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Market Structures for U.S. Water Quality Trading

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The use of transferable discharge permits as a water pollution control policy is rapidly increasing in the United States. Drawing on evidence from existing water quality trading programs, this paper provides a taxonomy of the forms that such markets take. Four main structures are identified: exchanges, bilateral negotiations, clearinghouses, and sole-source offsets. Each of these structures has its own strengths and weaknesses; none is optimal for all scenarios. Since market structure is largely determined by a program's rules, policy makers should be aware of the differences between these structures and the conditions under which each comes to be.

Once viewed as little more than a fantasy of academic economists, the trading of environmental flows increasingly is being sought by policy makers to address a wide range of issues. In addition to the well-known market in sulfur dioxide (SO_2) established by the 1990 Clean Air Act, markets for other air pollutants are active in numerous states, wetlands mitigation banks are being widely used, and carbon dioxide trading was written into the Kyoto Protocol to the United Nations Convention on Climate Change.

Water pollution has not escaped this growing interest in pollution. In 1996, the U.S. Environmental Protection Agency (EPA) released draft guidelines for water-pollution trading that implicitly sanctioned the development of water quality trading (WQT) programs and laid the ground rules for programs that the agency is likely to accept (U.S. Environmental Protection Agency, Office of Water, 1996). While only three programs existed a decade ago, a recent report to the EPA lists 16 programs that are in various stages of implementation and 9 more programs under development (Environomics).

In this paper, we discuss the current state of WQT in the United States and evaluate the forms these programs have taken. There is substantial variability in the structures of markets to allocate pollution rights. Four main market forms

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are identified: exchanges, bilateral negotiations, clearinghouses, and sole-source offsets. These alternative market forms lead to different outcomes in terms of both the programs' cost efficiency and environmental efficacy.

The fact that markets for pollution credits have taken on a variety of forms begs the question, "Are these diverse structures sustainable or will a single market form come to predominate?" In this paper, we attempt to answer this question. While some structures are more appropriate for WQT than others, each structure has advantages and disadvantages so that we do not expect that all such markets will eventually look alike. Just as a variety of structures exist in markets for traditional goods, we believe that it is likely that a variety of market forms will persist in WQT due to the diverse conditions in which WQT is used. Appreciating the strengths and limitations of alternative market structures is important because, by and large, the form that a pollution market takes does not arise naturally as a consequence of market pressures, but is instead a result of decisions made by agencies and legislators.

A pollution-trading market's design is a result of numerous constraints and competing interests, both between and within government agencies. Agencies might seek five goals for a WQT program: (1) achieving environmental objectives as statutorily defined, (2) minimizing the total social cost of achieving a pollution control objective, (3) maintaining the agency's responsibility for pollution abatement while minimizing day-to-day efforts and legal risks, (4) minimizing transaction costs that must be borne by participants in the program, and (5) minimizing agency and market participants' costs of initiating the program. No market structure can achieve all of these goals. Because agency priorities vary, different market structures are likely to be preferred by different agencies.

The market structure that is most appropriate in a given situation also depends on the physical nature of the pollution problem and the characteristics of the polluters. Because the potential number of trades is limited by the geographic extent of a pollution problem, thin markets may be unavoidable. Furthermore, because many of the current WQT programs involve nonpoint pollution, the challenges of quantification, monitoring, and enforcement are substantial. The program's design must address these challenges. How this is done plays a critical role in determining the resulting market's structure.

In the next section, we discuss the current state of water-quality trading in the United States. The interest in this policy tool has exploded in recent years and is likely to expand in the near future. We then discuss some of the reasons why the popularity of water-quality trading is rapidly growing. It is particularly interesting to note that policy makers are attracted to WQT not only because it reduces abatement costs, but because the traditional approaches have been unable to achieve the required environmental standards. The traditional regulatory approach has focused on effluent from point sources (PSs) without addressing the growing problem of nonpoint source (NPS) pollution. WQT is seen as a way to fill the regulatory gap.

We then discuss four important legal principles that must be addressed in the establishment of a WQT program. These are authorization, entitlements, enforcement, and monitoring and reporting. This sets the stage for the principal analysis of the paper where we discuss the four main organizational structures in pollution trading markets, consider the advantages and disadvantages of each, and evaluate the conditions in which each might be most appropriate. We conclude by summarizing the lessons that can be learned, emphasizing the need to consider market structure in the development of future programs.

The State of Water-Quality Trading in the United States

Table 1 lists 15 cases in which WQT programs are either in place or under development. Of the 11 existing programs, only 2 existed prior to 1989 and 7 have been started since 1996. The programs are expanding not only in number, but also in scope; Michigan is in the process of approving rules that will allow WQT in any watershed in the state. To date, WQT programs have focused exclusively on surface water pollution, although its application to groundwater contamination is an important area for future research (Morgan, Coggins, and Eidman).[1]

There are a variety of reasons for the growing interest in WQT. First, to some extent the idea is simply catching on. The highly visible success of the sulfur dioxide program has led to widespread recognition that pollution trading can work. In reviewing the SO_2 trading program, Schmalensee et al. state, "large-scale tradable permit programs can work roughly as the textbooks describe; that is, they can both guarantee emissions reductions and allow profit-seeking emitters to reduce total compliance cost" (p. 66). Furthermore, the numerous air pollution-trading programs, such as California's RECLAIM program, have given many states experience with managing such programs (Klier, Mattoon, and Prager).

Svendsen reports that both environmental and industry groups have favorable opinions of transferable discharge permit programs in air pollutants. Within agriculture, however, support for WQT is still lagging. McCann and Easter surveyed farmers and agency staff to determine their perceptions of 17 different policies, including WQT.[2] Among the surveyed group, WQT was ranked 10th by farmers and 12th by agency staff, who perceived the program's administrative costs to be the fifth most expensive among the policies considered. Overcoming resistance from the agricultural sector will be critical to the success of WQT trading involving these NPS polluters.

The increased interest in WQT can also be attributed to the new emphasis on the development of total maximum daily load (TMDL) programs across the nation. TMDLs have long been a requirement of the Clean Water Act (CWA) but were rarely implemented until recent lawsuits forced EPA's hand.[3] The perspective that a TMDL process brings to water quality management differs sharply from the traditional approach. Instead of asking, "How much pollution should each source be allowed to emit?" the management questions under a TMDL become "What is the total pollution load that should be permitted?" and "How should that load be allocated among the various sources?" Market-based approaches become a more obvious option when the focus turns from technological requirements to the allocation of responsibilities.

With the increased emphasis on TMDLs, regulators have broadened their focus from toxic effluent from PSs to all pollutants. Historically, water pollution regulations have focused on those sources that are largest and most easily monitored. The result has been a set of "end-of-the-pipe" restrictions on PSs such as those embodied National Pollutant Discharge Elimination System (NPDES) permits. While this approach has eliminated the nation's most egregious water problems, many problems remain and a majority of these are associated with excess nutrients in the water coming primarily from NPSs (Faeth). As seen in table 1, WQT is primarily being sought to address nutrients and NPSs pollution.

The difficulties of regulating NPS pollution have long been recognized (Griffin and Bromley). NPS loads are difficult to monitor or predict, making it virtually impossible to regulate their pollution loads directly. Incentive-based policies to control NPS pollution can be broken down into two main categories: performance-based incentives and design-based incentives (Ribaudo, Horan, and Smith).[4] Performance-based incentives use taxes and subsidies based on ambient pollution levels that can be observed (Horan, Shortle, and Abler; Segerson). While attractive on the surface, this approach has been applied very little and has been criticized because it is applicable only under very restrictive conditions and because of its onerous informational requirements (Ribaudo, Horan, and Smith).

The second basic approach to NPS pollution control uses incentives based either directly or indirectly on management practices. These incentives can be subdivided into those based on predicted runoff and those that are directly tied to particular practices or inputs. Of these two, the former is most directly applicable to WQT markets. However, policies that tie economic incentives to predicted loads do have some important shortcomings. First, as shown by Shortle and Abler, when the mix of inputs affects both the mean and variance of runoff, optimal policies must take risk into account. Furthermore, the accuracy with which runoff can be predicted is directly related to the amount of information available on management practices. Since such information is costly to obtain and process, and producers may be reluctant to divulge their management practices in detail, runoff predictions are typically based on a set of relatively few easily observed management variables. Because this "second-best" approach typically allows farmers to choose only from a list of sanctioned "best-management practices" (BMPs), it restricts their flexibility and can be quite expensive relative to optimal management choices (McSweeny and Shortle).

Despite these shortcomings, NPS credits in the programs presented in table 1 are uniformly calculated based agronomic models. While this approach can have high costs of administration and monitoring, it may be the only feasible way to involve NPSs in WQT. An alternative worth considering, however, is to tie incentives directly to inputs. Ribaudo, Horan, and Smith favor such incentives as quite easy to implement and list numerous studies that have found input incentives can induce NPS pollution control with little welfare loss. As such, future programs may want to consider using a "pollution-for-inputs" approach to WQT.

The development of WQT markets is further complicated by the institutions that allocate water quantity. Water pollution is often directly related to the quantity of water that a source uses, particularly in the case of agriculture. However, the institutions that allocate water quantities are notorious for their inefficiency (Griffin and Hsu). Surface water is frequently sold at prices below the marginal cost; groundwater extractions are usually permitted without any concern for the stock externality that such reductions cause; rights to water are sometimes granted on a "use it or lose it" basis; and there are often restrictions on the transfer of rights between parties. These features of water quantity markets would have important implications for associated WQT markets, distorting trade and increasing transaction costs. In creating institutions to allocate water quality responsibilities,

Table 1. U.S. water-quality trading projects in progress or under development

Project	Participants in the Trading Program	Pollutants Traded	Status
Fox River, WI[a]	PS/PS	Phosphorus	Established in 1981, no trades until 1995.
Lake Dillon, CO[b]	PS/NPS, PS/PS, NPS/NPS	Phosphorus	Allowed since 1984, very limited trading.
Tar-Pamlico, NC[c]	PS/PS, PS/NPS	Nitrogen & Phosphorus	Initiated in 1989. Trading between point sources is common. Trading with NPSs has been limited.
Boulder Creek, CO[b]	PS/NPS	Ammonia, nutrients	Functioning since 1990.
New Jersey Chemical Industry, NJ[d]	Pretreatment by PSs	Metals	Pilot project initiated in 1996.
Rahr Malting Co., MN[e]	PS/NPS	BOD, Phosphorus, & Nitrogen	NPDES permit with trading allowed. Signed in January, 1997.
Grassland Drainage Area, CA[f]	NPS/NPS	Selenium	Program in place since June, 1998.
Tampa Bay, FL[g]	PSs and NPSs involved	Nitrogen	A cooperative approach without formal trading. Initiated in 1998.
Kalamazoo River, MI[h]	PS/NPS	Phosphorus	Two-year demonstration project begun in 1998.
Chatfield Basin, CO[i]	PS/NPS, PS/PS	Phosphorus	Approved August, 1999.
Southern Minnesota Beet Sugar Cooperative, MN[j]	PS/NPS	Phosphorus	NPDES permit with trading allowed. Signed in April, 1999.

Programs Under Development			
Long Island Sound, CT & NY[k]	PS/NPS	Dissolved oxygen	Under study.
State of Michigan, statewide rules[h]	PS/NPS, PS/PS	Phosphorus & Nitrogen	Rules under final review, October 2002.
Rock River, WI[l]	PS/PS, PS/NPS	Phosphorus	Draft rules as of June, 1999.
Lower Boise River, ID[m]	PS/NPS, PS/PS	Phosphorous	Under study and development.

Sources:
[a]Jarvie and Solomon.
[b]U.S. Environmental Protection Agency, Office of Water, 1996.
[c]Green.
[d]U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation. 1998.
[e]Minnesota Pollution Control Agency, 1997.
[f]Austin.
[g]Bacon and Greening.
[h]State of Michigan, Department of Environmental Quality.
[i]Colorado Department of Public Health and Environment.
[j]Minnesota Pollution Control Agency, 1999.
[k]Kearney Inc., 1996.
[l]Rock River Partnership News.
[m]U.S. Environmental Protection Agency Region 10.

therefore, it is imperative that the existing institutions that allocate water quantity be carefully considered.

Legal Considerations in Market Structures

The law plays a critical role in creating and empowering market structures for WQT. All market systems require legal authorization, defined entitlements in permits and trade instruments, enforcement of trade agreements, and monitoring and reporting to insure compliance.

Authorization

Market structures for WQT must be consistent with the substantive and procedural mandates of federal and state law. Congress, through enactment of the CWA, has given the EPA primacy in water quality and pollution control efforts. States have the opportunity to take over the administration and enforcement of market trading programs subject to federal oversight.[5]

Unlike the Clean Air Act, the CWA does not explicitly authorize effluent trading or other market-based incentive programs. However, legal authority can be inferred from several sections of the CWA (33 U.S.C. §1312, 1313), recently proposed revisions to TMDL regulations (U.S. Environmental Protection Agency, 1999), and the EPA's "Draft Framework for Watershed-Based Trading" (U.S. Environmental Protection Agency, Office of Water, 1996). Although federal authority can be inferred, Congress could remove any doubt by explicitly authorizing effluent trading. Nonetheless, questions over enabling authority do not appear to be major barriers to WQT markets and because state regulations must be consistent with the CWA, that legal authorization would appear to extend to states (see Bartfeld).

Entitlements

Markets for WQT are premised on the idea that discharge levels can be defined as legal entitlements that have divisible, apportionable, and transferable elements. Economic theory posits that defined, privatized, enforceable, and transferable rights are central to market-based transactions. Any WQT program must recognize and embody three features that are crucial to market-based transactions:

- *Entitlement*: legally protected entitlements to discharge to a specified limit;
- *Transferability*: the right to convey all or part of the entitlement to others; and
- *Enforceability*: the right to protect the entitlement and ensure compliance of terms of transfer.

Enforcement

Responsibility and liability are the primary enforcement concerns with trading programs: under what conditions does a trade fail; if a trade fails, who is responsible for correcting the situation; who can be sued; and who is liable? Transaction costs are increased by enforcement structures that are complex, costly to enforce, and fraught with uncertainty.

Enforcement processes are determined, in great part, by the regulatory authority of the agency and by the type of trade contemplated. Liability for noncompliance is predicated either on permit or contract conditions. Permit-based enforcement actions are dictated by the CWA and by state statutes and administrative rules that generally mirror the federal requirements. Contract actions are based on bilateral or multilateral party negotiations and terms are enforced through a civil process. Enforcement flows under permit terms are usually unidirectional from the agency to the permittee, whereas contract enforcement flows may be multidirectional.

Monitoring and Reporting

The burden and process for monitoring and reporting on trading is an important consideration in all market structures. It has a direct bearing on transaction costs and may present a significant barrier to trading. The CWA imposes substantial monitoring and reporting requirements on PS dischargers (see 33 U.S.C. 1318(a)(4)(A)). States with PS-PS and PS-NPS trading programs continue this practice. These requirements include water quality sampling, maintenance of monitoring equipment, record keeping, and reporting.

For trades involving NPSs, monitoring and reporting must be incorporated in the market structure. Two questions must be addressed: (1) "which party will carry this burden—the source or the agency?" and (2) "who will monitor the monitor?" For example, in the Michigan system, the state has addressed these questions by administrative rules (State of Michigan Department of Environmental Quality, §323.3014). The rules outline a process for determining NPS reductions based on changes in management practices, and require the applicant to certify to the agency the accuracy of the credits registered for trade. The person recording credits for sale is strictly liable for assuring that the reductions are real, surplus, quantifiable, and equal to the quantity of credits that are registered (Rule 323.3023). The agency does not conduct an independent investigation of compliance or monitoring but instead relies on trade partners or citizens to notify the agency if participants fail to satisfy the terms of their credit. In a sense, the Michigan program is an honor system and citizens and trade partners "monitor the monitor." Such monitoring is possible since the program grants credits based on verifiable BMPs and the accepted practice changes are to be posted on a publicly accessible Internet site.

Market Structures in Pollution Trading

While the recent surge of interest in WQT can be attributed to some common factors, the resulting programs vary quite dramatically. Just as markets for exchanging goods range from commodity exchanges to grocery stores to one-on-one negotiations, the markets that have formed to transact pollution abatement credits have taken on a variety of forms. Pollution trading "markets" can be categorized into four main classes: *exchanges, bilateral negotiations, clearinghouses,* and *sole-source offsets.*

There is significant variability in the transaction costs associated with different market structures.[6] The issue of transaction costs in pollution trading markets has received substantial attention in recent years (e.g., Stavins), and some authors have recommended steps that can be taken to minimize these costs (Hahn and Hester; Tripp and Dudek). Transaction costs are traditionally viewed as a wedge between the actual trading program and an ideal frictionless market. From this perspective, one of the roles of government is to find ways to reduce transaction costs to move the market closer to the ideal.

In this paper, we present a slightly different perspective. We view transaction costs as an inevitable consequence of market structure and different structures yield different transaction-cost outcomes. Consider the parallels to markets for the allocation of goods. Some goods are traded on exchanges, some are sold by retailers, and others typically involve bilateral negotiations. Clearly the unit transaction costs vary across these alternative structures. However, because this variety of market forms persists, it must be that they are, in a sense, "efficient" means of allocating a particular class of goods.

As in goods markets, diversity is also found in the institutions that have arisen in pollution trading markets. Permits to emit SO_2 can be bought and sold on the Chicago Board of Trade; PSs in the Tar-Pamlico Basin can buy uniform credits from a government clearinghouse; traders in Michigan's Kalamazoo watershed need to establish an individual contract with each trading partner; and, in Boulder, Colorado, a water treatment plant does not actually trade but is given more flexibility in how it achieves its pollution reduction requirement. In the remainder of this section, we show that different market structures reflect differences in both the trading environment and the priorities and goals of the agencies that oversee these programs.

For the purpose of this discussion, a pollution-trading program will refer to any program that allows polluters to satisfy regulatory requirements by arranging to reduce pollution at some other point. The agent wishing to pollute more than would otherwise be allowed will be referred to as the buyer of a pollution credit while the agent who has reduced pollution will be referred to as the seller.

In most of our discussion, we will assume that a baseline allocation of pollution rights has been granted to the polluters. For a variety of reasons, including economic efficiency and political expediency, rights in transferable discharge programs have traditionally been "grandfathered," that is, allocated based on historical pollution levels (Levinson). Alternatively, the initial rights could be held by the public, requiring sources to purchase credits from the public for any pollution they emit. Although in theoretically ideal conditions, the initial allocation of rights has no impact on the efficiency of their final allocation, this does not hold when transaction costs and uncertainty prevail (Montero). Since the transaction costs associated with the different market structures vary, the decisions that lead to market structure and those regarding baseline rights should not be made in isolation.

Exchange Markets

Exchanges such as the New York Stock Exchange are in many ways the textbook ideal of a market. Buyers and sellers meet in a public forum where prices are observed and uniform goods are traded. At any one time, there is a unique market-clearing price so that any interested parties can enter the market to make marginal purchases or sales at the market price. Because a single price exists at any given time, net of transaction costs, all parties' willingness to pay for additional units of the good must be less than or equal to the willingness to accept of those that own the good: no potentially Pareto-improving trades should remain unfulfilled.

Not all goods and services can be bought and sold on exchanges. One critical characteristic for the sale of goods on an exchange is *uniformity*. That is, exchanges can develop only for goods for which a unit from one seller is viewed as equivalent to one from any other source. Such goods can typically be described quite completely and concisely, for example, a share of IBM common stock or one ton of Chicago #2 Hard Winter Wheat. This uniformity not only reduces the information costs, but also means that market participants reveal little about their own operations when they make transactions.

In market-based approaches for controlling air pollution, numerous markets have developed that can roughly be categorized as exchanges. Uniformity in the SO_2 market was achieved by an explicit decision to treat all SO_2 emissions equivalently, regardless of their geographic origins or the nature of their sources. This has resulted in a fluid and growing market that moves SO_2 rights from one source to another at very low cost. In July 1999, brokerage fees were as low as 20¢ per permit, which, at that time, was trading for about $200 (McLean).

There are a variety of reasons why uniformity breaks down in water quality markets. First, water pollution from two sources may have substantially different impacts. If two sources impact different water bodies, they cannot trade pollution rights without reducing water quality at one location and improving it somewhere else, a violation of the CWA. Hence, at a minimum, separate markets must exist for each watershed. Using trading ratios to equate the marginal damages from two sources can reestablish uniformity when sources have differential impacts on a single point of concern (Malik, Letson, and Crutchfield).[7] Establishing the necessary uniformity is further complicated when there are multiple points, but, in principle, this can be accommodated in a similar fashion (Montgomery).

The relative locations of polluters within a watershed can also create unique relationships between buyers and sellers that might influence trading. Many sources use water from and discharge water to the same river, treating both their uptake and their effluent. For such users, upstream pollution reductions not only reduce overall pollution in the river, but might also improve the quality of the water they use, thereby reducing their treatment costs. Hence, upstream pollution reduction can create benefits for downstream sources, creating a further incentive for trades. At the same time, in such circumstances, a buyer's willingness to pay for pollution reductions will depend critically upon the relative location of the source that provides those reductions, further diminishing the uniformity of credits.

Uniformity will also be violated if trades require substantial interaction between the buyer and seller, particularly if that interaction is in the form of a continuing relationship. For example, when the approval process involves substantial reporting by both the buyer and the seller, parties will take into account how easy it is to work with one another. In this case, a buyer of credits may not be indifferent between two sellers, even if they are offering a standardized credit at the same price. Similarly, uniformity is violated if liability for shortfalls is shared between the buyer and the seller.

Finally, achieving uniformity in WQT is also difficult because of the regulations that govern water quality. The CWA requires agencies to monitor the distribution of pollution within a watershed and does not authorize any program that might lead to a reduction in water quality. Hence, WQT programs typically require substantial reporting, agency approval, and, in some cases, a requirement that purchasers of credits monitor the sellers of those credits. These requirements are often imposed to overcome the difficulties associated with NPS pollution, but even for PS contamination, the safeguards in the CWA make it very difficult to define pollution credits in a manner that achieves uniformity.

Hence, although exchanges have a distinct transaction-cost advantage over any other market structure, we do not anticipate that this structure will be widely used for WQT. Exchanges require a standardized unit of trading that captures all salient features of the credit. Such uniformity might be achieved if all rights are initially held by the public and then sold to the polluters. In general, however, because of the requirements of the CWA, the geographical diversity of most water pollution problems, and difficulties with NPS pollution, such uniformity is usually very difficult to achieve. If agencies attempt to force a WQT program into an exchange framework, the results are likely to be disappointing.

Bilateral Negotiations

Bilateral negotiations are common when buyers face a diversity of sellers and the characteristics of the goods are variable. Consider the market for used cars sold by private parties. Car buyers must choose between a wide range of vehicles, each with unique characteristics. Yet information about each vehicle is difficult to obtain. As a result, this market typically involves bilateral negotiations so that buyers can personally inspect the vehicles and parties can bargain over the price. Obviously, the information, contracting, and enforcement costs in such a market are quite high when compared with an exchange, but these costs are largely unavoidable.

The lack of uniformity in WQT markets has led most water-quality trading programs into a pattern of bilateral negotiations. Of the cases listed in table 1, trading in six programs involves bilateral negotiations: Wisconsin's Fox River program, the PS/PS trading in the Tar Pamlico Basin in North Carolina, California's Grassland Drainage Area program, the plan developed for the Southern Minnesota Beet Sugar Cooperative, and both the statewide and Kalamazoo case study programs in Michigan.

The reporting and monitoring required by the CWA tends to force the establishment of a bilateral trading structure. Nonetheless, agencies have substantial latitude in how these requirements are implemented and there can be important tradeoffs between the functioning of the market and the extent to which pollution flows are monitored. In the Fox River program, for example, each trade was subject to a review process that could take up to six months before a permit modification was granted. The result was a program in which transaction costs were so great that they have been blamed for the failure of the program to generate any trades (Hahn and Hester).

Aware that excessive oversight can inhibit market activity, more recent programs are seeking to decrease agency oversight while maintaining adequate control over pollution flows. For example, in the Michigan statewide program, formulas, conversion tables, and even an Internet-based calculator (www.nutrientnet.org) are available to calculate the levels from a variety of land uses.[8] Improvements have also been made in the trade-approval process. Before a trade can be finalized, the credits to be purchased must first be registered with the Michigan Department of Environmental Quality (State of Michigan Department of Environmental Quality, §323.3018). This two-stage process should reduce the uncertainty during negotiations since sellers can ensure that the credits generated will be acceptable to the agency. The regulatory burden is also reduced by provisions requiring agency action at both stages within 30 days.

However, the efforts of the Michigan rules to streamline trading cannot overcome the problem that credits will not be seen as equivalent. Some restrictions on trades exist including, under some circumstances, that remediation takes place upstream of the user of the credits (§323.3007). Furthermore, in order to improve compliance and decentralize monitoring, strict penalties are levied if a traded credit is found to be inconsistent with the rules of the program or credits are not valid. Hence, purchasers of credits will seek reliable sellers. The fact that buyers will pay attention to the characteristics of the seller, even if the credit has already been approved by the overseeing agency, implies that the uniformity necessary for an exchange cannot arise.

Compared to exchanges, bilateral negotiations tend to require relatively high transaction costs. This structure however does have advantages that cannot be achieved in an exchange. The structure allows for case-by-case assessment of trades to ensure that environmental standards are met. Furthermore, such markets can accommodate rules that are written to provide incentives to monitor each other, helping to overcome some of the monitoring challenges associated with NPS pollution. Furthermore, when markets are thin, bilateral trading may be the only option, because it has relatively low initial costs to establish the market. Despite its disadvantages, bilateral negotiations have advantages that make them particularly well suited to WQT. We expect, therefore, that this structure will be the most common form used in WQT markets.

Water-Quality Clearinghouses

The next market structure we consider is one in which the link between the generator of abatement credits and the user of those credits is broken by an intermediary. In this market structure, which we will call a WQ clearinghouse, the state or some other entity pays for pollution reductions and then sells credits at a fixed price to polluters needing to exceed their allowable loads. A clearinghouse differs from a broker in a bilateral market in that clearinghouses eliminate all contractual or regulatory links between sellers and buyers so that parties interact only with the intermediary.

WQ clearinghouses have much in common with retailers in the market for goods. For example, the packages of a particular grade of ground meat in a supermarket are of uniform quality and price. The retailer or its supplier, on the other hand, may have purchased the meat from a large number of producers and may have paid many different prices. The retail process converts a product of variable price and quality into a uniform product with a single price. The intermediary reduces contracting and information costs that would be required by bilateral negotiations. WQ clearinghouses are, therefore, like retailers for pollution abatement credits.

The PS/NPS trading program in the Tar-Pamlico Basin PSs is a good example of a WQ clearinghouse. Starting in 1989, PSs and NPSs in the Tar-Pamlico Basin began a two-phase program to reduce nitrogen loadings by 30% and hold phosphorous loadings constant (North Carolina Department of Environment and Natural Resources). Two types of trading take place in this program. First, trading via bilateral negotiations takes place between members of an association of PSs that, as a group, must stay below an aggregate annual phosphorous cap. Second, trading between the PSs in the association and agricultural NPSs takes place via a WQ clearinghouse. This clearinghouse, managed by the state's Agricultural Cost Share program, pays farmers 75% of the cost of implementing BMPs that reduce runoff of nitrogen and phosphorus. The price of nitrogen credits sold to PSs is equal to the actual average cost of achieving reduction (U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, 1997). Although the PSs had not exceeded their cap, by 1996 they had purchased $900,000 worth of credits including a $750,000 federal grant that was obtained by the PS association (Green).

A somewhat different WQ clearinghouse is found in the program established for the Rahr Malting Company in Minnesota. To gain approval to construct a wastewater treatment plant on the Minnesota River, Rahr was required to pay $250,000 into a fund "dedicated to projects that encourage adoption of nonpoint source reduction practices" (Minnesota Pollution Control Agency 1997, p. 9). The board of the fund has representatives from the government, Rahr, and environmental organizations. Using formulas specified in Rahr's NPDES permit, the board determines the quantity of effective CBOD reduction achieved through these BMPs. As long as the original payment is sufficient, Rahr will have purchased its needed credits at a fixed price.[9]

There are a number of features of WQ clearinghouses that distinguish them from exchanges and bilateral negotiations. First, relative to bilateral negotiations, a WQ clearinghouse reduces the transaction costs faced by both buyers and sellers of credits, since they need only interact with the clearinghouse. Furthermore, purchasers face a known fixed price for credits that have already been approved by regulators. If all pollution rights were initially held by the public, a clearinghouse structure would be the natural means by which to sell rights to sources. While there certainly are costs for the establishment and management of the clearinghouse, one would expect that these expenses could be passed on in the credits' price.

Potentially offsetting some of the transaction cost savings of a WQ clearinghouse is an efficiency loss in terms of abatement costs. Hoag and Hughes-Popp show that if pollution reductions are purchased by covering implementation costs and are sold based on the average cost paid, then even in theory a clearinghouse will not achieve the cost-minimizing allocation since the price will not equal the marginal cost. The economic significance of this efficiency loss relative to transaction cost savings is an empirical issue that should be evaluated when considering whether to adopt this structure.

For regulating agencies, a WQ clearinghouse may be attractive since its centralized structure would facilitate monitoring of all trades for compatibility with environmental standards. On the other hand, when an agency takes on the role of a clearinghouse, it also assumes additional risks associated with trading. Agencies may be either reluctant to accept such a role or prohibited from doing so. While an agency's exposure to risk might be reduced by delegating oversight responsibility to a third party as was done in the Rahr case, this might diminish the benefits in terms of monitoring and control.

It must be recognized, however, that a clearinghouse structure is not suitable for all environments. While a clearinghouse avoids the problems of contracting and liability, uniformity of the pollution damages must be satisfied. A clearinghouse is only appropriate if the impacts of pollution discharges are sufficiently uniform in the watershed to allow transferability of rights between a large number of polluters.

Clearinghouses have, therefore, both advantages and disadvantages. This structure reduces transaction costs to participants and can facilitate greater control and monitoring by government oversight agencies. However, these benefits can be accomplished only if the agency is either willing to accept the responsibility associated with being the clearinghouse or willing to delegate that responsibility to a third party. In light of the experience in the Rahr and Tar Pamlico programs, we believe that clearinghouses will find a sustainable niche in WQT.

Sole-Source Offsets

The final structure for WQT programs that has been promoted as market-based actually does not involve trading at all. In this approach, sources are allowed to reduce pollution off site or through nonstandard means in lieu of reductions in their normal effluent stream.

The program developed for the City of Boulder's wastewater treatment plant is representative of this approach. In 1995, the plant needed to renew its NPDES permit. This set in motion a TMDL process that eventually found that great reductions in un-ionized ammonia were necessary, reductions beyond those that could be achieved even by closing the plant. The city addressed the problem through partial improvements in the plant's treatment and also took measures to restore the riparian zone along Boulder Creek in hopes that this would reduce the need to make further capital investments in the future. After accounting for the cost of the stream improvements, it is estimated that the city will save over $1.5 million because of the program (U.S. Environmental Protection Agency, Office of Water, 1998). Although no formal trading took place, landowners contributed to the design of the interventions along the creek so that they received nonmonetary benefits from the improvements (Rudkin). At least one private landowner granted a protective easement to the city for a portion of the project (U.S. Environmental Protection Agency, Office of Water, 1998).

A sole-source offset is analogous to a firm's decision to vertically integrate production processes that could have been provided by outside suppliers. Because these programs do not involve trading, transaction costs might be substantially diminished. Nonetheless, in Boulder's case, negotiating to make improvements on land that was not owned by the city required substantial bargaining (Rudkin). From a regulator's perspective, the attractiveness of sole-source offsets relative to other trading approaches is that the program does not introduce additional parties into the equation, keeping oversight costs to a minimum.

Even if trading is permitted, in some instances sole-source offsets might be the choice of a polluter looking to reduce its net pollution load and should always be an option. However, if only sole-source offsets are allowed, the resulting program may not deliver the efficiency gains that could be achieved through WQT. Not all polluters have opportunities for offsets. Moreover, sole-source offsets do not create incentives for pollution reduction by entities that are in compliance with pollution standards.

While an improvement over strict command-and-control regulations, sole-source offsets are quite limited relative to the other structures discussed. However, we would expect that when opportunities for such offsets arise and other types of trading are either unavailable or not permitted, these will be increasingly sought to reduce the cost of achieving water quality standards.

Conclusions

In this paper, we have argued that pollution markets can be thought of as falling into four main categories. These categories are neither mutually exclusive nor rigidly demarcated. In practice, two or more market structures may function side by side. Nonetheless, this taxonomy does provide a helpful framework in which to analyze the institutions that have evolved to transact pollution rights. A variety of market structures exist and persist in the goods markets, and each is a relatively efficient means of distributing a particular class of goods. Likewise, we expect that there will, in the long run, be a variety of structures for the trading of pollution credits. If complete uniformity is possible, then steps to achieve an exchange type market can be taken. When uniformity cannot be achieved and the agency wishes to take a hands-off approach to trading, then bilateral negotiations will likely be the standard. If the agency is willing to either take on or delegate responsibility for all activity in the market, then cost savings may be achieved by developing or sanctioning a WQT clearinghouse. Finally, if obvious opportunities for firms to reduce pollution off site exist and the agency is averse to overseeing new market participants, then adopting sole-source offsets on a limited basis may make sense.

WQT programs will only succeed if they are able to demonstrate that they are able to achieve environmental goals while yielding significant cost savings. Policy makers would be wise to explicitly consider the market structure that is most suitable given the pollution problem at hand and to the agency's goals and constraints. If properly designed, these programs have the potential to be an important part of water quality control in the nation's changing regulatory environment.

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Endnotes

[1] Although the application of WQT to control groundwater pollution is in many ways similar to surface-water programs that involve nonpoint source pollution, our analysis is most directly applicable to surface-water contamination.

[2] One of the policies considered by McCann and Easter is "Payments from factories and waste treatment plants to farmers who implement BMPS," a program that describes a PS/NPS trading program similar to many in table 1.

[3] Lawsuits have been filed in 36 states and the District of Columbia against state environmental agencies and the EPA for failure to implement TMDL programs as required by law (U.S. Environmental Protection Agency, 1999).

[4] Ribaudo and Horan discuss the possible role that education might have in reducing NPS pollution and conclude that, for the most part, incentives of some form, either in regulations or the kind of market-based approaches discussed here, are needed to achieve water quality objectives.

[5] For example, see 33 U.S.C. §1342(b) allowing for delegation of the NPDES permit program; §1316(c) for new source performance standards; §1344 wetlands dredge and fill permit program; and §1345(c) the sewage sludge permit program.

[6] In general, "transaction costs refers to an actor's opportunity cost of establishing and maintaining internal control of resources" (Eggertsson, p. 8). Most writers identify three main types of these costs: search and information, bargaining and decision, and monitoring and enforcement (Stavins). Dahlman refers to additional types of transaction costs associated with transportation and setup.

[7] For example, in the trading program proposed for the Long Island Sound, each of eight regions has its own abatement coefficient leading to 36 trading ratios (U.S. Environmental Protection Agency, Region 10). These ratios convert differential impacts into a single unit of trade that measures impact on the Sound.

[8] The proposed regulations call for effluent from agricultural sources to be measured by planners certified under the program administered by the United States Department of Agriculture, Natural Resource Conservation Service (§323.3014).

[9] As of February 2000, it was predicted that projects funded by Rahr should lead to pollution offsets more than 30% above those required by the permit (Klang, table 1).

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