision without any prior information on how other participants would respond to the policy and therefore we get a test of the initial effectiveness of the voluntary/threat instrument.

Interestingly, the majority of participants voluntarily abated at least the optimal amount. For each of the three treatments there were 24 observed decisions in round 6. The number of participants that chose to emit 12 or fewer units was 17 (tax threshold 66), 21 (tax threshold 50) and 20 (endogenous tax threshold). The fact that over 80% of participants voluntarily abated at

or above the amount necessary to reach the standard is a testament to the fact that the threat of the regulatory policy was strong.

Two intuitive hypotheses could explain why the remaining participants refused to adequately abate. First, it is possible that they believed that other participants would not abate and therefore it was not in their best interest to abate. Second, they were either confused or they made a miscalculation regarding the payoffs of the various strategies. While we cannot make a definitive statement on this matter, it appears that the latter explanation is most accurate. Evidence in support of this conclusion comes from the endogenous threat treatment, where participants should abate even if they believe that others will not follow suit. Further, we have some limited evidence from an experiment we ran where the ambient standard was based on individual rather than group emissions. In this case, it is always optimal to emit 12 units, since whether or not you meet the ambient standard is only a function of your own decision. In this sub-treatment we observed 2 of the 8 participants not abate in the first policy round, approximating the twenty percent of participants that did not abate in the group setting.

Having twenty percent of participants make a miscalculation in the initial period of a policy does not seem as if it should be an overwhelming obstacle. In many experimental settings it takes numerous decision periods and substantial learning before theoretically optimal outcomes are achieved (if they are achieved at all). In that regard, it is important to investigate the evolution of decisions over time. In addition, since we have seen from Table 3 that the majority of groups did not meet the standard voluntarily, it is important to examine what happens in the tax policy rounds of the experiment. We can then compare the voluntary/threat mechanism results under both the voluntary and the tax policy settings, to the pure tax settings of Treatments 1 and 2.

To get a sense of how individual decisions varied across treatment conditions, our objective is to generate an expectation for the emissions decision of a random participant in a random group in one of the treatment scenarios. Recall from the last section that the individual observations come from a hierarchical data generating structure, where groups were nested within treatments, participants were nested within groups and each participant made a decision over a series of rounds. Additionally, in the voluntary/threat treatments, participants either made a decision in a voluntary setting or in a tax policy setting. This complex data structure implies that we cannot treat each of the individual decisions as an independent observation. It is

reasonable to presume that there is serial correlation among the individual decisions across rounds and that the individual decisions within a round are correlated across the six participants in a group.

To address the complications having to do with the fact that groups that meet the ambient standard voluntarily will necessarily participate in more voluntary rounds, we calculated the mean emissions decision made by each subject in Part A and the mean emissions decisions made in the voluntary and the tax policies of Part B for three aggregate round groupings. The three aggregate groupings correspond to rounds 6-11, 12-17 and 18-23. By aggregating, we ensure that the voluntary decisions made by each individual are weighted equally.

To compare the individual emissions decisions across treatments we then estimate three mixed models. In each of the models, the general structure can be written as

$$y_{igr} = X\beta + \varepsilon_{igr} \ . \tag{11}$$

where y_{igr} is the emissions decision made by individual i in group g and treatment r. In the above formulation, X is known as the design matrix, which is a matrix of 1's and 0's used to represent the form of the fixed effects, and β is a vector of fixed effect coefficients to be estimated. The model error is represented by ε_{igr}.

In the first mixed model we use the data from the decisions made in Part A and specify a fixed effect for each of the six treatments[12]. The error term in the first mixed model is assumed to be independent, homogeneous and follow a normal distribution.

The second mixed model that we estimate uses data from the tax policy rounds of Part B. Here we include fixed effects for the three aggregate round groupings, the individual treatments and the interaction between the round groupings and the treatments. Additionally, we include a random effect α_g to account for the fact that individuals make decisions within groups. We assume the model error, ε_{igr}, to be serially correlated across the three round groupings and assume that this correlation follows an AR(1) process. Finally, since the variability of the emissions decisions are likely not equal across treatments, we allow the error variance and the correlation coefficient, ρ, to be treatment specific. Utilizing the identical structure, the third mixed model is estimated using the emissions decisions made under the voluntary policy. As such, the tax only treatments are not included in this model.

[12] There is insufficient variation at the group level to include a random group effect.

The coefficients in equation (11) for each of the threes models are estimated using the SAS proc mixed command and included in Table 4. The results show that in Part A of the experiment, when no policy was in place, emissions were not different from the prediction of 20. In other words, with no regulatory policy or threat of a regulatory policy in place, participants on average reached the unconstrained optimum. In each of the Part B policy scenarios individual emissions were significantly below 20, which suggest that all of the policies that we investigated resulted in positive levels of abatement. Individual emissions are, however, significantly different from the NE prediction, which is also the socially optimal emissions decision, of 12 in at least one aggregate round grouping of each of the policy scenarios.

Result 4: In all of the policy scenarios without communication, mean decisions deviate from the Nash prediction in at least one period.

In the pure tax setting with the threshold set equal to the ambient standard, which serves as our baseline, the estimated emissions decision is significantly higher than the NE of 12. Despite the statistical significance of this outcome, the fact that participants on average exceed the optimum by 10% is not large in economic terms and closely approximates earlier experiments by Spraggon (2002) and Poe et. al. (2004)[13].

When the tax threshold equals 50, the expected decision in the pure tax policy is significantly less than the NE in all three round groupings, indicating a tendency towards tax avoidance through excess abatement. The group's after tax profits are maximized when each participant emitted 8 units, however without communication we expect that individuals attempting to maximize individual profits would drive the average results towards the NE result of 12 units of emissions. Though limited evidence indicative of tacit collusive does occur, it erodes between the earlier and later rounds (although the erosion was not statistically significant).

In the voluntary/threat policy with an exogenous threshold of 66, the mean individual emissions level of 14.32 in the early rounds of the voluntary setting is significantly greater than the NE. Additionally, individual emissions increase significantly between early and late rounds, indicating that the response to the tax threat grew weaker over time as participants became

[13] Spraggon calculates average individual emissions under the pure tax mechanism to be 31.84 when the social optimum is 25. Poe et. al. calculate an individual average of 5.93 when the social optimum is 5.

convinced that other group members would also not abate voluntarily. In the tax stage of the treatment, emission levels are not significantly different from the NE in either early or late rounds.

In the voluntary/threat policy with an exogenous threshold of 50, individual emissions average 12.67 and are not significantly different from 12 in the early voluntary rounds, however we do again see a significant increase in later rounds, as expected emissions increase to 14.21. Mean emissions under the tax policy range from 9.26 to 10.14 and are significantly less than 12, similar to our results in the pure tax policy, which again suggests some tendency towards tax avoidance that may serve to weaken the tax threat.

When the threatened tax threshold is endogenous, estimated emissions in the early rounds average12.53 under the voluntary policy and 12.05 under the tax policy. These figures are closer to the social optimum of 12 than with any of the other treatments without communication. Further, the change in expected emissions is not significant between early and late rounds in either the voluntary or tax setting, although estimated emissions are significantly different from 12 and in the late round groupings of the voluntary policy.

Comparing the voluntary/threat policy to the pure tax policy we see that in the voluntary stage the expected emissions when the threatened tax threshold is set at 50 or is endogenous are not different from the baseline tax policy. In the tax stage of the voluntary/threat policy, expected emissions are statistically less than the baseline tax policy. As mentioned earlier, the threshold of 66 and the endogenous threshold yield expected emissions that are not significantly different from the NE. The endogenous threat therefore mechanism performs as well or better than the baseline tax policy in both the voluntary and tax portions of the policy.

Estimating individual emissions decisions is important in understanding how the various policy scenarios influence ambient pollution, however, they do not tell us how the voluntary/threat policies compare to the pure tax policy from the perspective of social efficiency. For example, if a policy approximates the cost minimizing emissions level for an average participant, this does not mean that costs have been minimized if there is a significant degree of variation around the mean decision.

To facilitate a more intricate comparison of decisions across treatments, we compute efficiency measures for each treatment assuming a damage function that is linear in ambient pollution, with a slope of 2,500. The choice of damage function does not have a significant

impact on the relative efficiencies across the treatments and the choice of a linear damage function is consistent with previous experimental analyses (e.g. Spraggon 2002; Poe et. al. 2004).

The efficiency measure is identical to that of Spraggon (2002). The economic surplus in a given round is determined by summing the pre-tax earnings of each of the six firms (the social benefit) less the social damage, determined by the ambient pollution in that round. The observed surplus in round t by group g, S_{gt}, is then measured against the surplus in the zero abatement scenario, S_{zero}, and the maximum surplus possible, S_{max}, to give a measure of efficiency according to the formula

$$Efficiency_{gt} = \frac{S_{gt} - S_{zero}}{S_{max} - S_{zero}}. \tag{12}$$

The mean efficiency measures for each treatment in each of the three aggregate round groupings are then compared using the mixed modeling procedure described for the individual emissions, except that the level of observation is at the group rather than the individual level. We again assume that the model error term follows an AR(1) process and allow the correlation coefficient as well as the error variance to vary across treatments. The estimated mean efficiency levels and standard errors are given for each treatment in Table 5 in addition to the estimated error variances and correlation coefficients.

Result 5: The social efficiency outcomes for the voluntary/threat treatments are either not statistically different or are higher than the outcomes in the pure tax treatments.

The three voluntary/threat treatments where participants without communication all have mean efficiencies that are not significantly different from the tax only baseline, though the voluntary policy with endogenous threat has the highest efficiency of the three. With, the efficiency results are significantly higher than the baseline (and are not significantly different from 100%). In the tax only setting with the threshold equal to 50, the mean efficiencies were significantly lower than all of the other treatments.

V. Conclusion

In this paper we evaluate a policy introduced Segerson and Wu (2006) that addresses nonpoint source pollution through a voluntary policy used in combination with a background

threat of regulation. In addition, we augment Segerson and Wu's theory by showing how the severity of the threatened regulatory policy can be made endogenous by conditioning on decisions made in the voluntary period, which removes the existence of an equilibrium whereby all firms abate nothing in the voluntary period. Using results obtained in the experimental economics laboratory, we show that although lowering the threatened exogenous tax threshold or making the threshold endogenous increases the probability that a group of polluting firms meet the ambient standard voluntarily, the standard is still only met by approximately 25% of the groups in the absence of communication. When participants are allowed to communicate the probability that a group meets the ambient standard voluntarily improves to nearly 100% with essentially no free-riding. This positive result supports the findings of Poe et al. (2004) and Vossler et al. (2006) that communication can greatly improve the social efficiency of ambient tax mechanisms.

Despite the fact that the majority of groups do not meet the ambient standard voluntarily in the absence of communication, the political attractiveness of allowing firms the opportunity to meet a standard voluntarily remains. In addition, in the approximately 25% of groups where the ambient standard is met voluntarily, policy makers would not need to expend the resources necessary to determine a theoretically optimal marginal tax.

When the ambient standard is not met voluntarily, the tax system that is imposed still results in the ambient standard being theoretically met at least cost. Our experimental results suggest, however, that this may not necessarily be the case. Lower levels of the tax threshold appear to introduce a greater potential for over abatement and increased variance in the tax setting and may therefore be undesirable. The relatively high exogenous tax threshold does not provide a strong enough incentive to convince individuals to abate voluntarily while the relatively lower threshold induces a greater number of subjects to abate voluntarily, but also exhibits over abatement under the tax policy in the groups that do not meet the ambient standard voluntarily. When the threshold in the tax policy is made endogenous, however, groups are more likely to engage in voluntary compliance the groups that are non-compliant exhibit near-optimal abatement levels in the tax policy.

Finally, our results show that in the three voluntary/threat policy treatments without communication, measured social efficiency levels ae not significantly different from the baseline pure tax policy advocated by previous studies. The voluntary/threat policy provides significant

political advantages in that landowners have an opportunity to reduce emissions voluntarily and avoid direct regulation. Therefore the voluntary/threat policy may be both more politically palatable and at the same time generate economic outcomes that are as good as or better than a strictly tax based mechanism.

The optimistic viewpoint that we take regarding the voluntary/threat policy certainly coul be bolstered with future research on variations of the policies tested here. Specifically, it would be interesting to see if increasing the severity of the endogenously determined threat by varying the scale could improve the probability that groups meet the standard voluntarily. Further, we did not examine how changing the number of rounds (*K*) or adding a stochastic component to the experiment influences the probability that an individual will abate optimally in both the voluntary and tax settings.

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Figures and Tables

Figure 1: Hierarchical structure of experiment

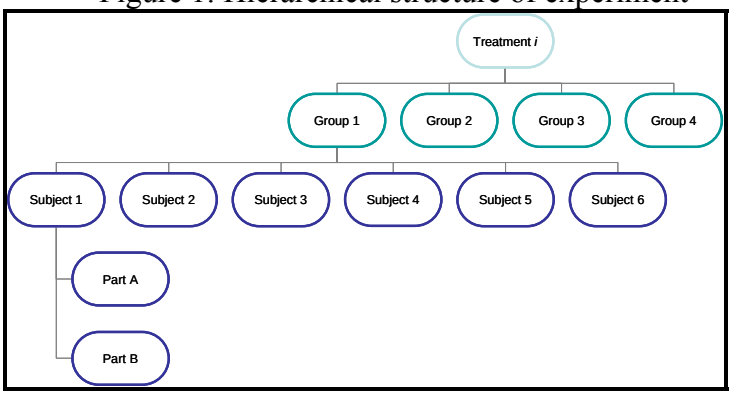


Table 1: Treatment Summary

	Policy Scenario	Tax Threshold $(\bar{x})$	Communication Allowed
Treatment 1	Tax Only	72	No
Treatment 2	Tax Only	50	No
Treatment 3	Voluntary/Threat	66	No
Treatment 4	Voluntary/Threat	50	No
Treatment 5	Voluntary/Threat	50	Yes
Treatment 6	Voluntary/Threat	Endogenous	No
4 groups per treatment, 6 participants per group, 138 total participants			

Table 2: Experimental Parameters

Description	Functional Form	Parameter Values
Abatement Cost Function	$\delta(\boldsymbol{a_i})^{\alpha}$	$\delta = 13 \;\; \alpha = 3$
Firm Earnings	$\boldsymbol{Y} = \boldsymbol{Y}^0 - \delta(\boldsymbol{a_i})^{\alpha}$	$\boldsymbol{Y}^0 = 75{,}000$
Firm Level Emissions	$x_i = \gamma_i - a_i$	$\gamma_i = 20$
Ambient Pollution	$x = \sum_{i=1}^{n}(\gamma_i - a_i)$	$\boldsymbol{n} = 6$
Regulatory Only Policy	Tax payment = $max[\tau(x - \bar{x}), 0]$	$\tau = 2{,}500$ $\bar{x}$ = See Table 1
Voluntary/Threat Policy	<u>Voluntary Round</u> Tax payment = 0 <u>Regulatory Round</u> Tax payment = $max[\tau(x - \bar{x}), 0]$ (*instituted for* $\boldsymbol{K}$ *rounds if* $\boldsymbol{X} > \boldsymbol{X}^s$ *in voluntary round*)	$\tau = 2{,}500$ $\bar{x}$ = See Table 1 $\boldsymbol{K} = 3$

Table 3: Number of Part B rounds in which the ambient standard was met voluntarily

	No Communication			Communication
	$\bar{x}$ = **66**	$\bar{x}$ = **50**	$\bar{x}$ = **End.**	$\bar{x}$ = **50**
Group 1	6	0	0	18
Group 2	0	5	0	14
Group 3	0	18	0	18
Group 4	0	0	14	18
Average	*1.50*	*5.75*	*3.50*	*17*
(standard deviation)	*(3.0)*	*(8.5)*	*(7.0)*	*(2.0)*

Table 4: Estimation Results

Dependent Variable: Mean Individual emissions
Number of Observations: 756

Tax Threshold	**Part A Rounds 1-5**	**Policy Scenario**	**Part B Rounds 6-11**	**Part B Rounds 12-17**	**Part B Rounds 18-23**	$\sigma^2_{T,V}$	ρ
72	20.02 *(0.337)*	**Tax Only**	13.82* *(0.526)*	13.07* *(0.526)*	13.72* *(0.526)*	5.85	0.766
50	19.76 *(0.337)*		9.70* *(0.527)*	10.31* *(0.527)*	10.75* *(0.527)*	6.91	0.718
66	19.24 *(0.337)*	**Voluntary**	14.32* *(0.986)*	16.29* *(0.986)*	17.42* *(0.986)*	11.88	0.565
		Tax	11.42 *(0.363)*	11.39 *(0.356)*	11.56 *(0.356)*	2.25	0.916
50	19.94 *(0.337)*	**Voluntary**	12.67 *(0.932)*	13.50* *(0.932)*	14.21* *(0.932)*	9.42	0.568
		Tax	9.44* *(0.654)*	9.26* *(0.654)*	10.14* *(0.654)*	8.61	0.859
Endogenous	19.69 *(0.337)*	**Voluntary**	12.53 *(0.881)*	13.15 *(0.881)*	13.69* *(0.881)*	7.18	0.675
		Tax	12.05 *(0.612)*	11.86 *(0.636)*	11.44 *(0.653)*	8.18	0.860
50 (Com)	19.73 *(0.337)*	**Voluntary**	12.00 -	12.00 -	12.10 -	-	-
		Tax	- -	- -	- -	-	-
		Estimated Group Level Variance				**Tax** = 0.132 **Voluntary** = 1.91	

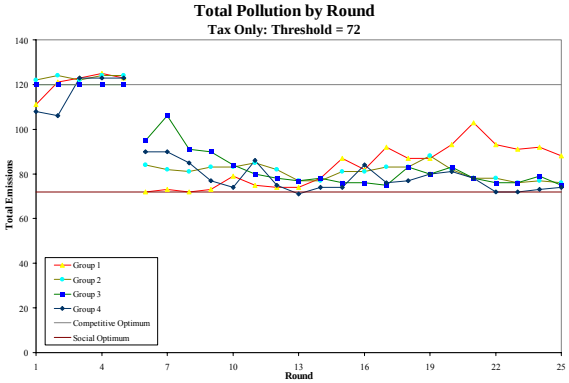
* Indicates that the coefficient estimate in Part B is significantly different from 12 at the 5% level. None of the results from Part A are significantly different from 20.

Table 5: Mean efficiency levels by treatment

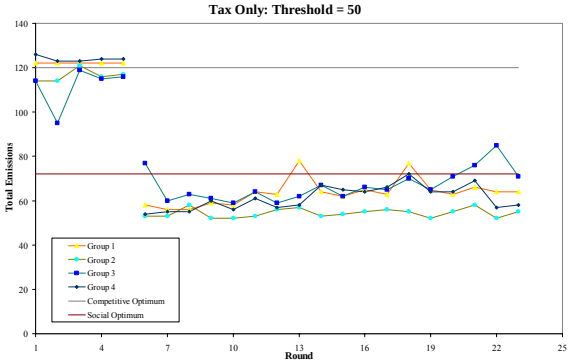
Tax Threshold	**Policy**	**Rounds 6-11**	**Rounds 12-17**	**Rounds 18-23**	$\sigma^2_{T,V}$	ρ
72	Tax Only	78.85 *(6.50)*	85.27 *(6.50)*	80.25 *(6.50)*	0.017	0.296
50	Tax Only	79.05 *(9.87)*	74.51 *(9.87)*	72.51 *(9.87)*	0.039	0.872
66	Voluntary/Threat	81.04 *(3.03)*	85.47 *(3.03)*	73.31 *(3.03)*	0.004	0.511
50	Voluntary/Threat	57.86 *(6.11)*	64.18 *(6.11)*	70.71 *(6.11)*	0.015	0.587
Endogenous	Voluntary/Threat	84.25 *(8.02)*	82.97 *(8.02)*	79.85 *(8.02)*	0.026	0.960
50 (Com)	Voluntary/Threat	100.00 *(2.99)*	100.00 *(2.99)*	94.82 *(2.99)*	0.004	-

Appendix

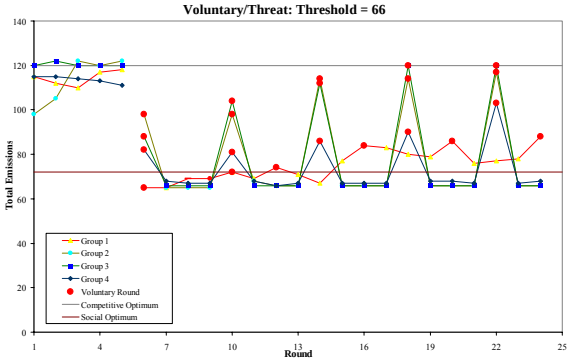
Total Pollution by Round
Tax Only: Threshold = 72



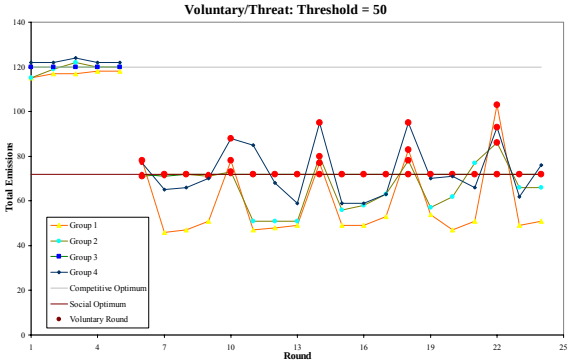
Total Emissions by Round
Tax Only: Threshold = 50



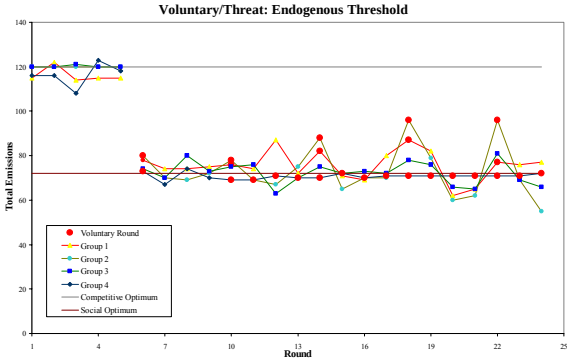
Total Emissions by Round
Voluntary/Threat: Threshold = 66



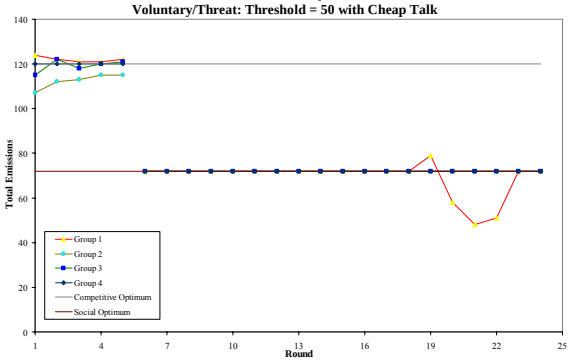
Total Emissions by Round
Voluntary/Threat: Threshold = 50



Total Emissions by Round
Voluntary/Threat: Endogenous Threshold



Total Emissions by Round
Voluntary/Threat: Threshold = 50 with Cheap Talk



Choice Experiments to Assess Farmers' Willingness to Participate in a Water Quality Trading Market

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Introduction

Water Quality Trading (WQT) has received increased attention as a means to achieve water quality goals. Several such trading programs have been adopted in several states throughout the nation, with more than 70 programs now in operation (Breetz et al., 2004). In principle, such programs could be applied to any water-borne pollutant and allow trading among point sources, among nonpoint sources, or between point and nonpoint sources (the latter is known as 'point-nonpoint trading'). Most of the existing programs are designed with point-nonpoint trading to limit nutrient loading: point sources are allowed to meet their nutrient emission limits by purchasing water quality credits from agricultural producers in the surrounding watershed. These producers are then obligated to implement a best management practice (BMP) that reduces expected nutrient loading by an amount commensurate with the number of credits sold.

Substantial evidence exists that nonpoint sources can reduce nutrient loading at a much lower cost than point source polluters in many watersheds. This suggests that a well functioning WQT program would be a more cost-effective strategy for meeting total maximum daily load requirements than regulating point source polluters alone (Faeth, 2000). The potential for pollution trading to lower control costs has already been realized in the active air quality trading markets (NCEE, 2001).

Despite the potential gains from WQT, perhaps the most commonly noted feature of existing programs is low trading volume; none of the programs have had extensive trading activity and many have had no trading at all (Hoag and Hughes-Popp, 1997). Our particular interest in this paper is the participation of nonpoint sources, almost always agricultural crop producers in existing programs. The reluctance of farmers to participate in WQT reflects a broader reluctance to adopt environmental practices in exchange for monetary payments (e.g., Cooper and Keim 1996).

Evidently, farmers perceive some intangible costs of participating in WQT markets that are not offset by the monetary gains from trading. These costs may include the disutility of the managerial effort required to maintain BMPs, and/or a distaste for the WQT market procedures and rules. For example, farmers may object to the intrusiveness of being inspected or monitored to ensure their BMP is in place, or find the process of signing up for the program to be too onerous.

Although the existence of intangible costs is apparent from empirical evidence, the factors giving rise to these costs are not well understood. The objective of this paper is to quantify the impact of different institutional factors on farmer's stated behavior in a WQT market. In particular, we wish to determine the importance – relative to monetary trading income – of various WQT market attributes on farmers' willingness to participate in such a market. The magnitude of these factors will provide information about how to design a program to encourage participation and, more broadly, will identify the situations where a WQT market is feasible given that certain rules are necessary.

The method of choice experiments is well suited to our research question. Choice experiments were originally developed in the marketing literature in order to determine the implicit market

value of various product attributes. Subjects in these experiments make a choice from a side-by-side comparison of 3 or more products, which vary by different attributes including price. The choice data is then analyzed using discrete choice regression models, such as conditional logit, to estimate the effect of each attribute on the probability that the consumer chooses the product. This method has been widely adopted by environmental economists studying choice behavior related to environmental quality, such as selection of recreation sites (e.g., Adamowicz et al., 1997) and housing location (e.g., Earnhart, 2001). Economists studying agricultural markets have also applied the method to understand the attributes of food products influencing consumers' shopping choices (e.g., Fox et al., 2002).

This paper describes a set of choice experiments designed to elicit WQT trading behavior of Great Plains crop producers in different situations. In our case, the attributes to be varied across choices are the features of trading, such as the effort required for signup and the monitoring the farmer would need to undergo. Choice experiments are being conduced in person with producers at events in different locations in Kansas from August 2006 through January 2007.

Only our first set of choice experiments has been completed to date. After describing the design of our choice experiments and the data collection procedures, we present an initial analysis of the small dataset assembled so far. This analysis is based on only simple, descriptive methods and is intended primarily to validate our data collection procedures. In addition, we collected qualitative data (written responses to open-ended opinion question), which provide insight on the appropriate model specification for our future econometric analysis.

Experimental Design

The purpose of our experiments is to identify market rules and attributes that influence farmers' willingness to participate in a point-nonpoint WQT market. After reviewing the operations of existing programs and consulting with Extension personnel and a small group of farmers in Kansas, we identified four market attributes that are likely to affect participation: (1) application time and effort, (2) the monitoring method, (3) penalties for violations, and (4) the BMP to be adopted. Embedded within the definition of BMPs is another key attribute: the degree of flexibility a farmer would have in fulfilling his trading obligations. As noted above, the price of credits is an additional explicit attribute, which will ultimately allow us to compute the implicit values of the other four. These attributes are listed in Table 1 and are described in more detail below.

Table 1. Design Attributes and Levels

Attribute	Variable Name	Levels
Application Time (hours)	*Time*	4, 16, 24, 40
Monitoring method	*Monitoring*	Annual verification, Spot check
Penalty ($/acre enrolled)	*Penalty*	50, 100, 250, 500
Annual trading revenue ($/acre enrolled)	*Revenue*	3, 7, 15, 25
Best Management Practice	*BMP*	Filter strip (no haying/grazing), Filter strip (with haying/grazing), 100% No-till, Rotational No-till

By designing our experiments with different levels of our five attributes, we generate a dataset that allows us to test whether the institutional attributes affect trading choices, and if so, the magnitude of these impacts relative to price. Farmers were asked to choose among different opportunities to trade, which varied across the five attributes. Such choice scenarios would arise in an actual trading program, for example, if a WQT program were established in some region that allowed buyers to spell out the terms of the trading contract. Different buyers would then develop different contracts suiting their needs, giving rise to a range of trading opportunities for farmers. In the choice experiment method, the attributes are varied systematically based on experimental design principles, so that the resulting dataset maximizes statistical efficiency. In what follows, we describe the attributes we vary in our choice experiments and then explain the procedures we followed to design our choice sets.

Design Attributes

This section describes each of the attributes varied in our experiments and rationale for the levels we selected (Table 1). As noted above, trading opportunities are defined as different combinations of these attribute levels. A sample choice scenario presented to farmers is in Figure 1. Each scenario asks farmers to choose one of two trading opportunities, labeled Option A and Option B, or else choose Option C - "do not enroll." To facilitate comparison, all trading opportunities were assumed to be for a 10-year contract on a 100-acre field.

Scenario 8

You have two opportunities to sell credits in a Water Quality Trading market, given by Option A and Option B below. Your choices are to enroll your entire 100-acre field in one of these options (but not both) or neither of them.

	Option A	Option B	Option C
Application time (hours)	24	40	Do Not Enroll
Monitoring method	Annual verification	Annual verification	
Penalty for violations ($/acre enrolled)	100	100	
Best Management Practice (BMP)	Filter strip (with haying/grazing)	Rotational no-till	
Price and Cost information			
Offer price per credit ($/credit/year)	$2.50	$1.40	
Credits generated per acre enrolled	6	5	
Credit Revenue ($/acre/year)	$15.00	$7.00	

Which option would you choose? *(mark one box only)* ☐ ☐ ☐

Figure 1. Sample Choice Set

The first attribute in the choice experiment is Application Time. This refers to the amount of time a potential seller would have to spend to establish his eligibility to enter into a WQT contract. This time would be expended on such activities as meeting with the staff of the entity managing the market, compiling data on the field to be enrolled, and filling out paperwork. Application time would vary depending on the complexity of the program and the desires of the buyer in the contract. We set the application time to vary from 4 to 40 hours to enroll a 100-acre field, a range we assumed was large enough to capture a wide range of contract complexity.

The Monitoring Method has two categorical levels. If Monitoring Method = Annual Verification, then farmers entering into a contract would be visited at an unannounced time each year to ensure they are meeting the terms of the contract. The field where the contracted BMP is to be installed would be inspected to verify that the practice is being implemented and maintained as agreed. If Monitoring Method = Spot Check, then the farmer would be visited with a 10% probability each year, implying that one visit would occur during an average 10-year contract period. If visited, the type of inspection would be the same as with Annual Verification. These two possibilities reflect varying levels of "intrusiveness" the seller must be willing to accept.

The Penalty is a one-time fine to be paid if the seller is found in violation of the contract. Levels of this attribute range from $50/acre to $500/acre, a sufficiently wide variation to ensure that farmers would not find it rational to "plan on cheating" and paying the fine when caught. For example, under the Spot Check system of monitoring, the upper end of this range produces an expected penalty from cheating of $50/acre/year. This exceeds the maximum revenue that could be earned from entering into a contract ($25/acre/year - see below), which is also the maximum possible gain from cheating on a contract.

The BMP is the fourth attribute, which takes on four categorical levels indicating four distinct BMPs. The four BMPs vary along two dimensions. The first dimension is the type of practice – the farmer must either install a filter strip or implement no-till. The second dimension is the level of flexibility the farmer would have in meeting his contract obligations. In the case of filter strips the more flexible option would allow farmers to hay and or graze the filter-designated area. For no-till, flexibility comes in the form frequency of use – "rotational no-till" allows for some other tillage practice in 5 out of the 10 years under contract. We designed our scenarios so that Option A was always of the filter strip variety and Option B was always of the No-till variety. This reduces the number of degrees of freedom in our experimental design, by effectively reducing this four-level attribute to a two-level attribute.

The BMPs will be a significant determinant of farmers' choice if they value flexibility, or if they perceive differences in implementation costs. One complication in comparing the BMPs is that filter strips involve up-front installation costs: the land for the filter strip must be tilled, leveled, and seeded to grass in the first year. On the other hand, KSU Extension crop budgets indicate an expected cost of zero for a typical Kansas farmer to implement no-till. To make this comparison more straightforward for respondents, they were told that the installation costs of filter strips would be covered from "an outside source." This is not unrealistic, as cost share funds from both state and federal programs are available to pay for installing buffer strips statewide.

Another reason we removed the installation costs was to focus the respondent's attention on comparing the ongoing managerial costs of the practices. To clarify the managerial costs of each of these practices, farmers were given specific definitions of the practices along with a list of maintenance responsibilities. "100% No-till," for example, was defined as the tillage practice where the only equipment that breaks the soil surface is a planter, and this occurs at most once annually. For filter strips, the maintenance requirements were to regularly check for and repair any gullies that develop, to avoid using the filter strip as a roadway, and to avoid broadcast application of chemicals or manure in the filter strip area.

The final attribute is trading revenue, or the price per credit multiplied by the number of credits generated from the BMP. We varied trading revenue from $3/acre/year to $25/acre/year, following the range used by Cooper and Keim (1996) and Cooper (1997). Each BMP was assumed to generate a fixed number of credits (Table 2), and the price per credit was calculated in each scenario so that price times credits equaled the specified revenue level. For example, in Option A of the scenario shown in figure 1, our experimental design called for a revenue of $15/acre/year and a BMP of Filter Strip (with haying/grazing), a practice which would generate 6 credits/acre (Table 2).The price per credit was then calculated as $15/6 = $2.50. As described below, we generated 32 different choice sets encompassing 64 distinct trading choices. Across all 64 choices, the variation in credits (see table 2) combined with the variation in revenue ($3-$25) produced a variation in the price per credit of $0.25 to $5.00.

Table 2. Credits Generated by Best Management Practices

Best Management Practice	**Credits Generated**
	credits/acre/year
Filter strip (no haying/grazing)	12
Filter strip (with haying/grazing)	6
100% No-till	9
Rotational No-till	5

Design Procedures

As noted above, our experimental subjects were to respond to choice sets, each of which contains two trading opportunities with five attributes. Thus there are a total of ten attributes to be varied across choice sets. Our experimental design problem is to construct a collection of choice sets by systematically varying these 10 factors. 6 of these factors have 4 levels and the remaining 4 have 2 levels, implying that a complete factorial spanning all possible combinations these factors would require 65,536 distinct choice sets – obviously a prohibitive number of scenarios to present to respondents.

We used the SAS %MktRuns macro (Kuhfeld, 2005) to identify the minimum number of choice sets in an orthogonal main effects design. An orthogonal main effects design is a small sample of all combinations in the full factorial, where the chosen combinations exhibit a zero correlation

among the attributes. The smallest orthogonal main effects design contains 32 choice sets, and such a design was constructed using the SAS %MktEx macro (Kuhfeld, 2005). The choice sets were then blocked into two sets of 16, so that our choice experiment came in two versions. The choice sets in our design are shown in table 3.

Table 3. Designed Choice Sets

		Option A Attributes					Option B Attributes				
Set	**Ver.**[a]	***Time***	***Monitoring***[b]	***Penalty***	***Revenue***	***BMP***[c]	***Time***	***Monitoring***[b]	***Penalty***	***Revenue***	***BMP***[d]
1	1	24	SC	50	7	FSH	4	AV	500	25	NT
2	1	4	SC	500	15	FSH	16	AV	100	15	NT
3	1	24	SC	250	15	FSNH	24	SC	500	15	RNT
4	1	40	AV	50	25	FSNH	24	AV	100	3	RNT
5	1	4	AV	500	25	FSH	4	SC	250	15	RNT
6	1	4	AV	100	3	FSNH	24	AV	250	25	NT
7	1	4	SC	250	3	FSH	40	SC	50	3	NT
8	1	24	AV	100	15	FSH	40	AV	100	7	RNT
9	1	40	SC	250	7	FSH	16	AV	250	7	RNT
10	1	40	AV	100	7	FSNH	4	SC	50	15	RNT
11	1	40	SC	50	15	FSNH	40	SC	250	3	NT
12	1	16	AV	500	3	FSNH	40	AV	500	7	RNT
13	1	24	AV	50	3	FSH	16	SC	50	25	RNT
14	1	16	AV	100	25	FSH	16	SC	500	3	NT
15	1	16	SC	250	25	FSNH	4	AV	100	25	NT
16	1	16	SC	500	7	FSNH	24	SC	50	7	NT
17	2	40	AV	250	3	FSH	4	SC	100	7	NT
18	2	4	AV	250	7	FSH	24	AV	500	3	RNT
19	2	16	AV	250	15	FSNH	16	SC	250	25	RNT
20	2	16	SC	50	3	FSH	24	SC	100	15	RNT
21	2	24	AV	250	25	FSNH	40	AV	50	15	NT
22	2	16	AV	50	7	FSH	40	AV	250	15	NT
23	2	4	AV	50	15	FSNH	4	SC	500	7	NT
24	2	24	SC	500	3	FSNH	4	AV	250	3	RNT
25	2	4	SC	100	7	FSNH	40	SC	100	25	RNT
26	2	24	AV	500	7	FSNH	16	SC	100	3	NT
27	2	24	SC	100	25	FSH	24	SC	250	7	NT
28	2	40	AV	500	15	FSH	24	AV	50	25	NT
29	2	16	SC	100	15	FSH	4	AV	50	3	RNT
30	2	40	SC	100	3	FSNH	16	AV	500	15	NT
31	2	4	SC	50	25	FSNH	16	AV	50	7	RNT
32	2	40	SC	500	25	FSH	40	SC	500	25	RNT

[a] Survey version. Sets 1-16 were in version 1; 17-32 in version 2.
[b] SC = Spot check; AV = Annual verification
[c] FSH = Filter strip (with haying/grazing); FSNH = Filter strip (no haying/grazing)
[d] NT = 100% No-till; RNT = Rotational No-till

Data Collection

Our choice experiments are being conducted in person with farmers at different producer-oriented conferences in Kansas. The first such event was already completed in conjunction with the 2006 Risk and Profit Conference, an annual event hosted by the Agricultural Economics Department at KSU. This conference was held on August 17-18, 2006 and our experiments were conducted with 39 producers in attendance. Our initial description and analysis below is based on this dataset. The second conference is a statewide Farm Bureau conference, to be held in January 2007 in Wichita. The third and fourth events are 1-day Agricultural Profitability Workshops run by KSU Extension economists, scheduled for December 2006 in northwest Kansas and for January 2007 in north-central Kansas. We plan to elicit an average of about 40 producers at each remaining conference, for a total of approximately 160 subjects.

Our data collection procedures at all these conferences are as follows. First, experimental subjects are recruited via a pre-registration mailing and an announcement at the opening conference session. The choice experiment itself is conducted during a 1-hour session, typically scheduled as a parallel session in the conference program. During this session, subjects are first shown a brief presentation on the concept of Water Quality Trading, followed by instructions to complete the choice experiments.

The instructions include much the same information as in the Design Attributes section above. A hypothetical situation was first described, in which subjects are asked to imagine that a WQT program had been developed in their region with different buyers giving them different types of opportunities to sell credits. The opportunities vary along five dimensions (the attributes in table 1). These attributes and their various levels are then explained. BMPs are explained in more detail than the other attributes, to ensure that the producers understood what their contract responsibilities would be under each. Finally, the respondents are shown an example choice set to give them practice in completing the experiment.

After allowing for clarification questions, the subjects then fill out a booklet with 16 choice sets. A printed copy of the background and instruction slides are also provided to subjects for their reference, and the instructions are also summarized at the beginning of the booklet. Each choice set in this booklet is followed by an open-ended question asking, “Why did you make this choice?” As explained in more detail below, these qualitative responses are among the first data items we are analyzing and are proving to be helpful in choosing our econometric specification. After completing the booklet each subject completes a questionnaire eliciting information on his/her farm operation, his/her attitudes toward water quality issues and policies, and demographic data. Copies of all materials used in these sessions are available from the authors.

After the instruments have been completed, each subject is paid an honorarium of $50 in cash. This is announced in the pre-registration mailing and at the opening conference session to encourage participation. Our data collection procedures and instruments were pre-tested with a small group (12) of producers from the Great Plains about one month prior to the Risk and Profit Conference.

Preliminary Data Analysis and Econometric Specification

Only preliminary analyses of the data have been performed to date. Our work so far has been descriptive and exploratory, with the intent of validating our data collection procedures and identifying the appropriate econometric specification.

Questionnaire Data: Summary Statistics

Summary statistics from our first 39 responses to the questionnaire are in Table 4. The average farmer in this sample owns 939 acres of cropland and rents 811 acres, for an average farm size of 1,750 acres. However, the distribution of size is skewed, with a few very large operations; the maximum owned acres is 6,000 and the maximum rented acres is 5,000. These statistics are reflective of the overall distribution of farm sizes in Kansas, which has a few large farms at the upper tail of the distribution. Based on the 2002 Census of Agriculture, about 10% of all farm operations in Kansas exceed 2,000 acres (NASS).

Many of the producers in the sample currently use one or more BMPs. The most popular BMP is minimum tillage, used by 53% of respondents, while the least popular on the list was subsurface application of fertilizer, with only 21% of respondents using this practice. Notwithstanding farmers' willingness to adopt BMPs, there is a persistent gap between their awareness of conservation programs and their participation in them. For example, 100% respondents are aware of the Conservation Reserve Program, but only 53% have participated in it. The gap is particularly stark for the Environmental Quality Incentives Program (EQIP), which has an awareness rate of about 90% but a participation rate of 30%. Similarly large gaps are present for the Conservation Security Program and the Kansas Buffer Initiative. Because these programs offer incentives that match and in some cases outweigh the monetary expenses of installing BMPs, the observed participation gap is consistent with the presence of intangible costs as reviewed above.

In terms of perceptions, farmers agree with the sentiment that water quality needs to be protected and that BMPs help reduce nutrient and sediment runoff. However, the average respondent was neutral on whether Kansas water supplies are polluted. The average response was also neutral on the statements that "*Mandating BMP installation and management is unfair to producers*," and that "*Environmental legislation is often unfair to producers*." Finally, the experiment itself appeared to increase subjects' knowledge of WQT, with the self-assessed level of knowledge increasing, on average, about 1.5 points on a 5-point scale.

The demographic data from our sample suggest it is fairly representative of the larger farm population, considering our relatively small sample size to date. The average age of producers in our sample is 46, compared to a population average of 56 based on the 2002 Census of Agriculture (NASS). Similarly, about 17% of our respondents were female, compared to 9% of primary farm operators in Kansas. Our sample is somewhat younger with a higher proportion of female respondents, although these may be small sample properties. If the final sample is skewed toward certain demographic cohorts, this can be corrected by assigning appropriate weights in our regression analysis.

Table 4. Summary Statistics of Initial Questionnaire Data

Item	Mean	Standard Deviation	Minimum	Maximum
Farm Characteristics				
Owned cropland (acres)	939	1602	0	6000
Rented cropland (acres)	811	1308	0	5000
Cropland bordering waterbodies (proportion)[a]	0.676	0.475	0	1
Best Management practices in use (proportion)[a]				
Filter strip	0.289	0.460	0	1
Minimum tillage	0.526	0.506	0	1
Rotational no-till	0.395	0.547	0	1
Exclusive (100%) No-till	0.289	0.460	0	1
Terraces	0.553	0.504	0	1
Sub-surface application of fertilizer	0.211	0.413	0	1
Contour farming	0.316	0.471	0	1
Familiarity/participation with conservation programs (proportion)[a]				
Conservation Reserve Program: Familiar With?	1.000	0.000	1	1
Conservation Reserve Program: Participated In?	0.526	0.506	0	1
Environmental Quality Incentives Program: Familiar With?	0.895	0.311	0	1
Environmental Quality Incentives Program: Participated In?	0.289	0.460	0	1
Conservation Security Program: Familiar With?	0.658	0.481	0	1
Conservation Security Program: Participated In?	0.081	0.277	0	1
Kansas Buffer Initiative: Familiar With?	0.421	0.500	0	1
Kansas Buffer Initiative: Participated In?	0.079	0.273	0	1
Perceptions				
Level of agreement with the following statements:[b]				
"Best management practices (BMPs) reduce nutrient and sediment runoff."	1.21	0.66	-1	2
"Kansas surface water quality needs to be protected."	1.37	0.49	1	2
"Kansas groundwater quality needs to be protected."	1.37	0.54	0	2
"Mandating BMP installation and management is unfair to producers."	0.16	1.01	-2	2
"Environmental legislation is often unfair to producers."	0.47	0.89	-1	2
"Kansas surface waters are polluted."	0.29	0.87	-2	2
"Kansas groundwater supplies are polluted."	-0.05	0.78	-2	1
Self-assessment of knowledge of Water Quality Trading:[c]				
Before participating in experiment	-1.03	1.10	-2	2
After participating in experiment	0.47	0.80	-1	2
Demographics				
Gender (1=male, 0=female)	0.834	0.374	0	1
Age (years)	45.8	12.4	23	69
Occupation				
Farmer/rancher	0.579	0.500	0	1
Landowner not actively farming	0.053	0.226	0	1
Land manager	0.053	0.226	0	1
Lender/farm advisor/educator	0.474	0.506	0	1
Farming primary occupation	0.444	0.504	0	1

[a] Responses in proportions indicate the share of subjects choosing a particular response, not a share of acreage.

[b] Responses measured on a 5-point scale, where -2=strongly disagree, -1=disagree, 0=neutral, 1=agree, and 2=strongly agree.

[b] Responses measured on a 5-point scale, where -2=very low, -1=low, 0=moderate, 1=high, and 2=very high.

Choice Data

Turning now to the choice experiments, we recorded the choice made in 16 distinct scenarios by 39 subjects, producing a dataset with 620 usable observations. Figure 2 shows the composition of these data across the 3 choices (options A, B, C) for all 39 subjects. Subjects in the figure are sorted by their frequency of choosing option C, the "do not participate" alternative. All 39 subjects chose to participate in the program (i.e., selecting either option A or B) in at least one scenario, and four subjects chose to participate in all 16 scenarios.

Participation was not dominated by either filter strip (option A) or no-till (option B) contracts. In scenarios where they participated, all but six subjects stated a willingness to choose either option, switching between the two as the non-BMP attributes (application time, monitoring, etc.) varied. In particular, only three subjects (#9, #25, #37) never chose option A and three additional subjects (#22, #26, #39) never chose B. In our entire 620-observation dataset, the distribution across the three choices are: A – 235 (38%), B – 205 (33%), and C – 180 (29%).

On the whole, these preliminary analyses indicate a quite balanced dataset across the three alternatives. This property is one way of validating the ranges of the non-BMP attributes: these attributes were varied widely enough to entice participation in both types of BMP contracts, but also led to nonparticipation in some cases. Balance is also important because we will employ a discrete choice econometric model for analysis – a model family known to be unstable and to predict poorly if the dataset is unbalanced across choices.

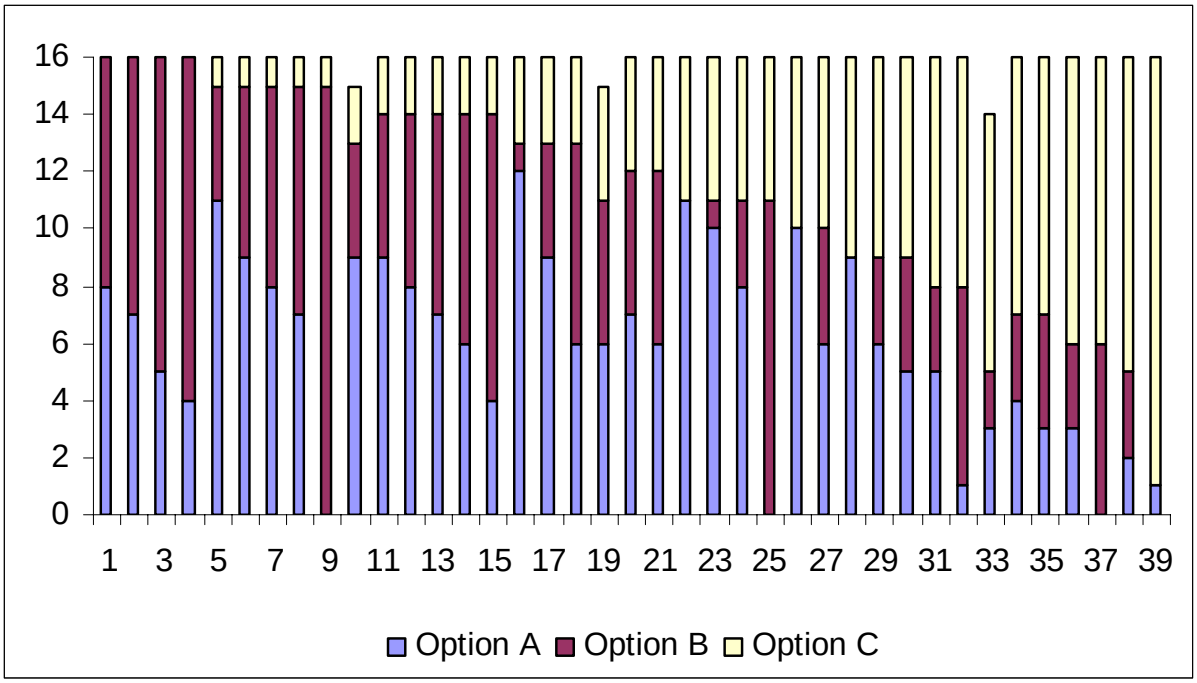

Figure 2. Distribution of Responses from Choice Experiments, First 39 Subjects

Qualitative Data: Insights for Econometric Specification

Various discrete choice econometric methods have been used to analyze choice experiment data, but all these methods are motivated by the random utility model. Suppose that on occasion t, individual i must chose one of several alternatives indexed by j. Let U_{ijt} denote the utility enjoyed by individual i if he chooses alternative j on occasion t. The random utility model posits that U_{ijt} can be partitioned into two additive components:

$$U_{ijt} = V_{ijt} + \varepsilon_{ijt},$$

where (dropping subscripts for simplicity), V is a function of observable variables and ε is a function of unobservable variables. Although individual i knows the values of both V and ε, the researcher lacks data on ε. This introduces a random element in utility across individuals from the researcher's point of view.

An estimable econometric model is developed from the random utility model by (a) assuming that individuals make choices to maximize utility, U, (b) specifying V as a function of a vector of observable variables, $\mathbf{x}$, and (c) making a specific distributional assumption about ε. For example, if V is specified as the linear function $V = \boldsymbol{\beta}'\mathbf{x}$ and ε follows an extreme value type II distribution then the probability that i chooses j at time t is

$$P_{ijt} = \Pr\{U_{ijt} > U_{ikt} \text{ all } k \neq j\} = \frac{\exp(\boldsymbol{\beta}'\mathbf{x}_{ijt})}{\exp(\boldsymbol{\beta}'\mathbf{x}_{ijt}) + \sum_{k \neq j} \exp(\boldsymbol{\beta}'\mathbf{x}_{ikt})}$$

This is known as the conditional logit model and is widely used in the literature. Given data on actual choices by sample of individuals, estimation of the parameters $\boldsymbol{\beta}$ can be achieved via maximum likelihood (Greene, 2003).

One assumption embedded in the conditional logit model is that the parameters, $\boldsymbol{\beta}$, are invariant across individuals. In our context, the variables in $\mathbf{x}$ would include the attributes of the various trading choices. The $\boldsymbol{\beta}$ parameters can be interpreted as the marginal utilities of these attributes, so that the conditional logit model would assume the marginal utility of each attribute is identical across subjects.

However, the qualitative data collected in our choice experiment survey directly contradict this assumption. For example, in their written follow-up responses to scenarios where one of the alternatives had a much higher Penalty than the other, different subjects provided different types of comments. One variety is well summarized by the response, "*I am assuming that I am going to comply and so I am not concerned with the penalty*." These individuals chose the option with the higher penalty, based on other attributes they found attractive such as higher revenue. Other subjects, who did not select the high penalty option, made comments similar to the following: "*Payment is great per acre … but penalty is very high and checked every year. Sure I probably would not violate but don't want to take the chance.*" Here, the concern appeared to be that the farmer would be found in violation of the contract even though he *intends* to comply.

These responses lead us to hypothesize that farmers have differing with respect to our key attributes. For the Penalty attribute, the heterogeneity in preferences would arise from differences in farmers' subjective probabilities of being found in violation when intending to comply, as well as differences in their risk preferences. In order to test this hypothesis, we must specify a model that allows the β parameters to differ across individuals. One such model is the random parameters logit model. One or more of the parameters in the β vector are assumed to have a distribution across individuals, which can be specified by the researcher (e.g., normal or log-normal distribution). Rather than estimating the values of the β's per se, the econometric problem is to estimate the underlying distributional parameters of the randomly specified β's across people (e.g., means, variances, and covariances). This model will be pursued to formally test whether the marginal utility parameters differ across farmers.

Concluding Remarks and Next Steps

The econometric model to be estimated from the choice data will be capable of predicting the trading choices of farmers in a WQT program under different trading rules. As part of our ongoing research project, our next goal is to run trading simulations under different types of rules to assess their effect on market performance. These simulations will be accomplished by inserting our estimated equations into a trading simulation model already developed by Smith (2004), which in turn is based on the sequential bilateral trading algorithm of Atkinson and Tietenberg.

Once the trading simulation model is complete, it will be linked to a biophysical watershed model being developed for the Kansas/Delaware Subbasin using SWAT (Arnold et al., 1998; Neitsch et al., 2001). The linked models will then be run in tandem to assess the joint performance of various market designs on economic measures as well as on water quality in different river segments. The objective is to identify a set of trading rules that are simple enough to attract adequate participation while being sufficiently tailored to ensure that water quality goals are indeed met.

As this project is a work in progress and data collection is still underway, only very preliminary results are available. The initial results obtained from our choice experiments suggest that the attribute levels provide a range of incentives to which subjects respond in different ways. Demographic variables in our dataset suggest our sample is so far weighted somewhat toward younger and female producers. More formal tests of demographic representativeness will be conduced as data collection progresses, and adjustments will be made as needed to change our sampling strategy or correct our regression by reweighting different demographic cohorts.

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Incorporating Wetlands in Water Quality Trading Programs: Economic and Ecological Considerations

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Abstract

Water quality trading has grown in popularity and scope in recent years owing to its potential as a flexible low cost way to achieve water quality goals, especially nutrient removal goals. Wetlands provide a variety of ecosystem services. They can sequester CO_2, they can provide habitat and biodiversity and they can remove nitrogen from nonpoint sources of pollution before they enter receiving streams or rivers. Because of this last service regulators are interested in determining the best way to allow traders, primarily agricultural traders, to use restored and protected wetlands in a water quality trading policy. Key to the problem is the existence of the ancillary benefits of wetlands. In this paper we examine the options of 1) including the ancillary benefits of a properly functioning wetland in the market for nutrient removal through subsidies and unique trading ratios, or 2) allowing a producer to trade the various services offered by wetlands in various markets. We also examine which option might be preferred depending on the shape of the marginal benefits curve.

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Introduction

Though great successes are credited to the air quality trading programs, water quality trading has proved problematic. Authors like King and Kuch (2003) find that there are both supply-side and demand-side obstacles to trading. For example, water quality trading programs that control nutrients competed with "green payments" for reducing nonpoint sources of nutrient pollution. Green payments, such as the Conservation Reserve Program, Wetlands Reserve Program, etc., provide assistance to landowners to address environmental issues like soil erosion and damaged or lost wetlands and habitat. Thus, these activities reduced the potential supply of water quality trading credits. Point sources, or potential credit demanders, find the idea of trading with nonpoint sources inequitable given the existing subsidy or green payment programs. Perhaps the largest obstacle facing water quality trading is the fact that the markets are too small to take advantage of those things markets do well.

To this end it has been suggested by many that increasing the size of the market for nutrient trading through the inclusion of wetlands, which act as a nutrient reduction technology, will increase the size of the market enough to bring about a successful program (Raffini and Robertson 2005). There are other benefits from using wetlands that make them attractive. Wetlands sequester CO_2, and wetlands provide habitat. There exist markets for the other two services provided by wetlands. Should wetlands be incorporated in the water quality trading market through the use of trading ratios and subsidies? Or should those who do restore or create wetlands for the purpose of nutrient reduction be able to sell the other services on other markets? The answer depends on a variety of legal, economic, and ecological factors (Heberling et al. 2007).

Austin et al. (1997) and Feng and Kling (2005) both study the ancillary benefits in pollution trading markets. Austin et al. (1997) examine the cost-effective allocation when NOx emissions affected both air quality and water quality. The constraint was water quality standards for the Chesapeake Bay; therefore, the air benefits were ancillary. Feng and Kling (2005) consider the cobenefits of planting practices that sequester carbon. Certain sequestration activities, like planting cover crops or changing tillage practices, also reduce soil erosion and runoff or improve water quality. The reduction in erosion or improved water quality is an externality to the carbon market. Both papers focus on the ancillary benefits of reducing the particular pollutant when they model their problems, which is slightly different from the issue we address here. When using wetlands in water quality trading programs, it is not the reduction in the pollutant that "co-causes" the ancillary benefit; rather, it is the abatement activity or specific technology itself that creates the ancillary benefits.

This paper proceeds as follows, first we discuss the nutrient removal capacity of wetlands and the ancillary ecological and economic benefits they provide. Then we look at some of the economics literature on the theory underlying the choice to use one market or allow the use of multiple markets. Next, we look specifically at the ecology of the wetland system in an effort to appropriately characterize its creation of benefits. Several authors look at the costs and benefits of reducing nutrient loading to the Gulf of Mexico in "The summary evaluation of the economic costs and benefits of methods for reducing nutrient loads to the Gulf of Mexico" (Doering et al. 1999). In that paper there is a brief discussion of price vs. quantity controls, a la Weitzman (1974), focusing on the relative slopes of the marginal cost and marginal benefits curves. It has been suggested elsewhere in the literature (e.g., Woodward and Han 2004, Montero 2001) that this might be not simply be an interesting secondary focus, but rather an integral policy-guiding

feature of the problem. It may dictate whether we prefer a separate market for the ancillary benefits of wetlands or use subsidies and unique trading ratios to encourage their creation.

Wetlands and Water Quality Trading Markets

The basic requirements for a well functioning transferable permit market have been outlined numerous times (see, for example, Heal 2000, Godard 2001, and Biller 2003). These requirements include such things as clear, transferable property rights, bankable permits, securitization, adequate information about damages, legal cap or limit, defensible initial allocation of permits or rights, heterogeneity in ability or cost of control and damage, and a large number of participants. It has also been outlined in many places how water quality trading schemes around the country are not living up to their hype, and there is a general feeling that limited participation or "thin markets" are the primary culprit (King and Kuch 2003). There are few opportunities for traders to realize the full potential of the market, robust and efficient trades are seldom seen. Allowing the use of wetlands in water quality trading programs serves many purposes including increasing the size of the market and increasing the acres of wetlands.

Assuming we can find watersheds where the supply-side and demand-side obstacles are minimized, why do we need to specifically discuss wetlands and trading markets? If wetlands were, in most respects, similar to other nutrient abatement technology, no further discussion would be needed. Producers would choose from a suite of available abatement technologies based on minimizing their costs and would choose wetlands if they represented the least cost method of creating nutrient credits.

Unlike some other types of abatement technology though, wetlands have other functions that benefit humans directly or indirectly. Economists refer to these functions as wetland

services; wetlands may control nutrients, and they may also produce habitat for birds, control flooding, and reduce sediments. The wetlands could be restored or constructed for the purpose of nutrient abatement and could also create these additional services. Some individuals who are not involved in the water quality trading transaction could benefit from these wetland services, but they would not have to pay for them. U.S. EPA considers them ancillary benefits of water quality trading which could accrue to the general public or just to the landowner.

Byström (1998) examines the abatement costs of using wetlands to control nutrients. He suggests that the social benefits could substantially lower the abatement costs of using wetlands, but he does not explicitly estimate these costs.

Ribaudo et al.(2001) looks at reducing nitrogen in the Mississippi Basin through fertilizer reduction or wetland restoration. Not only did Ribaudo et al. include the private costs, social benefits, such as erosion benefits and wetland benefits (e.g., $550/acre), were also incorporated in their model. They find that the social marginal costs of control using wetlands become lower after about 1250 tonnes of nitrogen reduction which occurs when the marginal cost of control of fertilizer reduction catches up to the opportunity costs of land.

Regardless of the wetland functions, economic theory suggests that the producer will not consider the ancillary benefits (positive externality of producing wetlands) because the benefits do not enter the profit maximising decision. If the externality were internalized, then, and only then, would the producer face the social (net) costs. What regulators need to determine is whether the ancillary benefits actually should play a role in the decision of the credit producer (i.e., should regulators ignore the benefits of wetlands and allow producers to minimize their costs of reducing nutrients and sediments?).

Proposition 1: Command-and-Control

Regulators could require all producers of pollution credits to build wetlands to abate nutrients. This, in effect, takes the decision out of the hands of the producers. There would likely be situations where wetlands are not the least cost option and requiring the use of wetlands would not be cost-effective (e.g., limited land space and increasing opportunity costs). Forcing a particular abatement technology goes back to the problem with command-and-control policies which are rarely cost-effective. If regulators decide these benefits should be considered, and U.S. EPA's Water Quality Trading Policy suggests they should, are there other approaches that make economic sense?

Model

For this paper, we assume that the water quality trading market is the primary market and follow the model presented in Horan and Shortle (2005). They focus on a trading program based on expected loadings for the nonpoint source (rather than on inputs). The model assumes a single point source (e.g., a municipal separate storm sewer system (MS4)) and a single nonpoint source (e.g., a farm) for a watershed.

Emissions for the point source, e, are controlled with certainty and known costs c(e). The nonpoint source emissions are considered random, $r(\mathbf{x}, \theta)$, with jth element of $\mathbf{x}$ (a mx1 vector) representing the set of production decisions related to the technology for production and pollution control. The random variable, θ, represents stochastic events that affect runoff, like weather. We assume the nonpoint source profit depends on the choice of $\mathbf{x}$ and the difference between the profits with no regulations ($\mathbf{x_0}$) and profits under regulations ($\mathbf{x}$) is the nonpoint

source pollution control costs, $c_r(x) = \pi(\mathbf{x_0})-\pi(\mathbf{x})$. Pollution from each source causes damage costs, D(e, r) and social costs are then $TC=c(e) + c_r(\mathbf{x}) + E\{D(e, r)\}$.

We assume that some pollution abatement technology provides benefits to third parties outside of the market; an additional component representing ancillary benefits is needed. This assumption differs from Austin et al. (1997) and Feng and Kling (2005), who model the benefits as a function of the reduction of the pollutant, not the technology. Therefore, total ancillary benefits are $B[x_j]$; however, $B[x_j]>0$ only when j=w where w represents a specific pollution control technology that affects individuals outside of the market.[1] We assume $B[x_j]$ is known with certainty for this paper, but we understand that this is an oversimplification. The benefit function is twice continuously differentiable, increasing in x_j ($B'[x_j]>0$) and exhibits decreasing marginal returns ($B''[x_j]<0$).

An *ex ante* efficient allocation of pollution control minimizes the total social cost (TSC): $TSC=c_e(e) + c_r(\mathbf{x}) + E\{D(e, r)\}- B[x_j]$. The necessary conditions are:

$$(1)\ \frac{\partial TSC}{\partial e} = c'(e) + E\left\{\frac{\partial D}{\partial e}\right\} = 0$$

$$(2)\ \frac{\partial TSC}{\partial x_j} = \frac{\partial c_r(\mathbf{x})}{\partial x_j} + E\left\{\frac{\partial D}{\partial r}\frac{\partial r}{\partial x_j}\right\} = 0, \forall j \neq w$$

In the case at hand however, since the abatement technology employed by the nonpoint source leads to ancillary benefits, the marginal external benefit is included in the necessary condition:

[1] For this model, we acknowledge that some abatement technology could lead to external costs. However, for this application, we assume only external benefits; we ignore the case too of non-convexities in the production of the various benefits.

$$(3)\ \frac{\partial TSC}{\partial x_j} = \frac{\partial c_r(\mathbf{x})}{\partial x_j} + E\left\{\frac{\partial D}{\partial r}\frac{\partial r}{\partial x_j}\right\} - B'(x_j) = 0, j = w$$

For all x_j, where $j \neq w$, the marginal expected damages should equal the marginal private benefit for using the input and the marginal private costs of using abatement technology should equal the expected reduction in marginal damage costs. When j=w, the marginal private costs should equal the total of the expected reduction marginal damage costs and the marginal external benefits from the technology.

Market Equilibrium

Following existing trading markets, we use two sets of permits: point source, $\hat{e}$, and nonpoint source, $\hat{r}$. The MS4 must have a mix of these permits at least equal to their emissions. A trading ratio, t, equates emissions to expected loadings: $t = \left|\frac{d\hat{r}}{d\hat{e}}\right|$.

The MS4 will choose emission levels that minimize costs, given price p for emission permits and price q for expected loadings permits to minimize costs, $C=c(e) + q[\hat{e}_{ps} - \hat{e}^0_{ps}] + p[\hat{r}_{ps} - \hat{r}^0_{ps}]$, where superscript 0 represents the initial holdings of permits. It faces the constraint that emissions cannot be greater than the permits it holds, $e \leq \hat{e}_{ps} + (1/t)\hat{r}_{ps}$, where (1/t) is the trading ratio to convert nonpoint source permits to emissions. Assuming that the constraint is satisfied as an equality and assuming the initial allocation of nonpoint source permits for the MS4 is zero, we can substitute the constraint into the cost function. First order conditions remain unchanged from Horan and Shortle (2005). We learn that the trading ratio at the margin is t=q/p and the MS4's costs can be simplified to $C=c(e) + q[e - \hat{e}^0_{ps}]$.

The nonpoint source also has to meet conditions for a market solution. The social cost function for the nonpoint source is $P=c_r(\mathbf{x}) + q[\hat{e}_{nps} - \hat{e}^0_{nps}] + p[\hat{r}_{nps} - \hat{r}^0_{nps}] - B[x_j]$ which is defined similarly as above. We assume that the nonpoint source does not hold any point source permits initially and it faces a loadings constraint, $r \leq \hat{r}_{nps} + t\hat{e}_{nps}$, where t is the trading ratio. Assuming the constraint is met as an equality, we can rewrite social costs as $P=c_r(\mathbf{x}) + p[E[r(\mathbf{x}, \theta)] - \hat{r}^0_{nps}] - B[x_j]$. The first order condition for optimal input use is

$$(4) \quad \frac{\partial P}{\partial x_j} = \frac{\partial c_r(\mathbf{x})}{\partial x_j} + pE\left[\frac{\partial r}{\partial x_j}\right] - B'[x_j] = 0, j = w$$

Finally, we know that for the market to clear, we need to have more permits than emissions and expected loadings:

$$(5) \quad \hat{e}^0 + \left(1/t\right)\hat{r}^0 \geq e + \left(1/t\right)E[r(x_j, \theta)].$$

By basing the number of permits allocated and trading ratios on the results above, we can create the optimal water quality trading program. However, an optimal trading program is not realistic, and Horan and Shortle (2005) present a "conditionally optimal" trading program, based on an environmental authority choosing the number of emission permits available for the market.

We follow their approach for determining the prices and conditionally optimal trading ratio, but allow for the inclusion of at least one of the recognized ancillary benefits of wetlands as the abatement technology. We substitute the derived demands x(p) and e(q) into the total social cost function subject to the market clearing constraint . The Lagrangian is

$$(6) \quad L = c(e(q) + c_r(x(p)) + E\left[D(e(q), r(x(p), \theta))\right] - B[x(p)] + \lambda[(\hat{e}^0 - e(q)) + \left(p/q\right)[\hat{r}^0 - E(r(x(p), \theta))]]$$

where lambda equals the shadow value of increased permit numbers.

The important necessary conditions when ancillary benefits are produced are the market clearing constraint and

$$(7)\quad \frac{\partial L}{\partial p} = \frac{\partial c_r(\mathbf{x})}{\partial x_j}\frac{dx_j}{dp} + E\left[\frac{\partial D}{\partial r}\frac{dr}{dx_j}\right]\frac{dx_j}{dp} + \lambda\frac{1}{q}(\hat{r}^0 - E[r]) - \lambda\frac{p}{q}E\left[\frac{dr}{dx_j}\right]\frac{dx_j}{dp} - B'[x_j] = 0, \forall j = w$$

Based on equation (7), an increase in p has two effects: it leads to a decrease in input use and expected loadings and it decreases the trading ratio, t. The first two right-hand terms show that a decrease in emissions increases abatement costs and decreases expected damages. The fourth term shows that, at the margin, decreasing expected loadings will have a social cost given the constraint.

From equation (7), we can estimate the conditionally optimal price for the expected loadings permit and the conditionally optimal trading ratio. The basic results for the conditionally optimal emission permit price are taken from Horan and Shortle (2005), but with the inclusion of a term that captures ancillary benefits which has interesting implications for the nonpoint source permits and trading ratio. Suppose the only change a nonpoint source makes on the land is adding wetlands for controlling nutrients and it creates additional habitat for wildlife. Substituting the necessary condition for the nonpoint source from the market equilibrium and the estimate of the trading ratio into equation (7), we can solve for p:

$$(8)\quad p = \frac{E\left[\frac{\partial D}{\partial r}\frac{dr}{dx_j}\right]}{E\left[\frac{\partial r}{\partial x_j}\right]} + \frac{\lambda\frac{1}{q}(\hat{r}^0 - E[r])}{E\left[\frac{\partial r}{\partial x_j}\right]}\frac{dp}{dx_j} - \lambda\frac{p}{q} - \frac{B'[x_j]}{E\left[\frac{\partial r}{\partial x_j}\right]}$$

$$= E\left[\frac{\partial D}{\partial r}\right] + \frac{\operatorname{cov}\left(\frac{\partial D}{\partial r}, \frac{\partial r}{\partial x_j}\right) - B'[x_j]}{E\left[\frac{\partial r}{\partial x_j}\right]} - \lambda\frac{p}{q} + \lambda\frac{p}{q}\left(\frac{(\hat{r}^0 - E[r])}{E[r]}\right)\varepsilon_{pr}, \forall j = w$$

where $\varepsilon_{pr}<0$ is the nonpoint source's inverse elasticity of demand for expected pollution loads. With no ancillary benefits, the marginal external benefits drops out and the price of the expected loadings permit is the same as Horan and Shortle (2005). With ancillary benefits, the change in price depends on the sign of the covariance. A negative sign suggests that expected loadings permit price should be higher when ancillary benefits are created. With a positive sign, the change in price depends on whether cov($\partial D/\partial r$, $\partial r/\partial x_j$) is greater, less than, or equal to $B'[x_j]$.

Malik et al. (1993), Shortle (1987), and Horan and Shortle (2005) discuss the sign of the covariance term. If the damage function is convex in r, then the covariance term has the same sign as cov(r, E[$\partial r/\partial x_j$]). The sign of this equals the change in the variance of nonpoint source pollution given a change in the level of abatement. If the level of abatement decreases the variance of nonpoint source pollution, then the covariance is negative. While one would think that increasing the level of a specific abatement technology would always reduce the variance of the targeted pollution this is not necessarily the case in such complex systems as wetlands. Bÿstrom et al. (2000) and Mitsch and Gosselink (2000) indicate that wetlands are able to reduce the variance of the nonpoint source pollution. If true, the covariance term is negative and price should be higher when ancillary benefits are generated. But evidence from constructed wetlands in Ohio gathered by Spieles and Mitsch (2000) points to a possible increase in variance in a high

nutrient riverine system, which means the covariance term is positive. And Moustafa et al. (1996) find in a wetland in south Florida covariance for abatement of Phosphorous decreased but that for Nitrogen did not, further highlighting the complexity of these systems.

Continuing our assumption that wetlands are created on the nonpoint source land, we can try to understand how the additional benefits affect the trading ratio. Knowing that the trading ratio is the ratio of permit prices, we can use the results above for p and q and develop a trading ratio when ancillary benefits are generated:

$$(9) \quad t = \frac{E\left[\frac{\partial D}{\partial e}\right] - \lambda\left(\frac{(e-\hat{e}^0)}{e}\right)\varepsilon_{qe} - \lambda\left(\frac{(\hat{r}^0 - E[r])}{E[r]}\right)\varepsilon_{pr}}{E\left[\frac{\partial D}{\partial r}\right] + \left[\frac{\operatorname{cov}\left(\frac{\partial D}{\partial r}, \frac{\partial r}{\partial x_j}\right) - B'[x_j]}{E\left[\frac{\partial r}{\partial x_j}\right]}\right]}$$

If nonpoint loadings are known, no ancillary benefits are produced, and the number of permits is set optimally, the trading ratio reduces to the ratio of damage impacts from emissions and loadings. Incorporating stochastic nonpoint loadings adds the second term in the denominator, what Malik et al. call the "marginal damage premium." It becomes apparent for this trading ratio that the sign of the marginal damage premium depends on the covariance term. When ancillary benefits occur, the marginal damage premium includes the marginal external benefit. The sign for the marginal benefit is assumed positive. We assume that the loading function is decreasing in x_j, meaning the denominator is negative. If the covariance is negative, the term in the large bracket is positive and the trading ratio should be smaller. With a positive sign, the trading ratio depends on whether $\operatorname{cov}(\partial D/\partial r, \partial r/\partial x_j)$ is greater than, less than, or equal to $B'[x_j]$.

When we assume multiple changes by the nonpoint source, the trading ratio becomes

$$(10) \quad t = \frac{E\left[\frac{\partial D}{\partial e}\right] - \lambda\left(\frac{(e-\hat{e}^0)}{e}\right)\varepsilon_{qe} - \lambda\left(\frac{(\hat{r}^0 - E[r])}{E[r]}\right)\varepsilon_{pr}}{E\left[\frac{\partial D}{\partial r}\right] + \left[\sum_{j=1}^{m} \frac{\operatorname{cov}\left(\frac{\partial D}{\partial r}, \frac{\partial r}{\partial x_j}\right) - B'[x_j]}{E\left[\frac{\partial r}{\partial x_j}\right]}\right]}$$

We propose two ways to internalize this positive externality: one is to provide some kind of subsidy and unique trading ratio within the program that specifically rewards the use of wetlands over other technologies and further that rewards "better" wetlands incrementally. The other way is to allow wetlands to be traded in multiple markets. That is, the nonpoint source would get credit for the creation of a wetland in the water quality trading program, and could solicit credit for the same wetland under a carbon sequestration market and if applicable a biodiversity market.

Proposition 2: Subsidy and Unique Trading Ratio

There are two principle reasons to capture the ancillary benefits of wetlands in the nutrient trading market, one is the reduction of transactions costs and the other is the increase of market size. It seems that nutrient reduction and habitat preservation occur in the same places, combining a market will increase transfer opportunities and extend the range of solutions open to agents, while reducing transaction and organization costs (Godard 2001).

Given that the expected marginal external benefits from abatement technology only enters the price of the expected loadings permits and the trading ratio, there are likely incentives within those components that might encourage the use of wetlands. If the external benefits were internalized, then the nonpoint source and point source would have additional incentives for using wetlands in a water quality trading program.

When no external benefits exist with the abatement technology, the trading ratio is that calculated by Horan and Shortle (2005). Ancillary benefits lead to either a higher or lower trading ratio depending on how wetlands affect the variance of the loadings. According to Malik et al. (1993), sources will take into account the abatement costs when conducting trades, but not costs from the variability of nonpoint source pollution. This would be similar for the ancillary benefits. Malik et al. (1993) propose that adjusting the trading ratio will help to internalize the costs.

A subsidy provided to the producer of the credit of the size $\frac{-B'(x_j)}{E(\partial r / \partial x_j)}$ is needed to correct the price of the expected loadings permit.[2] It is the appropriate subsidy to encourage the farmer to construct or restore a wetland that creates the largest ancillary benefits possible (given land and cost constraints). The subsidy does not equal the marginal benefits; it differs because we cannot measure loadings with certainty. Because loadings are estimated, the marginal benefits are adjusted depending on how the runoff function is affected by the abatement technology. In addition, a unique trading ratio would be used for demanders of credits created by wetlands. If the covariance is negative or if the covariance is positive, but smaller than the marginal benefits, then the trading ratio should be smaller. A smaller trading ratio means fewer nonpoint source permits trade for one unit of emissions, making the nonpoint source permits more attractive for the MS4. If the covariance is positive and is larger than the marginal benefits, the nonpoint source permits are not as attractive for the MS4. This means that to encourage the use of wetlands, wetlands must reduce the variance of the loadings, have a relatively large marginal benefit, or both.

[2] This still might not be enough to encourage the use of wetlands if the other abatement technology is less expensive.

Proposition 3: Multiple Markets

By allowing producers to sell different types of credits in different markets, we allow them to make decisions about their own land that will maximize their utility (or profit). Rather than having a regulator pay for the proper wetlands, we allow the markets to create the incentives of what should be bought and sold. Therefore, this does not necessarily encourage the use of wetlands if the markets do not support the production decisions. Here the point source purchases the credit of nutrient abatement and the other markets provide incentives to the nonpoint source as to how the credit should be produced. If properly designed, the externality is internalized as all additional services could be bought and sold in a market. In addition, there are probably different versions of this proposition related to how the wetlands are restored or constructed and how all the wetland services interact (e.g., substitutes or complements).

Unlike Proposition 2 where economists must estimate the value of the additional wetland services, the second proposal allows the market to value them. 'Multiple markets' refers to the producer's ability to sell different types of credits in different markets (Woodward and Han 2004, Kieser and Associates 2004, and ELI 2005). If well-functioning markets (as described above) were to exist for the different services provided by wetlands, the ancillary benefits would be accounted and the externalities would be internalized. Building wetlands might create credits for nutrient abatement, endangered species habitat, greenhouse gases, and possibly wetland mitigation banks. The services are no longer externalities of the water quality trading market as they are sold as credits in other markets. The incentive for creating wetlands, then, becomes the additional income from trading in other markets. The socially optimal level of wetlands would occur once markets exist for all relevant wetland services. If this were the case, the prices for the

permits and the trading ratio would be the same as Horan and Shortle (2005). The marginal benefit term would drop out of equations (8) and (9), leading to the conditional optimum.

If the producer can sell different credits in different markets, then they may have incentive to build wetlands. Producers will react to the multiple markets and make their decisions based on their profits. Holding the number of acres constant, the producer, of course, would choose the mix of abatement technologies that produce the most money. Unlike trading ratios and subsidies, the incentives created by multiple markets are the prices received for the credits (not the value of the ancillary benefits) and the production and monitoring costs.

One market or multiple markets?

Determining which way of internalizing the externality is a difficult process and we appeal to the ecology of wetlands to determine which of these two propositions bring about the socially optimal amount of wetland use for mitigation of nutrient loading. It is clear that wetland services should not be ignored due to externalities and potential suppliers of credits should not be forced to use wetlands as a way to control nutrients because of the inefficiencies that could be created. To decide on what option makes the most sense, we turn to Montero (2001) and Woodward and Han (2004) who suggest that the decision to combine all services into the nutrient market using trading ratios and subsidies or to create multiple markets depends on the relative shape of the marginal benefits and marginal cost curves and the underlying ecological attributes. Based on Weitzman (1974), a flatter marginal benefit curve relative to the marginal cost curve suggests that multiple markets will cause a larger dead weight loss. The decision to combine or not to combine depends on the relative shape of the marginal benefits and marginal cost curves and the underlying ecological attributes.

Before looking at the marginal benefits curve, however we need to examine the graphical relationship between the creation of ancillary benefits and the reduction of nutrient loads by the wetland. If pollutants are co-produced then reduction of one will automatically reduce the other to some extent. In our example, when nutrients are reduced through creation of a wetland (of a certain quality) the ancillary benefits are increased. As the farmer spends more on the wetland such that it abates more nutrient runoff, it creates more ancillary benefits. In figure 1 we have adapted Helfand (1991) to show that as the farmer pays along $C_N = P$ in the market for nutrient reduction, he creates more ancillary benefits without it costing extra, as he does so along the zero isocost line C_b The amount of ancillary benefits, in this case we have chosen to call it "bio" or some measure of ancillary biological benefits, created will be A.

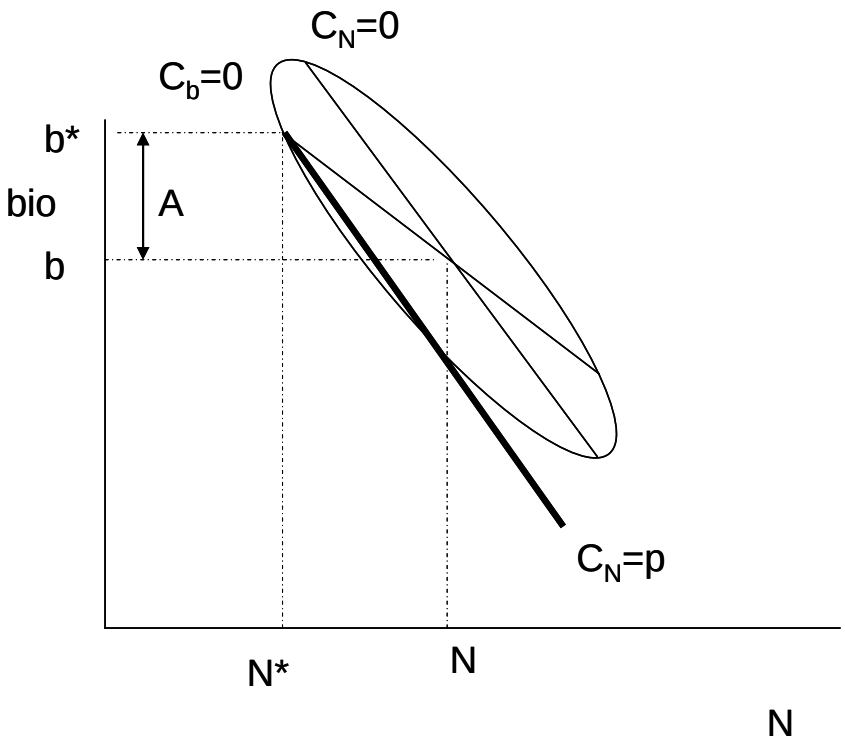

Figure 1

Woodward and Han (2004) build on that and use a figure similar to figure 1, to show that the flatter the MB curve the more deadweight loss separate trading programs will cause.

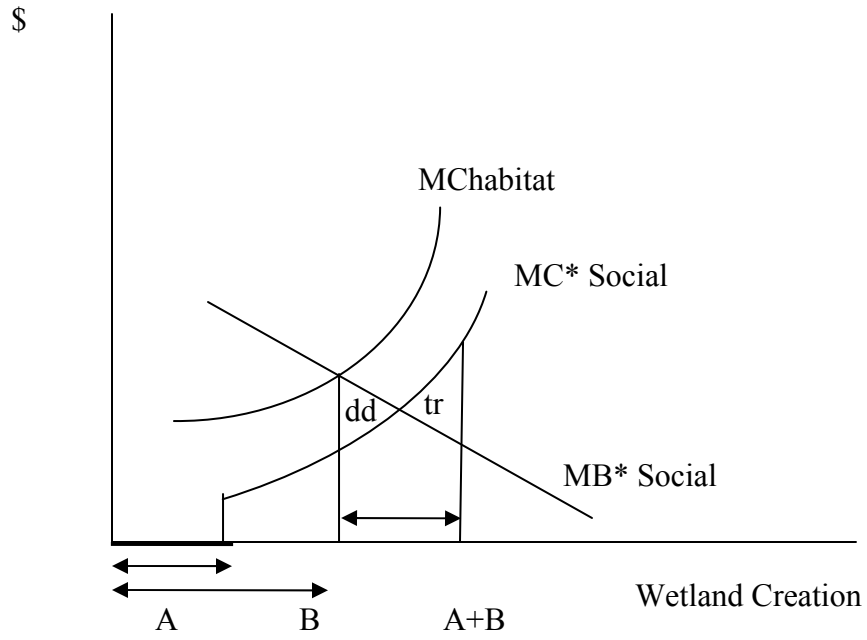

Figure 2

It becomes apparent that it is critical to have an accurate portrayal of the benefits curve. We asked three professional ecologists to quickly sketch the benefits curve for biodiversity creation from wetlands. This resulted in Figures 3, 4, and 5, which range from a simple natural log relationship to rather complex series of inflection points and threshold levels.

Our ecologists gave us total benefits curves, so note that the marginal benefits curves TB', will have similar inflections and nuances. Note also that it will be critical to accurately

portray the benefits curve and to determine where on the benefits curve the proposed policy plans to operate.

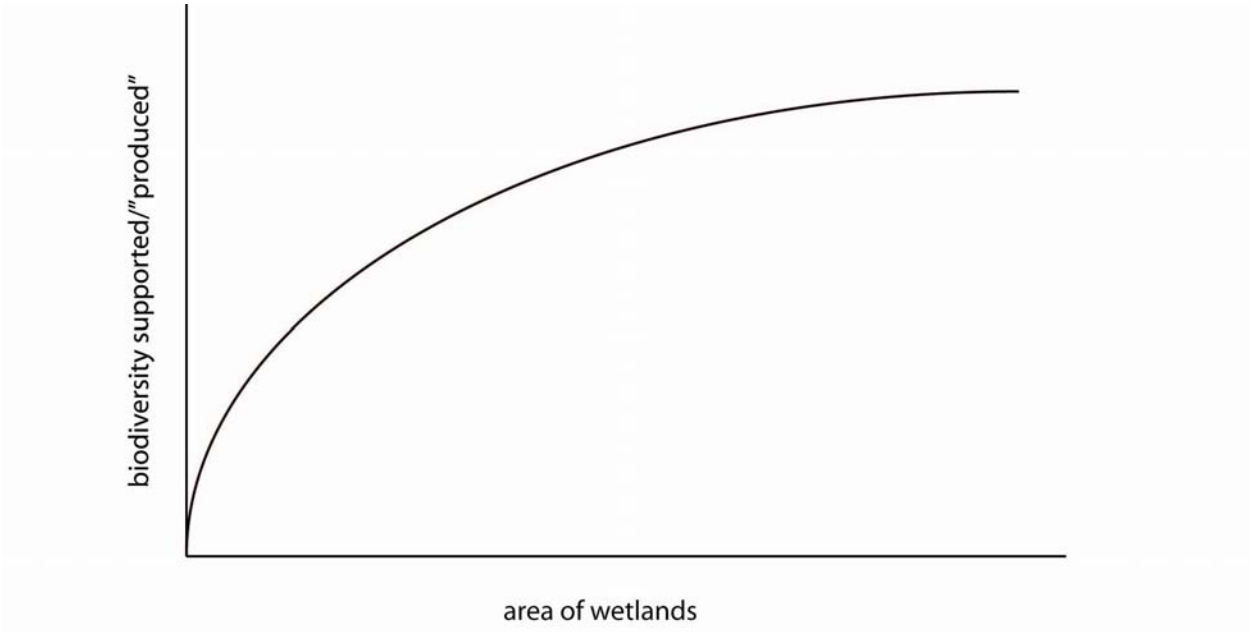

Figure 3

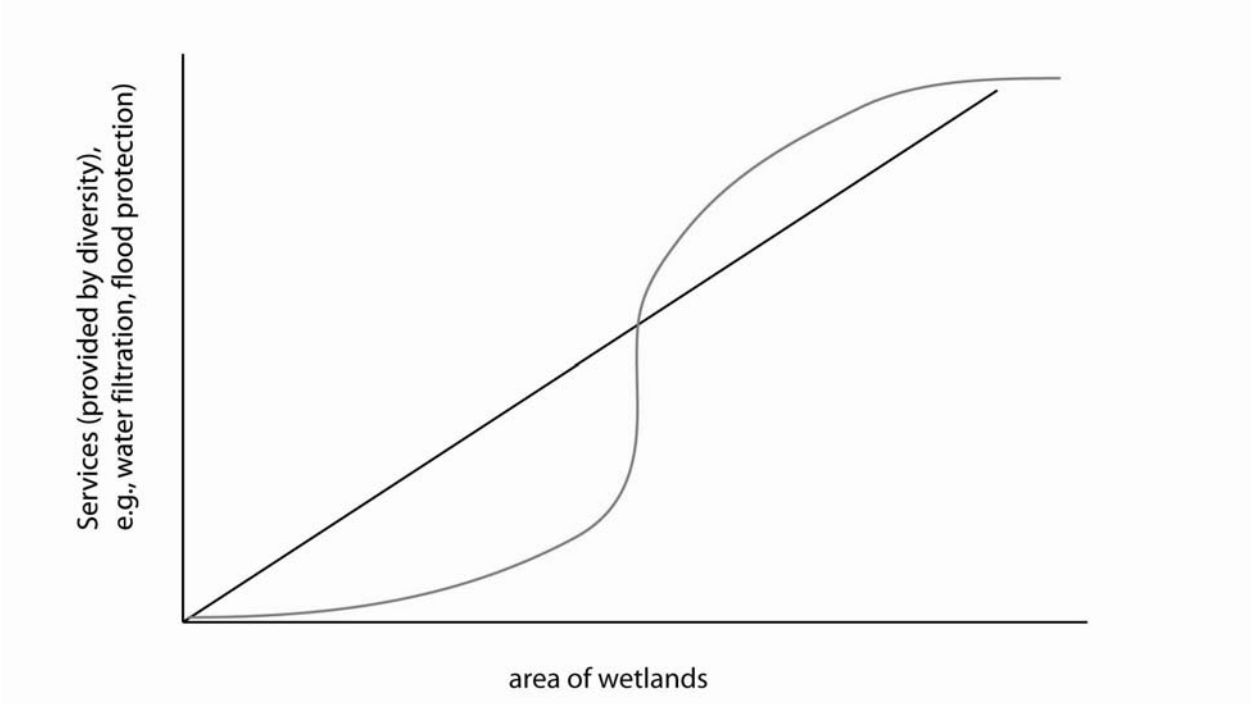

Figure 4

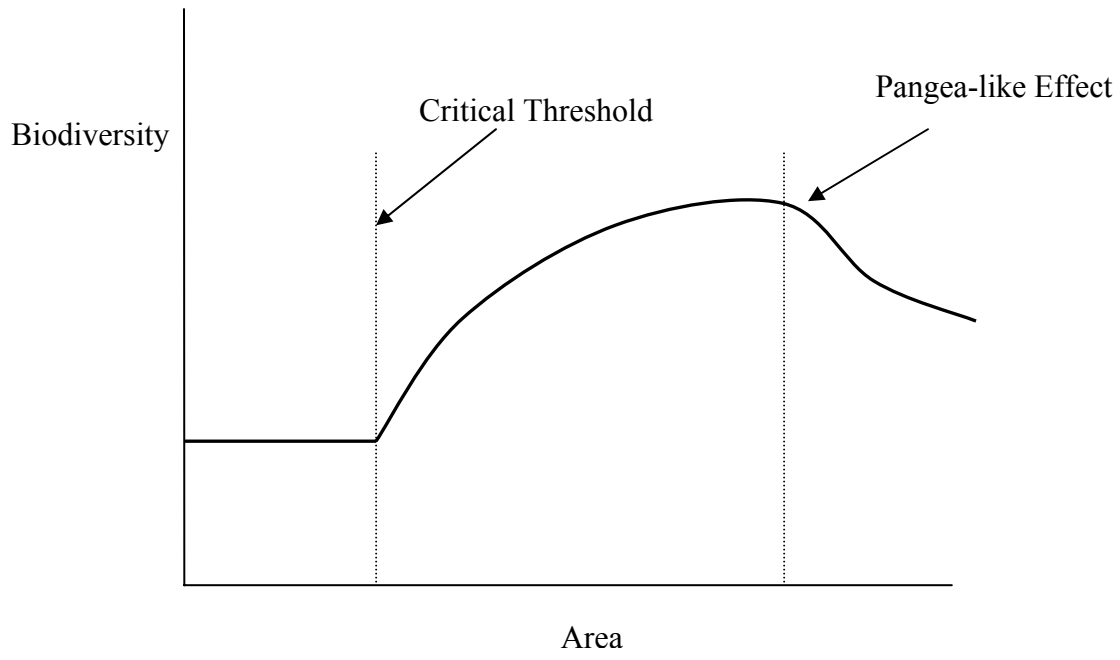

Figure 5

Conclusions

In this paper we argue that wetlands can be included as nutrient abating technology in a point-nonpoint source water quality trading program. However, we have shown that the program that does incorporate wetlands needs to take into account the ancillary benefits created by wetlands. This can be done in one of two ways: (1) the ancillary benefits are included in the market price for expected loadings permit and the point/nonpoint source trading ratio is adjusted to account for the ancillary benefits, or (2) the producer of wetlands can sell the nutrient trading capacity of the wetland in the nutrient market and the ancillary benefits are sold in another market, should one exist. We have shown a novel approach toward the adjustment of the

point/nonpoint source trading ratio in that the choice depends on whether the wetland serves to reduce or increase the variance of the loadings from the nonpoint source of nutrients and the size of the marginal benefits. The choice of using one market versus multiple markets depends on the shape of the curve representing the marginal ancillary benefits. If the curve is relatively steep the policy maker should allow the nonpoint source to trade the wetland ancillary benefits in a separate market. If the marginal benefits curve is relatively flat, the policy maker should allow the nonpoint sources extra credit, through the corrected trading ratio, in the single market. We have introduced the idea, however that there is not necessarily agreement on the shape of the benefits curve, and indeed the curve may be different for different kinds or locations of wetlands. Future research includes a multidisciplinary approach to this problem wherein the benefits curves for several wetlands are measured empirically.

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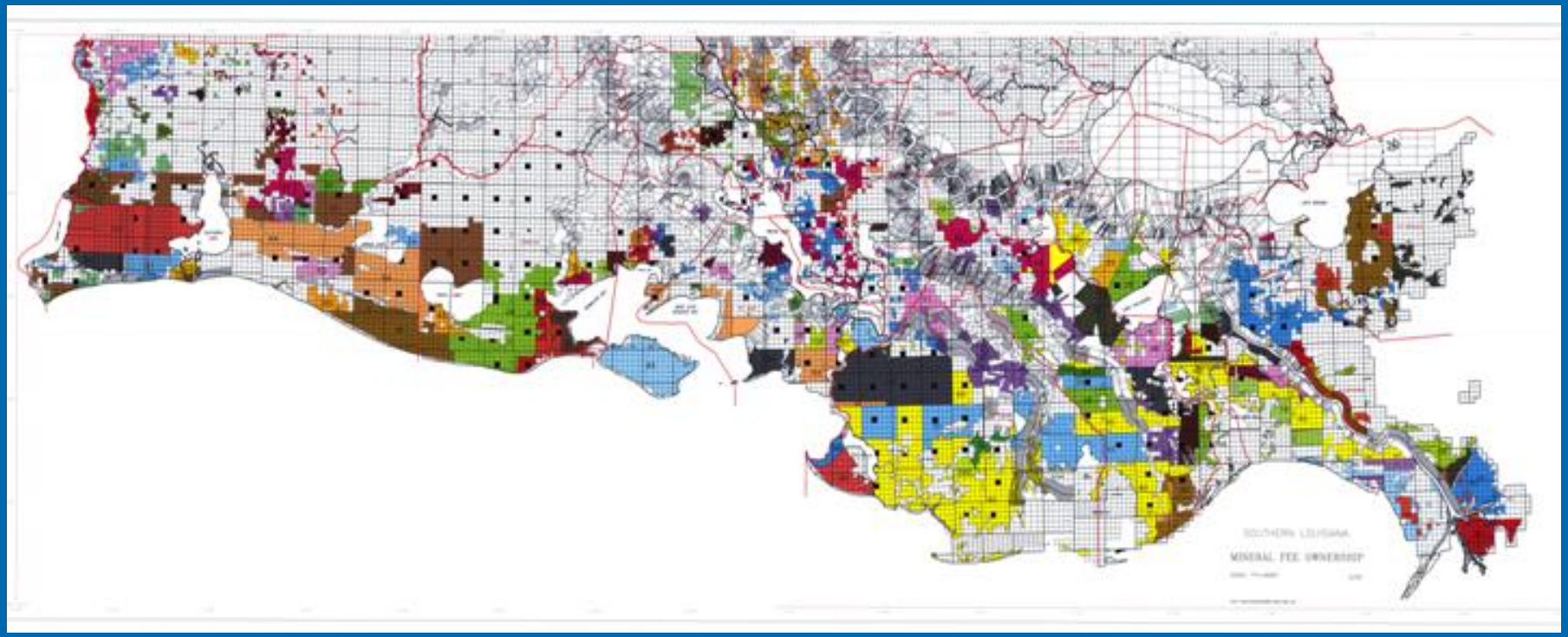
Progress Report on

Designing Incentives for Private Maintenance and Restoration of Coastal Wetlands

Walter R. Keithly, Jr.

Center for Natural Resource Economics and Policy (CNREP)
Louisiana State University, Baton Rouge

Landholdings in the Coastal Zone



- Coastal zone is primarily held privately
- Large tracts held by land / oil / gas companies
- Numerous small landholders throughout the coast

Threats To Louisiana's Coastal Wetlands

- coastal zone made up of low marshes and swamps susceptible to

  → subsidence / sea-level rise
  → erosion / oil & gas activity
  → vegetative destruction by nutria

- Channeling of rivers has directed alluvial sediments offshore

- Historical susceptibility to hurricanes – Katrina / Rita eliminated >200 sq. miles of wetlands, dispersed many landholders

Intervention to Meet the Threats

- Public Actions:
  → large-scale diversions, but operation at a fraction of capacity due to user conflicts
  → re-vegetation projects on a small-scale
  → land-rights for projects difficult to obtain

- Can Private Actions Help?
  → federal laws and programs recognize importance of local coastal stewardship
  → long history of water / land management in coastal agriculture
  → investment incentives needed to overcome increasing uncertainty and complexity

Project Goals

- Develop a framework for investigating incentive structures for private coastal management
- Determine attitudes and reactions to various incentives for private coastal management
- Examine how the combined socioeconomic and physiographic characteristics of landholdings affect private investment decisions
- Assess the efficacy of potential policy instrument designs aimed at private restoration activities

Current Progress

While participating in coastal triage and waiting for resettlement / locating of landholders:

- Estimated a hedonic model of coastal land value to determine the changes in private wetland values that would be forthcoming from various restoration scenarios
- Examined the ability of price-based incentives to encourage private maintenance of wetlands through nutria control programs

Example of Primary Data

am 29

FILE#260681

LIMITED WARRANTY DEED

STATE OF LOUISIANA §
PARISH OF CAMERON §
§

'89 JUN 23 PM 3:20

Conveyance

BE IT KNOWN, That on the date(s) shown below, before us the undersigned Notaries Public in and for the Counties or Parishes and States indicated below, duly commissioned and qualified, and in the presence of the undersigned, competent witnesses:

PERSONALLY CAME AND APPEARED: **AMOCO PRODUCTION COMPANY**, a Delaware corporation ("**Grantor**"), appearing by and through Kenneth Wayne Sweeney, its Attorney-in-Fact, and **JAMES C. ROBINSON**, 4315 Ashland Drive, Lake Charles, Louisiana 70605 ("**Grantee**"), who declare that, for and in consideration of a sum in excess of $ 300,000 cash in hand paid, the receipt and sufficiency of which are hereby acknowledged, Grantor does hereby GRANT, SELL, CONVEY, ASSIGN and DELIVER unto Grantee the real property situated in Cameron Parish, Louisiana, described in **Exhibit A** attached hereto and made a part hereof (the "Property") subject to zoning laws, regulations and ordinances of municipal and other governmental authorities, and any matters which are of public record affecting the Property and any encumbrances (to the extent they are in effect) described in **Exhibit B** attached hereto and made a part hereof (collectively, the "Permitted Encumbrances"), and subject to all of the provisions hereof.

TO HAVE AND TO HOLD the Property, together with all and singular the rights and appurtenances thereto in anywise belonging, unto Grantee, Grantee's successors and assigns forever, and Grantor does hereby bind itself and its successors and assigns to warrant and forever defend the title to the Property, as to Grantee, Grantee's successors and assigns against every person whomsoever lawfully claiming, or to claim the same, or any part thereof by, through or under Grantor, but not otherwise, subject, however, to the Permitted Encumbrances and the following provisions.

SAVE AND EXCEPT, and there is hereby reserved unto Grantor, its successors and assigns, the following:

(1) all rights in and to all oil, gas and other minerals, of every kind, both similar and dissimilar, in, on and under and that may be produced from the Property, together with the right of ingress and egress at all times for the purpose of mining, drilling, exploring, operating and developing the Property for minerals and removing the same therefrom, as further elaborated in Exhibit "B" item #3; and

(2) a servitude, easement and right-of-way for ingress, egress, and passage, at all times, over and across the Property to and from other lands currently owned by Grantor, or previously owned by Grantor and now owned by others, in Township 12 South, Ranges 12 and 13 West, Louisiana Meridian, Cameron Parish, Louisiana, provided, however, this servitude for ingress, egress, and passage shall be confined to existing roads, levees, trails, water channels, canals, pirogue trails and ditches, and such other passages as Grantee may reasonably designate from time to time for common usage.

BY THE ACCEPTANCE OF THIS DEED, GRANTEE TAKES THE PROPERTY "AS IS, WHERE IS" EXCEPT FOR THE WARRANTIES OF TITLE AS PROVIDED AND LIMITED HEREIN. GRANTOR HAS NOT MADE AND DOES NOT MAKE ANY REPRESENTATIONS AS TO THE PHYSICAL OR ENVIRONMENTAL CONDITION, LAYOUT, FOOTAGE, EXPENSES, ZONING, OPERATION, OR ANY OTHER MATTER AFFECTING OR RELATING TO THE PROPERTY, AND GRANTEE HEREBY EXPRESSLY ACKNOWLEDGES THAT NO SUCH REPRESENTATIONS HAVE BEEN MADE AND RELEASES GRANTOR FROM ANY AND ALL LIABILITY OF EVERY KIND AND CHARACTER WITH RESPECT THERETO, WHETHER OR NOT CAUSED BY OR ATTRIBUTABLE TO GRANTOR'S NEGLIGENCE. GRANTOR MAKES NO WARRANTIES, EXPRESS OR IMPLIED, OF MERCHANTABILITY, MARKETABILITY, FITNESS OR SUITABILITY FOR A PARTICULAR PURPOSE OR OTHERWISE. ANY IMPLIED WARRANTIES ARE EXPRESSLY DISCLAIMED AND EXCLUDED. THIS DEED IS EXPRESSLY SUBJECT TO THE TERMS AND CONDITIONS OF THAT CERTAIN AGREEMENT

1

EXHIBIT "A"

TRACT 1:

Approximately 2300 acres of land located in unofficial Sections 1, 11-14 and 22-27, T12S-R13W, Louisiana Meridian, Cameron Parish, Louisiana (based on that certain unadjudicated Agreement Survey of a portion of said township made by A. B. Hill for Pan American Petroleum Corp. (predecessor of Amoco), survey plat for which is dated July 14, 1969, and filed in-house in Amoco's Land Survey Engineering group located in Houston, Texas), being a portion of the same property acquired by Stanolind Oil and Gas Company (predecessor of Amoco) from Wright Morrow by Act of Sale dated July 31, 1935, recorded in COB 27 at Page 280 of the Conveyance Records of said Parish, said land being more particularly described as follows:

All of the captioned Section 1.

The following portions of the captioned Section 11: The East half (E/2) of the Southeast quarter (SE/4) of the Northeast quarter (NE/4) of the Southwest quarter (SW/4) of the Northwest quarter (NW/4); the East half (E/2) of the East half (E/2) of the Southeast quarter (SE/4) of the Southwest quarter (SW/4) of the Northwest quarter (NW/4); the Southeast quarter (SE/4) of the Northwest quarter (NW/4); the North half (N/2) of the North half (N/2) the Northeast quarter (NE/4) of the Northeast quarter (NE/4) of the Southwest quarter (SW/4); the Southeast quarter (SE/4) of the Northeast quarter (NE/4) of the Northeast quarter (NE/4) of the Northeast quarter (NE/4) of the Southwest quarter (SW/4); the East half (E/2) of the Southeast quarter (SE/4) of the Northeast quarter (NE/4) of the Northeast quarter (NE/4) of the Southwest quarter (SW/4); the Northwest quarter (NW/4) of the Southeast quarter (SE/4); all that portion of the East half (E/2) of the Southwest quarter (SW/4) of the Southeast quarter (SE/4), the West half (W/2) of the Southwest quarter (SW/4) of the Southeast quarter (SE/4), and the Southeast quarter (SE/4) of the Southeast quarter (SE/4) of the Southeast quarter (SE/4) of the Southwest quarter (SW/4) lying southeasterly of a line running five feet (5') northwesterly of, and parallel to, the centerline of that certain existing levee which traverses northeasterly-southerwesterly through said aliquot parts; and all that portion of the North half (N/2) of the Northeast quarter (NE/4) of the Northwest quarter (NW/4) of the Southwest quarter (SW/4) of the Southeast quarter (SE/4), and the North half (N/2) of the North half (N/2) of the Northeast quarter (NE/4) of the Southwest quarter (SW/4) of the Southeast quarter (SE/4) lying northwesterly of a line running five feet (5') northwesterly of, and parallel to, the centerline of the above said levee.

Hedonic Model of Coastal Property Value

$$\ln(PRICE) = ß0 + ß1*\ln(ACRES) + ß2*\ln(FRESH/OW) + ß3*\ln(INTER/OW) + ß5*\ln(BRACKISH/OW) + ß6*\ln(OTHER/OW) + ß7*\ln(DISTANCE) + ß8*\ln(DROAD) + ß9*\ln(SEPARATE)$$

Variable	Estimate	S.E.
Intercept	5.3220*	0.4774
ln(acres)	-0.0179	0.0459
ln(fresh/ow)	0.0403*	0.0134
ln(inter/ow)	-0.0573*	0.0147
ln(brack/ow)	-0.0203	0.0123
ln(other/ow)	0.0263*	0.0129
ln(dist)	0.2588*	0.1351
ln(road)	-0.0643	0.0463
ln(separate)	-0.2290	0.1440

Preliminary Implications

- The type of wetland present affects property value in different ways:

  positive effect – freshwater marsh, non-marsh

  negative effect – intermediate marsh

- As distance from the coast increases, property value increases

- Estimated price differentials suggests that incentive programs may need to be tailored around wetland types

Ongoing Work

- Expanding the dataset to include coastal parishes in the central and southeastern parts of the state
- Will include analysis of historical wetland loss (1960-2000) on property value
- Will include analysis of ‘expected’ wetland loss (possibly to 2050) on property value

Impact of Bounties on Nutria Harvests

Average Cost Model

$$\ln(H)_t = \beta_0 + \beta_1 \cdot \ln P_t + \beta_2 \cdot P_t + \beta_3 \cdot OC_t + \beta_4 \cdot alligator_t + \beta_5 \cdot freeze_t + \beta_6 \cdot cncp$$

Parameter	Estimate	S.E.	P-value
intercept	-3.9594	0.3640	<0.0001
ln(price)	2.5828	0.2974	<0.0001
price	-0.1792	0.0386	<0.0001
opportunity cost	0.1129	0.0242	<0.0001
alligator	-0.0174	0.0060	0.0064
freeze	0.0025	0.0025	0.3247
cncp	0.5584	0.2654	0.0422
DW = 1.80	SSE = 3.0191	MSE = 0.0816	

Impact of Bounties on Nutria Harvests

Marginal Cost Model

$$\ln(H)_t = \beta_0 + \beta_1 \cdot \frac{1}{P_t} + \beta_2 \cdot OC_t + \beta_3 \cdot alligator_t + \beta_4 \cdot freeze_t + \beta_5 \cdot cncp$$

Parameter	Estimate	S.E.	P-value
intercept	0.7606	0.1246	<0.0001
1/price	-6.8830	0.5171	<0.0001
opportunity cost	0.1014	0.0208	<0.0001
alligator	-0.0180	0.0056	0.0027
freeze	0.0038	0.0026	0.1448
cncp	0.3231	0.2393	0.1850
DW = 1.81	SSE = 2.9625	MSE = 0.0779	

Preliminary Implications

- Data described by either the common or private property model – rights regime is mixed
- Average cost model can be used to predict harvests associated with different bounty levels

Bounty Level ($/tail)	Estimated Harvest (#)
4	253,000
6	425,588
8	651,574
10	831,477
12	956,279
14	1,022,497

Next Steps

- Finish pre-testing questionnaire
- Collection of field data from large (personal interview) and small (mail, telephone survey) landholders
- Estimate a double-hurdle Tobit model of restoration investment decision making
- Combine the analyses to assess the role of existing / potential policy instruments for encouraging restoration

Marc Ribaudo Comments for Market Mechanisms Workshop

An Experimental Exploration of Voluntary Mechanisms to Reduce Non-Point Source Water Pollution With a Background Threat of Regulation – Suter, Segerson, Vossler, and Poe.

In this paper an ambient-based tax policy as a regulatory back-up to voluntary adoption of management practices. The issue is to design the back-up to maximize the incentive for voluntary action. The goal is to find most efficient policy design.

The voluntary/regulatory policy is a very good subject for research, as this is the framework for addressing NPS. Section 319 of the Clean Water Act requires each State to: (1) identify navigable waters that, without additional action to control nonpoint sources of pollution, cannot reasonably be expected to attain or maintain applicable water-quality standards or goals, (2) identify nonpoint sources that add significant amounts of pollution to affected water, and (3) develop a NPS management plan on a watershed basis to control and reduce specific nonpoint sources of pollution. Among other things, the management plan is required to contain a list of best management practices (BMPs) for controlling NPS pollution, a timetable for implementing the plan, and enforceable measures to ensure the plan is implemented. Implies some sort of back-up regulations.

There are two basic problems with ambient based taxes that may severely limit what can be accomplished in practice. First, each producer must have some expectation of how his/her actions affect ambient measure. This means knowledge of fate and transport. Second, for this policy to work it requires that each firm or producer has some knowledge or expectation of how each other landowner in the watershed behaves. This is borne out by results reported in the paper, where allowing conversation between participants in the economic experiment resulted in more efficient results. Assuming this is the case, the transactions costs of such communications could be quite high, depending on the size of the watershed. Transactions costs are not accounted for in this research. Could there be a role for a central clearinghouse? Would producers be willing to reveal private information for the good of the regulated community?

This line of research has invariably used a tax as the regulatory back-up. The paper indicates that such a policy design can work. In reality, environmental taxes are taboo in this country, and it is not likely that this will change any time soon.

So the question is: can an efficient (or relatively efficient) program be developed that allows voluntary compliance with a regulatory back-up based on input or technology standards? Several States use triggers that result in regulations. Nebraska protects groundwater from nutrients with a policy whereby N concentrations trigger different nutrient management requirements. California uses a similar approach to protect groundwater from pesticides. Vermont allows voluntary adoption with financial assistance of recommended BMPs, but will require BMPs if progress towards water quality goals is not made. .

Conservation compliance is mentioned in the paper as footnote. The penalty based on input decisions rather than on actual effluent generated. This is a second best solution, but it is practical and it apparently works.

A more promising line of research from a policy perspective might be to examine the design of a program that uses the threat of technology-based standards to provide the appropriate incentives to spur voluntary action. Mandatory practices would provide less flexibility than voluntary actions. Adding a flat penalty could provide an additional incentive to act "voluntarily" Does this approach provide an adequate incentive to act voluntarily? I have not seen much on this.

Choice Experiments to Assess Farmers' Willingness to Participate in Water Quality Trading Market – Peterson, Fox, Leatherman, and Smith

This paper looked at factors behinds farmers' willingness to participate in water quality trading programs. Lack of participation in trading programs (supply-side impediment) is a real issue. This is particularly true given the joint USDA-EPA announcement in support of water quality trading projects across the country.

USDA not only emphasizing markets for water quality, but other environmental markets as well, such as carbon sequestration, wetland mitigation, and wildlife habitat (hunting). Such markets are seen as a means of increasing conservation through private funding. Increasing our knowledge about farmer willingness to participate in such markets is critical to the development and success of markets where farmers make a major contribution. We have much to learn about participation, so there is a danger of rushing ahead and being disappointed.

Research reported in paper not yet complete, so no results as of yet.

In the case of WQT, it has been suggested that being associated with regulatory programs (cap and trade on point sources) is a deterrent. Farmers are afraid that by selling abatement credits they are admitting they are polluting, and that they would be the next targets for regulation. This particular issue is not covered in this paper, but needs additional examination. This has an important bearing on the issue, since cap and trade is the best way to create demand for services from agriculture. This issue may only be a concern for pollutants created by agriculture. Agriculture is widely recognized as a net sink for carbon, so there would be no "stigma" attached to participating in a market for carbons. Not so with water quality, where agriculture is also contributes pollution.

Incorporating Wetlands in Trading Programs: Economic and Ecological Considerations – Thurston and Heberling

This paper looks at incorporating wetlands into water quality trading programs. The issue is wetlands also produce ancillary benefits, so they should be encouraged over other

nutrient-reduction strategies. This would also increase the number of participants in trading markets. "Thin" markets are seen as one of the issues raised by King and Kuch as preventing markets from operating efficiently. Allowing wetland restoration would conceivably increase the number of credit suppliers.

There are several issues here. First is the notion that lack of supply is a major stumbling block for trading. Increasing the size of the market by allowing wetlands will increase supply only. In many watersheds with nonpoint sources, there are already more sellers than buyers. Also, one of the few examples of a point-nonpoint trade involved a single buyer and four farms. This is not trading in the classical sense, but an offset. However, society still benefited. Having few participants does not necessarily prevent beneficial trades from occurring.

Are created wetlands more likely to participate in trading markets? If the creators are the same individuals not willing to participate now, what is gained?

Another issue is the potential competition for supply-side credits. Wetlands filter runoff from upstream. If upstream farmers agree to participate in the market, install BMPs and sell credits, the utility of wetland declines. The supply of credits from agriculture is not strictly additive. Potential interactions with neighbors' decision need to be taken into account. The transactions costs for estimating credits and developing side contracts could be high.

The paper present 2 approaches for incorporating wetlands:

- Capture ancillary benefits in the nutrient trading market by adjusting trading ratio, and therefore credit prices
- Separate markets for ancillary benefits

The latter seems to be the most palatable. One of the requirements of a successful trading market is that point and nonpoint sources produce the same good. In the first approach, a point source purchaser is looking for abatement credits for a particular pollutant, say nitrogen. However, a wetland creator is selling something that is different: nitrogen abatement PLUS some other ancillary benefit. If the credit price is lower, and point sources needs are met, then everything fine. But the results presented in the paper show that prices could increase. This would put credits from wetlands at a competitive disadvantage to simple nutrient management.

It seems the simplest approach would be to market services separately. Now, in many cases, markets won't exist for the simple reason that environmental services take on the characteristics of public goods. The traditional way of handling this is for government or land trusts to purchase benefits for society at large. Targeting wetland creation through public or other programs in watersheds with trading programs could be a way of rewarding wetland creation. It is ironic that the Wetland Reserve Program is the only conservation program that specifically prohibits the owner of created wetlands from selling environmental credits created by the restoration.

Shortle Discussion

Introductory Comments

- I have thoroughly enjoyed this conference. The papers that have been presented over the two days have been consistently interesting. Congratulations to EPA for the quality of work it has funded and the other participants it has invited.

- My comments about the quality of the papers at the workshop apply equally to those in this session.

- Prior sessions explore areas in which we have had much more experience with market mechanisms. Water is a new frontier that poses a lot challenges. These papers will help address those challenges**.**

An Experimental Exploration of Voluntary Mechanisms to Reduce Non-Point Source Water Pollution With a Background Threat of Regulation

Jordan Suter, Cornell University, Kathleen Segerson, University of Connecticut, Christian Vossler, University of Tennessee, and Greg Poe, Cornell University

- This paper comes from an interesting research program – ambient based instruments have received lots of attention in theory but not much in practice. They rely on very strong but assumptions about equilibrium behavior. Thus experimental testing of the type done in this research is clearly the way to go to learn how they might work in practice.

- The specific application examines an ambient tax as a threat to induce voluntary adoption of nonpoint pollution control practices. This too is interesting.

- Now I like the paper a lot, and it is distinctly a contribution to the economics literature on ambient instruments. But, I don't see it as squarely addressing the nonpoint problem. Some missing elements:

    - Observability of emissions – emissions are assumed unobservable by the environmental prinicpal, but observable and deterministically controllable by the agents.

    - Perfect mixing – no spatial heterogeneity or uncertainty

    - Stochasticity

    - Multiple choices, reliability and complexity

    - Different types – large versus small –

    - Capital and adjustment costs

- Policy Relevance?

    - The NPS economics literature versus the NPS policy problem

    - Group penalties are unlikely to happen –

        - partly because they are politically nonstarters,
        - partly because patently violate common sense notions of fairness
        - and there are better alternatives

Incorporating Wetlands in Water Quality Trading Programs: Economic and Ecological Considerations

Hale Thurston and Matthew Heberling, EPA, National Risk Management Research Laboratory, Cincinnati, Ohio

- Hale & Hebberling paper more directly embraces the complexity of nps pollution and a policy approach that is of greater interest
    - Outcomes a function of practices
    - Stochastic
    - Trading
- But most importantly – the complexity of the externalities that result from land use practices
    - In this case wetlands
        - Water quality
        - Carbon sequestration
        - Habitat service
- More generally,
    - Open space amenities
    - Air pollution
- These are joint products of production choices: The challenge – how to design policy instruments to address the set of outcomes?
- Currently, ag policies are highly uncoordinated, and often conflicting.
- Separate policies or multi-purpose?
- Theory of policy would suggest a tool for each target, but if not, then how to modify those we can take up.
- Trade ratio in "exchange type market." The next step would be to look at the levels of nps permits
- But more promising may be to reconsider the type of market – contracts for explicit services – this is where I am going in model reliability

Choice Experiments to Assess Farmers' Willingness to Participate in a Water Quality Trading Market

Jeff Peterson, Washington State University, and Sean Fox, John Leatherman, and Craig Smith, Kansas State University

- Non-participation is a huge issue in water quality markets – this paper explores how to increase participation by design "friendlier" markets

  Reasons for noparticipation:

  No gains from trade

  No cost heterogeneity? ?

  No cap?

  Bad rules?

  Coordination failures

  Mechanisms for bringing buyers and sellers together

  Implicitly, accepting liability for water quality problems

- Interesting approach – a few issues

  How were the attributes for the choice experiments selected?

  What are the policy implications of results on attributes?

  Lack of context about coordination mechanism

  Sample not random