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Incentive-Based Solutions to Agricultural Environmental Problems: Recent Developments in Theory and Practice

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ABSTRACT

Theory predicts that incentive-based regulatory instruments reduce compliance costs by encouraging efficient resource allocation and innovation in environmental technology. Cost reductions from pollution permit trading often have exceeded expectations, but the devil is in the details: the rules matter. In recent years, IB instruments of many kinds, from permit trading to various informal voluntary agreements, have been introduced in many countries. Point-nonpoint trading programs have been established in the U.S., but recorded trades have been rare. We speculate about prospects for performance-based monitoring of agricultural nonpoint pollution which, we believe, would encourage trading to the benefit of farmers and society.

In recent years, incentive-based (IB) approaches to environmental regulation have found increasing application. The basic idea—that IB regulatory instruments provide a level of flexibility that is absent in traditional command-and-control (CAC) approaches and thereby reduce compliance costs by encouraging efficient resource allocation and innovation in environmental technology—can be found in the economic literature since Pigou's proposal to tax externalities and Crocker's pollution-permit trading proposal. Implementation of IB policies proceeded slowly at first: pollution charges have been imposed in certain particular instances in Europe since the 1960s, and the US mounted some initial forays into pollution trading in the early 1980s. More

recently, however, more countries have adopted IB instruments and the array of environmental problems to which the instruments are being applied has been expanding rapidly.

We plan to conclude this article with some rather specific suggestions concerning point-nonpoint pollution permit trading. Along the way we will touch on the conceptual foundations of IB approaches and provide some evidence of their increasing application in the policy arena and their effectiveness. Most of the early applications have been to industrial and municipal point sources. Nevertheless, we will be alert to developments in the agricultural sector, which has been relatively slow to embrace IB approaches.

Incentive-based approaches encompass a wide variety of policy instruments that have in common the intent to reward, rather than mandate, environment-enhancing behavior. Here, we abandon all hope of comprehensiveness, ignoring entirely the rich tradition of Pigovian taxes to concentrate on voluntary agreements and trading mechanisms. Within

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even this narrowed scope we will be less comprehensive and more eclectic and anecdotal than might be desirable.

Background

A Perspective on Market Failure

Economists have traditionally diagnosed environmental problems as market failures: the failure of markets to transmit appropriate incentives and thereby achieve efficiency. Conventional solutions call unambiguously for government action to tax or regulate externalities and to raise revenue for public projects to provide public goods.

The "market failure, government fix" diagnosis and prescription have fallen under concerted attack from individualists arguing that allocative inefficiencies are caused mostly by incomplete property rights—and therefore privatization is the appropriate policy response—and asking what policy implications could possibly arise from market failure when the failures of government are even more pervasive.

Mercifully, we are no longer asked to choose between these two paradigms, with their mutually antagonistic diagnoses and prescriptions. There is an important class of problems, called *isolation paradoxes*, where insistence on individual action or none at all can leave everyone isolated and ineffective, and the search for arrangements that make coordinated action beneficial to all concerned may be rewarding. Abstract theory (from game theory, political science, and economics) and emerging experience have broken down the old simplistic dichotomy of government vs. market solutions. The isolation paradox concept suggests openness to solutions that invoke a variety of institutional forms. These include private enterprises, voluntary associations, and government ranging from the most local level to the national scale and beyond (Randall 1999). Given the centrality of information and coordination, the array of feasible institutions is continually shifting as information, communication, and exclusion technologies develop. For particular problems, the ap-

propriate institutions will be consistent with the dimensions and scale of the problem itself and with the prevailing technologies and political realities. Flexibility is the key in both institutional forms and the incentives those institutions transmit.

Isolation paradoxes abound in agriculture. Agricultural nonpoint sources are now the leading cause of water pollution in most areas of the United States (Davies and Mazurek) and can therefore expect to come under increasing regulatory scrutiny. However, the difficulty of monitoring nonpoint sources has thus far precluded the public from enjoying the benefits of adequate controls and farmers from profiting from gainful permit trades. Another example is biodiversity and habitat protection, where fragmentation of land into private parcels and failure to devise incentives for cooperation among landowners have denied the public adequate provision for biodiversity and farmers the opportunity to profit from the potential value of their land as habitat. Eclecticism in institutional innovation will be essential to progress in resolving many of the most persistent environmental problems of agriculture.

Pollution Permit Trading

Economists have long argued for policy instruments that take maximum advantage of voluntary exchange with its efficiency and Pareto-safety properties. Political scientists frequently make similar arguments, albeit in more accessible terminology, when they call for win-win solutions. Trading mechanisms are being implemented in air and water pollution control, wetlands and shoreline mitigation, land swaps to meet habitat protection and similar objectives, and resources-for-resources compensation provisions for natural resource damages (e.g., the Superfund law and the Oil Pollution Act).

Economic Theory. Economists since Crocker and Dales have argued, on efficiency grounds, for establishing markets in rights to pollute. Most pollution market proposals call for tradable pollution reduction credits (usually called *permits*), which establish property

rights (in terms of allowable discharges) within a public goods setting. Efficiency would be served, as low-cost abaters reduced their discharges and permits were reallocated to their highest valued uses through market exchange, and innovation in cost-efficient abatement technology would be encouraged. Various forms of property rights have been incorporated within tradable permit systems suggested in the literature (Montgomery; Krupnick, *et al.*; McGartland and Oates; Tietenberg; McGartland). Empirical simulations have shown that regulatory costs under CAC policies may be several times those of incentive-based policies (Atkinson and Lewis; Roach, *et al.*; Hahn and Noll; Seskin, *et al.*). The cost savings claimed for IB approaches, such as tradable permit markets, derive from their capacity to take advantage of differences in the cost of pollution abatement across firms and to provide incentives for innovation in pollution abatement.

First Steps: Air and Water Control in the US. Economists' proposals for pollution trading were roundly criticized by environmentalists and largely ignored by government throughout the 1960s and '70s. The US EPA took its first steps toward pollution trading in 1980—introducing offsets, banks, and bubbles, initially for point sources of air pollution. In the early 1990s, trading in sulfur oxides (SO_x) permits was introduced on the Chicago Board of Trade. Economists were surprised that trading was less active and the price of permits was lower than they had predicted (Joskow, Schmalensee, and Bailey). A plausible explanation is that the switch from CAC regulation to permit trading is actually a two-step process: first, the switch from regulation of control technology to performance standards that allow the firm to choose its abatement technology and, then, the introduction of trading (Burtraw). It is likely that the first step generates major savings in abatement costs, allowing firms to delay purchasing permits. Subsequent experience has been consistent with that conjecture, in that the volume of trades has increased over time, but the price of permits remains lower than was predicted *ex ante*.

Expanding the Scope of IB Instruments

The United States. In the US, the current trend is to encourage adoption of trading and related IB instruments, instead of traditional CAC approaches, to address a broad range of environmental problems (Keohane, *et al.*). Watershed-based trading involves the exchange of water quality or other ecological improvements between individuals responding to private market incentives (USEPA). Trading institutions, in forms ranging from tradable permit markets to wetlands mitigation, have increasingly been used for protection of water quality (USEPA; Netusil and Braden; Keohane, *et al.*; Stavins and Whitehead). Public trustees pressing claims for compensation for natural resource injury are now less inclined to assess the compensating monetary payment, seeking instead to determine the compensating scale of resource restoration (Randall 1997).

IB Instruments in Other Countries. The move to more flexible regulations is not limited to the United States. The role of IB regulations has grown in prominence throughout the world, as has the diversity of the policy instruments. Traditionally, tradable permits were seen as a uniquely American preoccupation; in Europe and much of the world, serious consideration of IB instruments was limited to environmental taxes. This is changing, as Australia, Canada, and Mexico all currently operate tradable permit systems for some particular environmental problems, and Denmark, Poland, the Netherlands, Norway and the U.K. are considering their introduction for the first time (OECD).

Perhaps the most important shift in environmental regulation in Western Europe has been centered on the use of voluntary agreements. Voluntary agreements, negotiated agreements in particular, have become a very popular policy tool since the early 1980s. Negotiated agreements are contracts that are created between regulatory authorities and the regulated firm or industry. Unlike traditional unilateral regulation, both the regulated and regulator contribute to policy formulation. This type of solution is being applied to a wide

Table 1. Diversity of Environmental Issues Covered by Voluntary Agreements

	Agri- culture	Energy	Industry	Total VA's
Austria			✓	20
Belgium		✓	✓	6
Denmark	✓	✓	✓	16
Finland			✓	2
France		✓	✓	8
Germany		✓	✓	93
Greece		✓	✓	72
Ireland			✓	1
Italy			✓	11
Luxembourg		✓	✓	5
Netherlands	✓	✓	✓	107
Portugal	✓		✓	10
Spain			✓	6
Sweden	✓	✓	✓	11
United Kingdom			✓	9
EU Total			✓	305

Source: EEA, 1997.

variety of environmental issues, including agriculture (Table 1).

The term *voluntary agreement* covers a wide range of agreements ranging from voluntary 'codes of conduct' to legally binding agreements. In general, they include all commitments undertaken by firms and sector associations, which are the result of negotiations with public authorities and/or explicitly recognized by the authorities (EEA). The term *voluntary agreement* can be misleading as it can also be applied to agreements reached under coercion in the form of future legislative threats (Segerson and Miceli).

In Eastern Europe, introduction of pollution trading is impeded by the larger challenge of (re)introducing markets in general and establishing a structure of property rights to support them. Nevertheless, the first Polish experiment with transferable permits for volatile organic compounds in Chorzów, while requiring complicated and painstaking legal maneuvers, proved very successful in bringing visible improvements more rapidly and at a lower cost than those attainable through traditional instruments (OECD). However, wider replication cannot be contemplated without major changes in laws.

In Australia, there has been a shift toward market institutions for handling things previously mediated by rigid bureaucracy; one example is the emergence of water markets. This change in thinking has influenced environmental policy. Trading in salinity reduction credits in the Hunter River (where the coal industry discharges saline water) was introduced on a pilot basis in 1995 and continues (SSC). In the Hawkesbury-Nepean river system (a highly productive agricultural region experiencing urbanization pressures from the growth of the Sydney metropolitan area), high nutrient loads have been attacked by issuing a bubble license involving the major sewage dischargers (EA).

Some Stylized Facts about the Performance of IB Instruments

Compliance Cost Savings: a Clear Benefit. Pollution trading programs have typically exceeded expectations, in that total discharge limits are attained with cost-savings greater than predicted at the outset. A plausible explanation is that moving to a tradable permit market involves two steps: a switch to performance standards and the introduction of trading. The switch to performance standards provides private incentives—absent under CAC regulations—to find cost-efficient abatement methods, generating cost savings in addition to those afforded by trading of permits.

"Innovation Offsets"? Porter and van der Linde suggest that in a dynamic setting properly designed environmental policies can trigger innovations that offset the increase in compliance costs, partially, completely, or even more than completely. Their claim is that explicit environmental improvement policies can reduce the uncertainty that investments addressing pollution abatement will be valuable and motivate innovation and progress (similar to the creative force of the market). Innovations can be developed and implemented to decrease environmental impacts while simultaneously improving the product and/or the related production process leading to these "innovation offsets" (Porter and van der Linde). The proper policy instruments for achieving

such offsets emphasize the use of private incentives, by leaving the approach to innovation in the hands of the producer (Porter and van der Linde). The "Porter hypothesis" has attracted critics who deny its plausibility, claiming that while offsets are theoretically possible, they are likely to be rare or small in practice.

For "end-of-the-pipe" pollution controls, offsetting productivity gains or cost savings seem unlikely. However, a plausible theoretical case can be made for offsets in the case where pollution controls can be integrated into production processes. Dixit and Pindyck argue that due to uncertainties of various kinds firms tend to replace productive assets less frequently than seems economically optimal. Productive assets typically are replaced with technologically enhanced assets, and uncertainty about the nature of technological enhancements to be introduced in "next year's model" may induce delays in asset replacement. The need to meet an environmental performance standard may induce investment in a new and technologically enhanced integrated production and pollution control system so that efficiency gains in production offset all or part of the pollution control costs. Purvis, *et al.* showed that certain livestock waste control practices offer advantages for both productivity-augmentation and pollution abatement.

The Problem of Uncertainty. A common impediment to all trading programs is uncertainty of various kinds (Carlson and Sholtz; USGAO; Purvis, *et al.*). Trading will be inhibited by market participants' uncertainty about future total discharge limits, enforcement of existing policies, and the cost and effectiveness of control technologies. As we will see below, uncertainty may afflict the regulatory community, too. For example, regulators motivated to meet environmental performance goals may hedge against uncertain performance of control technologies by specifying high trading-ratios (t-ratios), which provide an environmental safety margin but impede trades and limit the effectiveness of trading programs.

Wetlands Mitigation

The preservation of wetlands has gained attention in recent years as the acreage of natural wetlands has declined. There are essentially two types of wetland policies in the US. The Wetland Reserve Program represents the traditional approach: a federal incentive system that pays farmers to preserve and enhance wetlands. Section 404 of the Clean Water Act introduces a regulatory approach, mandating "no net loss" of remaining natural wetlands. However, Section 404 contains an interesting provision that allows individuals who wish to drain wetlands in one location to mitigate the loss by enhancing wetlands elsewhere.

Land developers must apply for a permit to alter any existing wetland. The regulator evaluates the physical qualities of the wetland and determines whether the applicant must minimize the impact of development or offset or minimize negative impacts on wetlands. On-site offsets include setbacks and filter strips designed to minimize degradation of the directly impacted wetlands. However, it can often be more effective to permit offsets to be implemented offsite. The developer pays to create new wetlands or improve an existing offsite wetland. The regulatory goal is to require that loss of impacted wetlands be offset by addition or enhancement of wetlands of higher ecological quality within the same hydrological and ecological region.

The effectiveness of constructed wetlands is uncertain, and some observers claim that constructed wetlands typically are inferior to natural wetlands. To compensate, a mitigation ratio is imposed by the regulator (i.e., EPA and the Army Corps of Engineers), requiring more than one acre of constructed wetlands to offset the loss of a single acre of existing wetlands. The most common mitigation ratio is 1.5:1 in Ohio, but ratios of 3:1 or more have been imposed for high quality and/or particularly sensitive wetlands. However, this ratio can be even greater if the impacted wetlands are of a higher quality. The mitigation ratio is determined on a case-by-case basis during the permit process.

Wetlands exhibit economies of scale and

scope, in that larger wetlands tend to support more diverse and productive ecosystems than small ones. Provision of larger and better wetlands is a classic isolation paradox such as those affecting many ecosystem issues: for many kinds of ecosystems, protection of biodiversity requires large areas of contiguous habitat. This is feasible only if considerable numbers of independent landowners can be encouraged to cooperate with each other and, often, to cooperate with public land agencies. Private mitigation banking creates incentives for such cooperation.

Wetlands Mitigation Banks. Mitigation banks are large constructed wetlands created for the sole purpose of providing future offsets for wetland loss due to conversion. The banker sells acreage in the constructed wetland to developers and others who are required to offset wetlands conversion in the same ecological and hydrological region. Twenty states have established mitigation banking policies. Some local communities, such as Eugene, Oregon, have established local mitigation banking policies as well. Nationwide, mitigation costs vary from \$7500 to \$60,000 per acre, and as of January 1997, over 200 wetland mitigation banks, mostly nonprofit, were in operation or under development in the United States, with at least one in each state (Environmental Law Institute, 1998). Forty for-profit mitigation banks have been approved and another 75 have been submitted for approval (Environmental Law Institute). Florida has 18 mitigation banks with more than 20,000 acres of wetlands, and mitigation banking constitutes a \$750-million industry in the state (Environmental Law Institute).

The Ohio Wetlands Foundation is a nonprofit organization that creates constructed wetlands banks and sells acreage to land developers for offsetting purposes. Since 1993, the Foundation has sold out three separate banks ranging in size from 33 acres to 330 acres (Sutliff). Mitigation banking allows marginal wetlands to be put to more valuable uses, while maintaining, and in some cases increasing, the total amount of high-quality wetlands.

Toward Performance Standards. The ecological functions of a wetland involve com-

plex ecological interactions that are difficult to measure and monitor and, especially for constructed wetlands, are subject to uncertain time paths. Standards for environmental performance are difficult to implement, so design (i.e., technology) standards have been the norm. The agency approves the plans for constructed wetlands and will set measurable implementation goals that are fairly good predictors of ecological function. Nevertheless, mitigation banking is arguably impeded by the widespread use of relatively high mitigation ratios, while environmental performance of constructed wetlands has been spotty enough to generate skepticism among environmentalists (Marsh *et al.*).

The Army Corps of Engineers has proposed and is the process of requiring all nationwide permits to be based on the use of the hydrogeomorphic (HGM) approach to assessment of wetland functions (*Federal Register*). HGM works in three stages: first, wetlands are classified on the basis of their differences in functioning (landscape setting, water source, hydrodynamics); then the functions that each class of wetlands performs are defined; and, finally, references are used to establish the range of functioning of the wetland. This proposal is intended to move wetlands mitigation closer to accomplishing in-kind replacement of lost wetlands. Thus, the HGM approach represents a shift toward performance standards for wetlands mitigation, as regulatory agencies respond to public anxiety about the performance of constructed wetlands.

Point-Nonpoint Pollution Trading

Agricultural nonpoint sources are currently the leading cause of water pollution in most areas of the United States (Davies and Mazurek). Yet they have avoided intense regulatory scrutiny until fairly recently, due perhaps to the long-standing tradition of using subsidies rather than regulatory pressure to influence the performance of agriculture and the claim that regulation is impractical in that it is inherently difficult to identify individual contributions to nonpoint pollution loads. The result is that agricultural nonpoint sources have been ad-

dressed mostly by specifying best management practices (BMPs)—if used as standards, BMPs are technology standards—which are encouraged mostly by subsidies of various kinds.

In recent years, however, the US EPA has encouraged point-nonpoint pollution trading programs in which farmers implementing BMPs would earn pollution reduction credits to be sold to point-source polluters. EPA lists 13 existing point/nonpoint trading programs, and a similar number are under development or consideration. Agricultural sources of pollution are included in the majority of these trading markets. Programs are set up at the catchment or sub-catchment level. Several levels of government are involved, as are point-source polluters, who may be private or public organizations, and nonpoint-source polluters. These trading programs simultaneously introduced a number of innovations in pollution control policy: (1) point sources of pollution were switched from command-and-control technology standards to performance standards, (2) economic incentives were introduced via permit trading opportunities, and (3) point sources in need of credits contract with nonpoint polluters collectively. Of these innovations, the first two are classic IB instruments, while the third solves the isolation paradox by providing benefits (i.e., income from the sale of abatement credits) to all members of the group whenever a group target is achieved.

Here we describe briefly the situation and performance to date for three trading programs that represent the existing range from formal markets to informal voluntary agreements.

Tar-Pamlico River Basin, North Carolina

High nitrogen and phosphorous levels within the Tar-Pamlico river basin led to eutrophication and fish kills. To deal with the problems, a permit trading system was created to reduce nitrogen and phosphorous loadings at low cost. The participants in the trading markets consisted of 13 point sources (12 water treatment works and one private firm) and numerous nonpoint sources within the watershed

(primarily cropland and livestock). The point sources organized themselves into a single group, referred to as the *Association*. The Association placed all individual point sources under a single “bubble.” If the total loadings attributable to the Association exceed the allowable nutrient load, then members are required to purchase offsetting nonpoint source abatement.

Permit prices are not established by textbook market equilibrium. Based on a computer simulation of potential trades, the price of a tradable permit was set for the market at a weighted average of \$29 per kg of nitrogen/per year (Gannon). Credits are good for 10 years. The regulator sets the trading ratio at 3:1 for crop agriculture and 2:1 for livestock, based on estimations of best management practice performance and expected costs (US EPA). The North Carolina Department of Soil and Water Conservation arranges “trades” through the North Carolina agricultural cost-share program. Should the Association violate its aggregate standard, it is required to deposit funds into the existing cost-share program. These funds are earmarked for programs in the Tar-Pamlico Basin and are used to enroll more land in the cost-share program.

The Association is required to maintain a minimum \$500,000 annual reserve in the Agricultural Cost Share Program; to date this has grown to \$1,031,000. This ensures the availability of funds for the implementation of any potentially required trades. Since the Association is not involved in the implementation of trades it does not carry the responsibility of ensuring compliance by the nonpoint source trading partner (Gannon). Instead, the State, through Soil and Water Conservation District officials, bears the cost of inspection and enforcement of compliance. This arrangement is thought to relieve the point sources of bearing excessive risk through trading.

In summary, while the US EPA is pleased to promote these arrangements as point-nonpoint pollution trading, they are in fact a rather rigid kind of trading and the regulator’s role is more prominent than the term *trading* ordinarily suggests.

To date, no mandatory trades have oc-

curred between point and nonpoint sources within the Tar-Pamlico market. However, the Association has purchased some nonpoint-source credits to offset potential future needs. In addition, point-source trading within the Association bubble is reported to be very active. During Phase I of the market's formation, each point source was required to perform an engineering analysis of its management and operation practices for pollution abatement (Hall and Howett). As a result of these analyses, many new low-cost methods of pollution abatement were implemented. In response to the flexibility derived from the switch to a performance standard the point sources were able to abate nitrogen and phosphorous discharge directly, and trading was not required. Association members still remain well below their allowances. Therefore, trades are not anticipated for a few years (Gannon).

Laguna Del Santa Rosa

Laguna de Santa Rosa, California, is the site of an informal trading arrangement. The City of Santa Rosa faced difficulties in meeting water quality standards during the summer months. Instead of increased abatement efforts, the city shipped treated wastewater to area golf courses as well as dairies and farms for application to pasture and some food crops (Smith). No overall trading mechanism exists and trades are not reflected within the City of Santa Rosa's NPDES, but they are accounted for within the Total Maximum Daily Load (Smith). The city initially paid dairies to take the water, but payments are no longer made due to the desirability of the nutrient content (US EPA). Local governments enforce noncompliance problems against the farmer or rancher who applies the wastewater to fields (Smith).

Boulder Creek, Colorado

Within a 15.5-mile segment of Boulder Creek, a trading program was established to reduce ammonia levels contributed by point-source wastewater treatment plants and nonpoint agricultural sources. High water temperature and pH were identified as the primary causes of

increased ammonia levels, which were linked to the physical degradation of the creek's riparian zone. Reducing the ammonia levels required cooperation of both point sources and nonpoint sources. Various forms of direct nonpoint-source abatement offsets were made available to the point source (the City of Boulder's Public Works Department) to meet ammonia reduction levels. Point sources have the option of reducing ammonia discharge directly or of increasing stream capacity for ammonia by funding projects which will return the creek to its original flow (i.e., removal of structural diversions), and/or projects which reduce nonpoint-source impacts (i.e., paying farmers to fence livestock out of the riparian zone) (US EPA). The point source has upgraded its plant to meet current regulatory standards, and has opted to adopt these unconventional pollution offsets in anticipation of future abatement needs.

Improving the Prospects for Point-Nonpoint Permit Trading: Theory and Hypotheses

The experience of the Tar-Pamlico River Basin trading program, in that no trades have yet been recorded, suggests that the potential benefits of point-nonpoint permit trading have yet to be achieved in full. One possible explanation is the stylized fact, discussed above, that efficiency gains from the switch to performance standards for point sources have reduced the demand for permits. Before we accept this explanation too complacently, we should entertain a second possibility: trading markets that have been introduced are too restrictive and too many bureaucratic controls remain so that permit exchange is impeded by market design.

While there is a considerable literature addressing permit market design, relatively little of it deals with extending permit markets to include nonpoint sources. It is often argued that including nonpoint source pollution within a permit trading market is difficult because monitoring individual contributions can be prohibitively costly, loadings are in large part driven by random weather events, and uncertainty exists regarding the effectiveness of pol-

lution abatement controls (Tomasi, *et al.*). Since nonpoint source discharges are difficult to observe at the individual level, existing trading programs have resorted to monitoring abatement technology (e.g., best management practices) rather than performance. As a result, trade within the point-nonpoint source permit market involves heterogeneous goods (point-source discharges and nonpoint-source best management practices).

Trading ratios have been introduced to allow for the exchange of heterogeneous goods within a tradable permit market (Mendelsohn; Hahn). The trading ratio specifies the number of units of nonpoint pollution reduction, estimated by modeling the effectiveness of the chosen best management practice (BMP) that must be exchanged for a single unit of point-source pollution. The optimal trading ratio depends on the relative costs of enforcing point and nonpoint source abatement as well as the uncertainty associated with nonpoint loadings (Malik *et al.*). This uncertainty has two sources. The first derives from the weather driven nature of nonpoint source pollution. The second is that there is considerable uncertainty regarding the effectiveness of nonpoint source pollution abatement controls. A t-ratio greater than one provides a safety margin for the environment. With more than one unit of (estimated) nonpoint source reduction credit required, deviations from the expected abatement performance of the BMPs are less likely to result in violations of the regulatory standards. To ensure that regulatory goals are met, the t-ratio tends to be set cautiously high, but high t-ratios impede trading, thus undermining the *raison d'être* for permit trading.

An alternative to monitoring technology (e.g., BMPs) is to monitor the nonpoint sources on the basis of performance. Removing the regulator's uncertainty about the effectiveness of the nonpoint source abatement technologies would, in concept, allow reduction of the t-ratio and generate an increase in the frequency of trades. If it is conceded that monitoring individual nonpoint sources on the basis of performance is technically difficult, and thus likely to be prohibitively expensive, arrangements based on collective monitoring at the catch-

ment level might be considered. Monitoring pollution loads leaving the catchment is a simple process; the difficulty is to provide the right incentives to individual farmers within the catchment. Griffin and Bromley have suggested the use of estimated individual nonpoint discharges, derived from the monitoring of total loadings in the catchment determined through a biophysical model relating inputs to loadings and ambient water quality standards. Segerson (1990) has suggested liability bonding. The game theory literature offers "scapegoat" and "massacre" solutions (Rasmussen), variations on the theme that all firms will make appropriate abatement effort if collective performance is monitored and randomly chosen individuals punished in the event the collective target is not met; schemes for punishing all members of a group for shortfalls in collective performance thus avoiding the arbitrariness of "scapegoat" and "massacre" while providing second-best incentives (Segerson, 1988) and tournaments (Govindasamay, Herriges, and Shogren) that reward firms for contributions to attainment of abatement targets.

Further research is required to refine methods for enforcing performance standards via collective monitoring of nonpoint sources. There are two key requirements for an acceptable collective monitoring and enforcement mechanism. The first is that it transmits to group members clear and readily comprehensible incentives that are consistent with group goals; in effect, incentive-compatibility and simplicity (which may come into conflict) are valued. The second requirement is that penalties and rewards imposed on individuals do not violate ordinary notions of fairness. Penalizing all members for a group shortfall may be considered unfair to those group members who did not shirk. The point-nonpoint trading programs introduced thus far have relatively little exposure to this problem because they involve rewarding farmers for pollution reductions rather than punishing them for exceeding regulated levels. Society seems to treat denial of a deserved reward as much less serious, in the moral sense, than imposition of an undeserved penalty: bonuses for team success are

a staple of contemporary management. Those who believe that the "polluter pays" principle should be extended to agriculture must, however, deal with the more difficult issue of specifying justifiable penalty structures for members of groups that collectively violate performance standards.

Performance monitoring, if successful, would reduce the role of technological uncertainty, thus allowing reduction of the optimal t-ratio. Malik, *et al.* have examined the optimal t-ratio in a static setting, and Letson emphasized that if technological uncertainty is too large it can eliminate the incentive for point sources to enter into trading agreements. However, regulatory schemes that manage technology are inherently static, whereas most water-pollution problems exist in a dynamic world, with technology that is constantly changing. It is important to assess how the level of trading will adjust and adapt to changes in the ability of regulators to monitor BMP effectiveness in reducing effluents and the relationship between nonpoint effluent reduction and ambient water quality.

Our central hypotheses are that adopting performance standards rather than technology standards in point-nonpoint trading programs will reduce the costs of pollution abatement within a watershed, and that with performance standards the t-ratio may be adjusted over time as innovation improves the technology available for reducing nonpoint source pollution. The efficiency of permit markets requires minimum t-ratios consistent with prudent environmental regulation. These hypothesized gains would result from allowing nonpoint source polluters in trading markets to determine the optimal technology, rather than having a cautious regulator choose the technology and hedge against uncertain performance by imposing a high t-ratio.

A performance-based system would focus on monitoring overall pollution levels and it would establish individual incentives among nonpoint sources through the use of some collective enforcement mechanism. Point sources would be able to purchase a given level of nonpoint source pollution reduction and the nonpoint sources would have their choice of

mechanisms to reduce their pollution discharges. Uncertainty as to the effectiveness of on-farm abatement technology is borne by the farmers (who are best able to handle it), allowing greater efficiency in the permit market as regulators and point source polluters enjoy a higher level of certainty. All parties would gain from the increased efficiency of permit markets. Nevertheless, some uncertainty remains because neither polluters nor the regulators know the exact relationship between nonpoint source reductions and ambient water quality.

A natural question that arises in a performance-based system is the choice of enforcement mechanisms. An objective of our on-going research is to survey the literature, assess the different mechanisms suggested, and develop and assess new or modified mechanisms. The choice of enforcement mechanism has important implications for the feasibility of a performance-based system due to uncertainty about the effectiveness of nonpoint source pollution reductions and risk aversion of permit market participants and the regulator. High levels of risk aversion and high uncertainty reduce the scope for trade and hence the efficiency and welfare gains from permit trading.

Conclusions

Our comments have addressed three major themes: (1) recognition that solutions to agricultural environmental problems will take a variety of institutional forms, (2) the expanding role of incentive-based policies including voluntary agreements and pollution trading programs of various kinds in many countries and applied to many kinds of environmental problems, and (3) the prospective gains that attend implementation of trading programs based on performance standards rather than technology standards.

Creativity and Eclecticism in Building Trading Institutions

Trading programs allow, in principle, for the inclusion of a wide range of trading partners

including point sources, nonpoint sources, local governments, and federal agencies. As seen in the examples above, trading regimes do not necessarily have to be developed in the traditional sense discussed by economists or as pioneered under Title IV of the Clean Air Act Amendments of 1990. Opportunities for trading can be created at many different levels and scales. For example, point sources may trade with other point sources or with nonpoint sources, nonpoint sources may trade with nonpoint sources, or government agencies may trade with other government agencies. Trading may be formal or informal, and enforcement of agreements made may be rigid or to some extent negotiable.

Despite this diversity of institutional forms for trading, some principles for success can be identified. Two in particular deserve special attention: a long-term and broadly inclusive process and markets scaled appropriately for the problem at hand.

A Long-term Process Involving All of the Legitimate Interests. Trading mechanisms bring together all of the stakeholders with the regulatory agency. The process of establishing a trading system identifies all relevant sources of environmental degradation, identifies the potential trading parties, and creates avenues of communication. The commitment of government minimizes institutional uncertainty, and the promise of gains from trade provides the glue that keeps participants in the game.

Problem-scale Trading Markets. Environmental performance typically has a strong regional dimension: there are good reasons why ambient pollution targets are defined at the catchment level and compensating wetlands must be located with due respect to aquifers and ecological boundaries. The geographical boundaries of wetlands mitigation banking districts and pollution permit trading markets should respect these considerations, as well as the need to be large enough to avoid "thin markets" yet small enough for administrative efficiency.

Wetlands can be mitigated on-site or in larger mitigation banks many miles from the conversion area. Wetlands mitigation depends upon evaluations of wetland quality and the

probable success of habitat creation. Loss of a wetland that is non-unique may be offset with contributions to an offsite mitigation bank providing greater habitat than the original acreage, while unique or highly critical wetlands may require on-site mitigation to prevent serious local habitat loss.

Many factors play into the determination of appropriate scale and distance in water pollution trading schemes. But the immutable fact that water tends to flow downhill provides an enduring organizing principle: trading markets should be delimited by hydrological boundaries such as catchments and watersheds.

Performance-based Trading Prospects for Agriculture

Regulatory institutions that provide private incentives hold the potential for improving the environmental performance of agriculture. "No net loss" provisions and mitigation banking hold the promise of maintaining and enhancing wetlands with minimal disruption to the land economy. Rather than the traditional public provision of cost-share assistance, innovative point-nonpoint pollution trading programs provide private incentives for pollution abatement on farms. The institutions for pollution trading can vary greatly: from informal to formal, from technology to performance based, and from market-clearing to administered-price trading. This variety in trading programs demonstrates creative institutional adaptation to the circumstances at hand. Nevertheless, we are convinced there are considerable gains to be had from further refinement of some of these trading programs.

Wetlands mitigation works in the northwestern two-thirds of Ohio, which is naturally a vast wooded wetland, and supports agricultural and urban development only with the aid of extensive artificial drainage. For most of the US, however, wetlands mitigation has had mixed success, and failed mitigation projects occur often enough to cast a shadow on the whole process. Regulators are currently moving toward performance-based mitigation banking by introducing a hydrogeomorphic approach.

Although existing cost-share programs can

change farmer practices, reducing agricultural pollution, they rely heavily on subsidizing approved technologies. The point-nonpoint pollution trading programs that have been introduced thus far have also applied a technology standards approach on the nonpoint side of the market. One distinguishing feature of many tradable pollution permit programs applied to point sources is that they require regulatory agencies to monitor performance rather than the installation of abatement technology.

Performance standards shift the burden of uncertainty from regulators to polluters who have access to information of various kinds that is unavailable to the regulator. Under the current regime, where cost-share incentives are based on technological inputs, the regulators face all of the uncertainty about performance of BMPs. Under a performance-based trading system, however, the parties involved in the trade would be held liable for non-compliance with water quality standards, placing the burden of uncertainty on the parties best able to adapt to it.

Under current technology-based point-nonpoint trading arrangements, regulators impose trading ratios to provide a measure of assurance that environmental targets are met via pollution trading. Yet high t-ratios, which reduce potential gains from trade, can provide serious impediments to the success of trading programs. A switch to performance-based trading seems warranted, but runs counter to traditional insistence that that nonpoint pollution cannot be monitored at the source. The day is not far away, technological optimists tell us, when effective and inexpensive spy-in-the-sky monitoring technology will render this objection moot. Alternatively, collective enforcement at the (sub)-catchment level would permit introduction of performance-based point-nonpoint pollution trading today. The opportunity for considerably enhanced gains from trade may be sufficient to induce farmers to accept collective enforcement of trading commitments.

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