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Abstract

Considerable interest has been expressed recently in prospects for water quality trading markets between nutrient sources in the Chesapeake Bay Watershed. Allowing such flexibility in response to the terms of recently announced total maximum daily load (TMDL) restrictions might considerably decrease costs of compliance with the TMDLs. Before an effective and efficient market for offsets can be established, however, certain preconditions must be met. In particular, there must be means by which nutrients can be measured, allowances can be assigned, and limits on nutrient discharges enforced. In this paper we consider some factors that may affect the realization of these preconditions. A recurrent theme is that there are tradeoffs in policy design. A regime that imposes tight restrictions on those who are eligible to trade may also limit the cost savings that might be realized from trading. On the other hand, a regime that maximizes market participation might fail fully to achieve the environmental goals of an offset or trading policy. We conclude with some recommendations for steps that might be taken to initiate limited markets in nutrient and sediment discharges. These markets might then be expanded as experience is gained and methods developed to assure improved market performance.

Key words: water quality trading, offsets, transactions costs, adverse selection, leakage, additionality, monitoring, Chesapeake Bay, nutrients

Subject matter classification: 2) water pollution, 26) land use, 43) non-point source pollution

JEL codes: Q15 - agriculture land use etc.; Q53 - water pollution etc.

Introduction

Water quality trading is a much-discussed policy instrument for reducing pollution in the Chesapeake Bay watershed. Executive Order 13508, issued in May 2009, heightened interest in the topic by directing federal agencies "to protect and restore the health, heritage, natural resources, and social and economic value of the Nation's largest estuarine ecosystem and the natural sustainability of its watershed" (US GPO 2009). In theory, water quality trading achieves environmental benefits at least cost. In practice, decisions made regarding details of implementation rules can affect the magnitude and direction of both benefits and costs. Several jurisdictions, both in the United States and in other countries, have implemented water quality trading programs during the past three decades. Here, we draw from the literature analyzing this experience to highlight tradeoffs in offset market design and offer suggestions regarding potential steps forward for a water quality trading program in the Chesapeake Bay.

Improving water quality in the Chesapeake Bay is a daunting task. The Bay's three principal pollutants, nitrogen,[1] phosphorus[2], and sediments, issue from a variety of sources. Some are "point sources," with identifiable ends-of-pipes or means of conveyance. Examples include municipal and industrial wastewater treatment plants (WWTPs), and municipal separate storm sewer systems (MS4s). Under the Clean Water Act (CWA), the major statute addressing water quality in America's streams, rivers, lakes, and estuaries, point sources are required to obtain and comply with National Pollution Discharge Elimination System (NPDES) permits. Concentrated animal feeding operations (CAFOs) are also point sources. Only CAFOs that discharge into jurisdictional waters, however, require an NPDES permit.

Nonpoint sources, which are not regulated under the CWA, are less easily monitored. About 60 percent of the nutrients and sediment reaching the Bay originate in farms, private septic systems, unregulated stormwater flows, or as airborne emissions (Batiuk 2010).[3] Ideally, nonpoint sources would face discharge limits and be free to determine the most cost effective means of meeting them. In practice, it would be difficult to measure actual discharges from such sources and determine the contribution of each to overall environmental degradation.

If regulating nonpoint source discharges[4] directly is not feasible, regulators can take alternative approaches to reducing pollution. One is to regulate polluting inputs, rather than the pollution itself. Examples include setting animal stocking levels, setting limits on feed imports into a geographic area, and regulating the composition of the animal feed. Compared to regulations controlling point source discharges, input regulations are imprecise. Nutrients fed to an animal,

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[1] More precisely, contamination arises from "reactive" nitrogen, i.e, nitrogen bound in molecules with atoms of other elements, in contrast to the inert form of nitrogen (N_2) comprising about 80 percent of the atmosphere. Since the latter is benign, pollution control strategies often "denitrify" wastes by converting reactive nitrogen to N_2. In this document, any references to "nitrogen" as a pollutant indicate its reactive form.
[2] By phosphorus, we mean bioavailable phosphorus and not forms of phosphorus that are bound to other elements such that they are not available for biological reactions.
[3] This figure is based upon the 2009 Chesapeake Bay model, and excludes contributions from POTWs and forested lands.
[4] Our use of the term "discharge" may differ from the more restrictive definitions given to the term in other contexts. By "discharge" we mean simply "something that is discharged – i. e., emitted or released – from some source". We do not necessarily suppose that a "discharge" is prohibited or regulated by any existing law or rule.

for example, have a different impact on Bay water quality depending on various characteristics such as soil type, location, weather, production practices, and time of year.[5] Another disadvantage to input-based regulation is that it may not be cost effective; it may be cheaper for polluters to reduce the damage to the bay by controlling effluent rather than inputs.

Another alternative is to require abatement actions at the farm or field level designed to reduce nutrient and sediment discharges. Examples include manure and fertilizer handling, crop choice and timing, tillage, and riparian buffers. Like input-based regulations, these Best Management Practices, or BMPs, have the disadvantage of being inexact instruments for discharge control. Topography, weather, soil conditions, and other factors determine their effectiveness. It is impractical for regulators to factor in location and circumstance with enough specific information to determine the precise relationship between BMP use and emissions for every source. Also, BMPs may not be cost effective if one can reduce discharges more cheaply by controlling polluting inputs.

Polluting input reductions and BMPs may either be required or rewarded. Rewards might come in the form of payments for participation in voluntary programs such as the US Department of Agriculture's Conservation Reserve and Environmental Quality Incentive Programs, or as payments for credits sold in environmental markets.[6]

Environmental markets could allow regulated point sources to meet their NPDES permit obligations by purchasing a credit from an unregulated nonpoint source that agrees to reduce polluting inputs or undertake BMPs to reduce loadings by an equivalent amount.[7] The economic argument for such transactions is straightforward, although the analysis becomes more problematic the farther one moves from textbook ideals toward real-world applications. A cap-and-trade program such as the Sulfur Dioxide (Acid Rain) program comes close to the ideal. The "cap" means that there is an overall ceiling on allowed loadings, and that the aggregate numerical quantity is allocated among all dischargers. No participant can increase its loading beyond its allotment without obtaining someone else's discharge permit.

With large numbers of entities participating in a permit market, there should be competition between buyers and sellers, trading institutions should arise, and the ultimate outcome should be cost effective. That is to say, the overall cap on discharges is not violated, and entities that can reduce their discharges at a lower cost sell their rights to those who would face a higher cost of reduction. The overall cap would thus be met at the least total cost. The intuition behind this outcome is simple: if any participant could reduce its loading at lower cost than another, it would have an incentive to sell its permit for at least one unit. Since such trading is possible, all such cost-reducing transactions should be consummated.

[5] Advances in modelling may help reduce the degree of uncertainty for some of these factors.

[6] A disadvantage to the reward approach is that it makes the polluting sector more profitable, which can encourage it to expand over time.

[7] Of course environmental markets can and do also allow regulated point sources to trade with one another. In this paper, however, we focus on the prospect of point-nonpoint source trades, however, as conventional wisdom has it that the latter as a class typically have considerably lower marginal costs of abatement than do the former, and hence the potential gains from trade would be greatest between point and nonpoint sources.

Although a total maximum daily load (TMDL) has been established for the Chesapeake Bay watershed, for the purposes of a water quality trading program it is a quantitative target rather than a strictly enforceable cap. A strict cap would imply that every participant in the trading system would require a permit to discharge. As currently envisaged only point sources covered by NPDES permits have a waste load allocation (WLA) stipulating their allowed disharge. State regulators assign a load allocation (LA) to nonpoint sources as a group, without restricting individual sources. The Clean Water Act, as noted above, lacks a mechanism to ensure that individual nonpoint sources reduce their discharges below a specific level. EPA requires that states provide "reasonable assurance" in their Watershed Implementation Plans that nonpoint sources will collectively meet the LA. Moreover, states may require monitoring of nonpoint sources that participate in a trading program. Individual farms that meet the regulatory definition of a non-point source, however, do not need to acquire a permit to expand their operations or change production practices in a manner that increases discharges to the Bay.

The remainder of this paper discusses policy design issues for an "uncapped" offset market. We begin by describing the theoretical benefits of water trading in the Bay. We then discuss practical implementation decisions policy makers face, identifying implicit tradeoffs between program cost and environmental performance. We conclude with suggestions for productive first steps in developing an effective water quality trading program.

Prospects for water quality trading in the Chesapeake Bay Watershed

The Bay's restoration goals require nitrogen and phosphorus reductions of roughly 15 percent to meet 2017 interim annual goals, and by 24 percent to meet the 2025 objectives (US EPA 2011).Under the CWA, EPA has direct regulatory control over point sources. From 1985 to 2008, WWTPs reduced annual nitrogen loading from direct discharge by 44.1 percent and phosphorus loading by 68.2 percent, despite serving growing populations (US EPA 2009). While further reductions may be possible by upgrading treatment technologies at these facilities, such upgrades will likely prove expensive. Moreover, WWTPs now account for 52 million pounds of nitrogen entering the Bay each year, while an annual reduction in nitrogen loading of 84 million pounds is sought. Thus, even if it were possible to eliminate WWTP loading completely, substantial reductions would be required from other sources to meet the goal.[8]

[8] These figures for reductions from WWTPs may overstate actual reductions since they represent reductions from the effluent streams of direct discharge. Except for the relatively small amount of reactive nitrogen that has been converted to gaseous form, nitrogen and phosphorus remain in the biosolids extracted from such treatment plants. At present much of the residual is applied to agricultural land in the Chesapeake Bay Watershed. If the nutrients are not appropriately managed and the biosolids do not displace fertilizer that would otherwise have been applied, they can contribute to the load of nutrients entering the Bay from the land on which they are applied. Phosphorus in biosolids is relatively non-soluble and hence less likely to move to water unless soils have reached saturation levels. The same is not true for nitrogen which can more readily be converted to a highly water soluble form. Hence, there can be a tradeoff between more effective reductions of nutrients in the direct discharge of WWTPs and the greater volume of nutrients in biosolids disposed of land that can potentially become a non-point source with concomitant lesser regulation under the CWA.

Stormwater runoff from MS4s contributes about 10 percent of annual nitrogen and 31 percent of annual phosphorus loads to the Bay. Increases in developed land have caused runoff loadings to increase over the last 25 years (US EPA 2010), while those from other sources have declined. Options for reducing runoff are limited, however, as stormwater management is among the most expensive ways to reduce nutrient loading in the Bay (Jones et al. 2010).

Due to these limitations on further reductions from WWTPs and MS4s, reductions in agricultural loadings are necessary for meeting the objectives of EO 13508. Agriculture now contributes 46 percent of the yearly nitrogen load to the Bay and 48 percent of the yearly phosphorus load (US EPA 2010). Agriculture may present more cost-effective alternatives for nutrient loading reductions than do WWTPs and MS4s. The World Resources Institute estimates that the cost of reducing a pound of nitrogen from agriculture is one-tenth of the cost of eliminating the same pound from a WWTP and one-fortieth the cost of eliminating the pound from an MS4 (Jones et al. 2010).

With the exception of some CAFOs, the CWA does not give EPA authority to regulate most agricultural operations. In the absence of authority to impose mandatory reductions or to force agricultural sources to pay for the right to pollute, the only option left is to pay them to reduce their pollution. The question then becomes one of financing. One alternative would be to use state or federal tax revenues to pay nonpoint sources to undertake reductions. Such an approach would be similar to existing USDA and state programs to pay for land set asides and adoption of BMPs. Another option is to place stricter limits on WWTPs and MS4s, but to allow those sources to meet their obligations by paying agricultural sources to adopt BMPs, i.e., encourage water quality trading.

In theory, a water-quality trading program has the advantage of cost effectiveness; the environmental objective is met and competition among buyers and sellers ensures that those sources that can reduce their emissions at the lowest cost do so. In addition, an offset program creates incentives for technological innovation to lower the cost of reducing nutrient loading. In contrast, the standard rule-making process can be slow and conflict-ridden as regulated entities try to affect regulatory design. A trading system also requires less knowledge by the regulator of abatement costs to be effective.[9]

The academic economic literature has long noted the advantages of market-based incentives such as fees, taxes, and pollution trading markets (Pigou 1920; Crocker 1966; Dales 1968; Montgomery 1972; Kneese and Schultz 1975). However, it has also noted the limitations of trading systems and the differences between market-based incentives in theory and in practice (see, e.g., Hahn 1989). In particular, there is a voluminous literature identifying potential problems in water-quality markets (e.g., Woodward 2002; King and Kuch 2003; Abdalla et al. 2007; Breetz and Fisher-Vanden 2007; Morgan and Wolverton 2008; Smith et al., 2010; Shabman and Stevenson 2011; Horan and Shortle 2011).

Based on observations of existing water quality trading programs, many researchers have come to pessimistic conclusions. Abdalla et al. (2007) find "the physical and regulatory context for

[9] For more details regarding the theoretical advantages of market based mechanisms such as pollution trading, see Freeman and Kolstad (2007).

agricultural NPS pollution does not match the conditions that economic theory suggests are needed for widespread trading to occur," while Woodward (2002) concludes that "programs to date have not generated a convincing record. Given the investment of agency time required to set up and monitor water quality trading programs, there is certainly reason to wonder if this regulatory approach is worth the effort." Horan and Shortle (2011) advise that "it is clearly incorrect to assume that the gains promised by idealized textbook models will simply materialize in similarly constructed water quality trading markets: if you build it, they may not come."

This pessimism generally stems from the cost of trades. It takes a considerable effort to develop and maintain the institutions required to operate an efficient and verifiable market. A trading program in environmental performance, like any market, needs a number of features in order to function smoothly. These features include:

- enough traders to prevent any individual from exercising monopolistic power;
- substantial differences in abatement costs among potential traders;
- ways for prospective traders to identify each other;
- systems for monitoring, recording, and certifying trades; and
- a legal framework to enforce contracts.

Establishing such features can be costly. Costs in these categories are collectively referred to as "transaction costs," and if they are too high, they can erode potential efficiency gains from trading, or even make trading infeasible.

For market efficiency to be realized, trades must occur. Due to high transaction costs, water quality trading markets have had low trading volumes between point and non-point sources. Ribaudo and Gottlieb (2011) find that no trades at all had occurred in 11 of 15 water quality markets allowing nonpoint source trades, and only two markets had more than four trades. Morgan and Wolverton (2008) report similar results.

There is a tension between reducing transaction costs and maintaining the environmental integrity of a trading program. In the next section we highlight several policy decisions necessary for implementing a trading program, discussing implicit tradeoffs between program cost and environmental benefits.

Tradeoffs in policy design

There is not a simple policy prescription that solves all potential issues with a water quality trading program. Rather, practical policy design involves balancing a program's effectiveness at reducing costs with its effectiveness at improving water quality. Here we highlight the tradeoffs involved in the key policy decisions.

Limits on eligible suppliers of credits

The larger the set of sources eligible to sell offset credits, the greater the possibility for efficiency-improving trades, and the lower the expected cost of purchasing a credit. The less stringent the eligibility requirements, however, the greater is the likelihood that some offsets are not true reductions in nutrient loadings. Leakage and additionality are two eligibility concerns that can result in trades that actually increase net discharges.

Leakage. Leakage (the term "slippage" is also used to describe the same phenomenon, particularly in literature on agricultural land retirement programs) refers to the potential for conservation programs to give farmers an unintended incentive to convert land to agricultural use or to increase the intensity of crop or livestock production on existing agricultural land. Leakage typically occurs due to indirect price effects. In the case of the USDA Conservation Reserve Program (CRP), for example, researchers have found evidence that paying farmers to idle cultivated land causes an increase in commodity prices that makes it profitable to bring new land into production (Wu 2000).[10]

Due to the relatively small size of crop production in the Chesapeake Bay watershed, the effects of an offset program on crop commodity prices is likely to be limited. Given the vertical integration of the livestock industry, however, and the regional demand at the processor level for intermediate livestock products, an offset program could generate significant leakage. If a farmer were to reduce livestock production as a result of selling a credit, the integrator may respond by providing additional animals to another farm.[11]

Another problem can arise from the price of the offsets themselves. Farmers will only sell offsets if it is profitable to do so. Therefore, the existence of an offset market may increase the profitability of cropland relative to other uses, such as woodland. Absent eligibility requirements on previous land use, an offset program could induce landowners who would have earned slightly less profit from other land uses to convert land to crop production and sell offsets – with the potential net effect of increasing discharges. As noted by the USDA National Resource Conservation Service, nationwide "land use is …. surprisingly dynamic, with …. constant shifts … among cropland, pasture, range, and forest land" (US NRCS 1997). Thus, this type of leakage is theoretically possible, although determining its potential magnitude would require further research.

Such policy-induced land use changes have been a concern in other contexts as evidenced by the fact that USDA agricultural programs often contain provisions to avoid land use changes arising from the program payments themselves. Commodity program payments, for example, are often made on the basis of historical "base acres." These provisions reduce the incentive to convert land to program crops in order to obtain more payments. Similarly, CRP provisions limit eligibility on the basis of previous land use to reduce incentives to convert forest or pasture to cropland, and then back to CRP.

Leakage presents a problem only if there is not a strict cap on all sources of discharges to the Bay. With a cap in place, land use changes would not affect overall discharges since these would be limited by the total availability of permits. An alternative to a cap would be to require all new

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[10] The magnitude of leakage in the CRP is controversial; see Roberts and Bucholtz (2005, 2006) and Wu (2005).

[11] Most livestock production in the Chesapeake Bay watershed follows a model whereby integrators provide young animals under contract to farmers who feed and care for them, returning them to the integrator after a specified amount of time. For details of these arrangements in the poultry sector see MacDonald (2008).

or expanding sources (including nonpoint sources) to obtain offsets. This requirement would eliminate the incentive to convert land in order to sell offsets, but may not be politically feasible.

An alternative approach, at least for crop agriculture, would be to base eligibility on previous land use. While reducing the incentive to convert land, this approach has the disadvantage of eliminating potentially beneficial trades. Landowners convert woodland or pasture to cropland for many reasons. If farmers decide to clear woodland or convert pasture due to an increase in commodity prices, for example, it may be efficient and environmentally sound to pay them to undertake BMPs on this newly cultivated land.

Another approach would be to recognize that a certain percentage of gains from nonpoint source offsets will be lost due to leakage, and to incorporate this percent into a trading ratio between point and nonpoint sources. The downside to this approach is that it effectively makes it more expensive to buy offsets from all nonpoint sources, thus discouraging some potentially efficient trades.

Additionality. A strict cap is also known as an absolute baseline; there is one limit set on the total amount of permissible emissions, from which all actual emissions are debited. In contrast, an offset program typically involves relative baselines; emissions from each source are debited from hypothetical pollution levels that would have occurred at that source. Relative baselines are costly to implement since counterfactual emissions must be evaluated before each trade (Jepma 2003; Rentz 1998).

Relative baselines raise the question of "additionality." Are claimed reductions offered as offsets really additional to what the source would have been doing in the absence of an offset program? For example, landowners may already be engaged in offsetting behavior for a number of reasons (they find it profitable, they are paid from some other source such as state or USDA programs, they choose to be good stewards, etc.). Suppose that a WWTP purchases offset credits from such a landowner instead of reducing its emissions. If the offsets are not additional, then emissions are exactly the same as what they would have been without the trade. Both the WWTP and the offset seller behave exactly as they would have otherwise. While money may change hands, it is a mere "paper trade"; loading is not reduced.

"Adverse selection" arises if those sources most likely to sell offset credits are those that would have been most likely to undertake the action in the absence of a program. Adverse selection can exacerbate the additionality problem. Consider, for example, a policy of rewarding farmers who maintain riparian buffer zones near streams on their property. For many farmers establishing a riparian buffer is costly due to foregone earnings from stocking more animals or planting crops closer to the water. For others, land near a stream might not have been suitable for grazing or cultivation anyway. As it costs nothing for such farmers to maintain natural vegetation in such areas, they will do so. If participation in the program is voluntary it is precisely those farmers who would have undertaken best management practices anyway who have the greatest incentive to sell offsets.

As with leakage, additionality is a theoretical issue whose practical relevance remains an open question. Further research on this topic in the context of the Chesapeake Bay would be useful. The following considerations suggest that it may be imprudent to dismiss this issue:

- Diversity with respect to farm landforms, size, crops and/or animals raised, ownership, and other factors likely imply a wide range of BMP costs, leading to potential adverse selection problems.
- The Acid Rain program was not always a pure cap and trade policy. Initially some unregulated firms were allowed to "opt-in" to the program. Evidence suggests that those who did so were the emitters whose allotted credits exceeded what they would have emitted anyway (Montero 1999). Similarly, it has been argued that the possibility of receiving payments under climate change programs for industrial plant closures encouraged China to "reduce" emissions from plants that otherwise would not have been economically viable (Wara 2006).
- Results from EPA's evaluation of the experimental Rural Clean Water Program (Gale et al. 1993) suggest that farmers participate in programs only if they believe the programs provide a material benefit to their operations.[12] They also only adopt and continue those practices that they believe to be profitable. Hence, adverse selection may be a problem not only with regard to which farmers participate, but also with regard to what practices (among a suite of potential practices) are implemented on those farms that do participate.

The ideal way to eliminate additionality problems is to have a strict cap in place. If such a cap is not politically or legally feasible, there are second-best approaches. Similar to leakage, one approach is to recognize that a certain percentage of offsets are not likely to be truly additional and to increase the trading ratio (or, equivalently, set a side a proportion of traded land into a reserve) to account for this. As before, this approach has the disadvantage of treating all nonpoint sources equally, thus discouraging trading with those sources for which additionality is not an issue. Nor is determining the trading ratio a trivial problem (see Montero 2000).

Another potential means of reducing the additionality problem is to require that sellers undertake a minimum amount of BMPs before they are allowed to sell additional offsets. This requirement could help to ensure that offsets sold are truly additional. To offer credits in Virginia, for example, farmers are required to implement soil conservation and nutrient management plans, plant cover crops on cropland, exclude livestock from streams, and install riparian buffers *before* selling credits for any further reductions in discharges. Pennsylvania and Maryland have similar requirements. Such requirements come at a cost, however. The minimum requirements exacerbate the adverse selection problem by making it more costly for some potential sellers to participate in the trading market, and they may decide to opt out. The sellers for whom reductions would have been costly, and, for that reason truly additional have the most incentive to opt out.

The difficulty in determining *a priori* the significance of leakage and additionality on pollution reduction from non-point sources of pollution argues for the adoption of Adaptive Management

[12] This program included projects located in the Chesapeake Bay watershed where the major pollutants of concern were nutrients.

in any trading program. At the core of Adaptive Management is an effective tracking or monitoring system for activities that potentially contribute to nutrient losses to the environment (NRC 2011). Although EPA and the states do have some Bay monitoring systems in place, they would need to be improved in order to identify and measure the consequences of leakage and additionality from trading.

Multiple payments for one offset

A discharge-trading system in the Chesapeake Bay would not take place in an environmental policy vacuum. There are other programs currently in place (e.g., the Conservation Reserve Program) that pay non-point sources for actions that would have the effect of improving Bay quality. In addition, there are proposals for programs providing payments for carbon sequestration, wildlife habitat, and other ecosystem services. In this context, the question arises as to what extent a nonpoint source should be permitted to sell a discharge offset credit for an activity that is remunerated from another program.

The environmental effect of allowing multiple payments depends on whether the additional impact of the offset payment induces a nonpoint source to change its behavior. Suppose that the amount of money received from other sources were sufficient to induce a nonpoint source to undertake a BMP. If a point source then purchases a credit based on that BMP, total emissions to the Bay would rise relative to the case in which the point source were not permitted to purchase the credit.

If, however, the amount of money received from other sources is not sufficient to induce the nonpoint source to undertake the BMP without the additional payment for the offset credit, then the discharge reduction is additional and results in real environmental improvement to compensate for the increased emissions of the purchasing point source. A relatively lax policy decision regarding payments from multiple sources is likely to result in less environmental improvement, while a strict policy will result in higher costs since some potentially efficient trades will be prohibited. The current diversity of state approaches to trading could provide a basis for researching the importance of these tradeoffs.

Accuracy of geographic trading ratios

The premise motivating trading programs is that dischargers with high abatement costs can trade obligations with sources with lower costs. The larger the pool of potential trading partners, the greater the expected differences in costs among them, and the greater the cost savings from trading. However, the greater the distance between would-be trading partners, the more likely that the discharges they trade would result in different damage.

For the purposes of the TMDL, the Chesapeake Bay is divided into 92 separate tidal segments. Under currently envisaged rules and policies, trades cannot result in violation of a TMDL in *any* segment. At present, 89 of the 92 segments are impaired (FLC 2010). This constraint is likely to limit the scope of potential trades, and with it, possible cost savings.

The theoretical solution to the problem of differential impacts arising from discharges from different locations is to define a system of impact-based trading ratios. While the underpinnings of market design with multiple geographical restrictions were developed by Montgomery (1972), it is so complex that such a design has never been implemented in practice (Freeman and Kolstad 2007). The Long Island Sound and Lower Boise River water quality trading programs do specify a number of different trading ratios between different dischargers depending on location and other factors (Morgan and Wolverton 2008); however, they do not use the theoretically appropriate rates. The Chesapeake Bay Watershed comprises 64,000 square miles, some four times greater than that of the Long Island Sound and 16 times greater than that of the Boise River. Complications of determining appropriate trading ratios are thus likely to be correspondingly greater.

The problem of devising accurate trading ratios can be exacerbated by the incentives of the regulators themselves. The pressure by participants and program goals can make administrators inclined to use simple uniform trading ratios to facilitate trades at the expense of quality. Salzman and Ruhl (2007) document this problem in the context of the wetlands banking program. There, high quality wetlands were often replaced by lower quality ones on an even acre-for-acre basis.

If calculating the ideal trading ratio is infeasible, policy-makers are faced with a decision regarding how many ratios to use and how much of a margin of error to incorporate. The cost of using the wrong trading ratios is that trading may reduce environmental quality if the damage from increased discharges at one location is greater than the benefits from the offsetting reductions at another. Attempting to fine-tune ratios, however, may eliminate many potential cost-saving trades. Multiple trading ratios would entail a potentially costly and cumbersome certification process prior to each trade, leading to increased uncertainty among traders and increased transaction costs. Nevertheless, the certification process is necessary for the integrity of the trading program.

Requiring relatively large reductions from nonpoint sources in exchange for a unit of increased emissions from a point source helps to ensure that the trade does not result in net environmental damage. Stringent ratios increase the cost of the program, however, by discouraging some potentially efficient trades.

Monitoring and Liability

Monitoring discharges and credit-generating activity is an essential component of a trading program due to the possibility of a credit seller not complying with contract terms. In conventional markets the consumer has an obvious stake in the quality of the traded good, thus giving sellers a strong incentive to develop a reputation for quality, even in the absence of third party monitoring. In environmental markets, this incentive is notably absent. Buyers only care about quality inasmuch as they fear the consequences of a government audit. If the seller of a credit did not meet the terms of its contract and did not reduce its own contribution to loading by the amount it had promised, the buyer of the credit might then find itself liable for penalities.

Monitoring systems are in place for WWTPs. With the possible exception of a few easily observed practices such as establishing riparian buffers, however, it is notoriously difficult to verify BMPs for non-point sources. A recent study conducted under the Conservation Effects Assessment Project that examined farmer compliance with nutrient management plans, for example, found that about 80 percent of farmers did not implement the practices that were required or were not aware that they were not in compliance with the conditions of the plan (Osmond 2010). In the case of the wetlands banking program, the benefits were severely limited by lack of effective enforcement (Salzman and Ruhl 2007; Shabman 2004).

An effective trading system must be able to punish participants who are not in compliance. A practical issue concerns whom to punish if a contracted offset is not delivered. It is useful to consider why a contract may not be fulfilled. If the cause is pure *force majeure*, then the assignment of liability is not important as long as someone is obliged to provide the missing offsets. In this case, requiring a trading ratio greater than one with the extra offset going into a state-held reserve may be a solution.[13]

If the offset provider can undertake some not-easily-monitored effort to reduce the probability that an offset fails, then assignation of liability is important. Assigning liability to the purchaser may create conditions of moral hazard since it does not give the seller incentive to undertake such preventative action, whereas assigning it to the provider does.

With respect to the last point, purchasers could presumably initiate civil cases against offset credit providers who did not fulfill the terms of their agreements. The uncertainties inherent in such litigation result in less of an incentive to undertake preventative action than direct liability for the seller since courts would first need to find the purchaser in violation, the purchaser would need to decide that it was worthwhile to pursue the case in civil court, and the court would need to rule against the seller.

In principle, concern about one's reputation could induce offset credit providers to meet the terms of their agreements. It is not clear, however, that landowners who had defaulted on earlier agreements could be effectively "blacklisted" or that contracting opportunities would arise often enough to make this a compelling consideration.

A key policy decision is thus where to assign liability if offsetting discharge reductions fail to take place. In most established U.S. water quality trading programs, point sources are liable for non-compliance in all trades with non-point sources.[14] Currently, if a nonpoint source does not fulfill its reduction obligation, EPA only has authority to undertake enforcement actions against the point source NPDES permit holder who purchased the credit. This potential liability may make point sources reluctant to enter into an agreement with a nonpoint source (see, e.g., Ribaudo and Gottlieb 2011), thereby reducing the scope for potentially efficient trades and increasing the cost of the program.

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[13] Pennsylvania sets aside 10 percent of credits into a reserve pool to cover possible failure of offsetting activity (Selman, et al. 2009).

[14] Morgan and Wolverton (2008) provide examples of several liability arrangements in water quality trading programs.

Placing Clean Water Act liability on credit sellers could reduce transaction costs associated with ensuring compliance, thus encouraging more trades. In practice, such an approach could be problematic if sellers are sufficiently small that the expected punishment is less than the cost of ensuring that the offset is successful. An alternative approach would be to set up reserve accounts so that if some promised discharge reductions do not occur additional credits may be drawn upon (see, e.g., Morgan and Wolverton 2008), although this strategy would not solve moral hazard issues. Liability could also be shifted to entities that aggregate offsets from many different suppliers.[15] Such aggregators would likely have a stronger concern for reputation than individual offset providers, and have greater assets to cover potential penalties. These features may give them an increased incentive to monitor the behavior of the suppliers.

Command and control requirements

NPDES-permitted point sources must meet their technology-based emission limits and cannot purchase credits to exceed them. Although EPA currently recognizes the possibility that point sources can purchase credits to meet water quality based effluent limits, such technological restrictions potentially reduce the cost effectiveness of a trading program. They do, however, provide a margin of safety regarding environmental benefits since the ultimate performance and reliability of nonpoint source offsets is not yet established. The crucial question for policy makers is how to balance the cost of technological requirements (including mandatory BMPs for nonpoint sources) with their benefits in terms of relatively assured environmental improvements.

Population and economic growth

One of the great challenges in meeting the objectives of EO 13508 is that nutrient loadings must be reduced against a backdrop of increasing population and economic activity in the watershed. One means of addressing this issue is to require that all new and expanding sources of discharges offset their emissions with reductions elsewhere.

Fundamental to the success of such an approach is the definition of “new and expanding.” Due to population growth, biofuel policy, and increased incomes in countries such as China and India, demand for agricultural outputs produced in the Bay watershed are likely to increase over time. If the definition of new and expanding sources who require offsets does not include crop and livestock producers, then even the reductions from a perfectly functioning offset program for WWTPs and MS4s may be insufficient to improve water quality in the face of increased emissions from these other sources.

Potential Steps Forward

In this section we discuss some alternatives to the point-nonpoint source water quality programs currently in development. Based on the previous section, it is clear that many potential problems with offset trading stem from the lack of a strictly enforceable watershed-wide limit on

[15] Since the CWA restricts EPA enforcement authority to point sources (i.e., the credit purchasers), such shifts in liability would need to be enforced by States under their laws.

loadings from all sources. The theoretical benefits of a cap-and-trade program (attaining an environmental goal at the least cost) crucially depend upon the existence of the “cap.” The ideal option would therefore be to require all sources (new and existing, point and nonpoint) that may potentially participate in a trading system to have a permit before discharging.

Recognizing that this policy may not be politically or technically feasible, however, we identify some alternatives that may increase the likelihood that a trading program achieves net environmental benefits. These options are by no means definitive solutions; some may require significant regulatory or even statutory changes to be feasible.[16] Rather, they are intended to stimulate further discussion regarding possible market-based mechanisms to reduce discharges to the Bay that are less susceptible to the policy dilemmas identified in the previous section.

Begin with expanded point source trading

Many potential problems of water quality trading arise from the inclusion of non-point sources in the trading system. Many of the benefits of trading could be captured while avoiding the problems mentioned above if trading occurs only between point sources. Since a cap on WWTPs and MS4s alone would be insufficient to meet water quality goals, the universe of point sources eligible for trading could be expanded to include CAFOs.[17] Such a program would have the following potential advantages.

- Precedent. As mentioned above, most of the successful water quality trading programs only allowed trades between point sources.
- Scope. Just under 40 percent of the Bay’s nutrient loading comes from WWTP and CAFO emissions. Thus a cap over these two sectors could go a long way to reaching the programs overall emission goals.
- Cost effectiveness. Since many CAFOs currently face comparatively few constraints on discharges, there is likely to be considerable scope for relatively low-cost discharge reductions, thereby creating the opportunity for large gains from trade with WWTPs.
- Additionality. Since point sources fall under EPA’s statutory authority under the Clean Water Act, in principle it could enforce a cap on the entire trading sector, thus eliminating many environmental concerns implied by additionality.[18]
- Reduced leakage. Price-induced leakage within the two sectors would not be a problem due to the cap. Moreover, such a system would likely lead to a reduction (or slower growth) in animal production, thus reducing pressure on local feed prices and reducing farmer incentives to apply fertilizer or cultivate new crop land.

[16] Treatment of the legal requirements is beyond the scope of this paper. None of this discussion conveys an EPA position regarding interpretation or implementation of any of the relevant rules or statutes.

[17] Existing CAFO rules may need to be modified to allow trading.

[18] Many non-trivial legal issues would need to be resolved to expand EPA regulation, i.e., require a greater number of CAFOs to have permits, and thus enforcement authority over CAFOs.

- Feasible monitoring. Monitoring CAFOs for compliance is likely to be significantly less expensive and easier than monitoring of non-point sources.

Although such a point-source trading program may realize significant reductions, it may not be sufficient to attain the desired reductions. It could therefore be complemented by an expansion of programs such as EQIP, WRP, or the CRP to pay for the production of environmental amenities that serve to reduce loadings from nonpoint source agriculture. Such programs can reduce the overall watershed-scale nutrient burden without running the risk that increased loadings from a particular point source are not being offset by non-additional reductions.

Finally, the experience gained from point-source-to-point-source trading can inform broader trading program. It may be relatively easy to resolve logistical issues such as determining geographic trading ratios in point-source to point-source trades. The lessons learned in the process of bringing the limited program to success could be applied to an eventual expansion to make non-point sources eligible for participation. Beginning with a point-source only trading program would also provide time to conduct further research regarding the practical importance of leakage and additionality in the non-point source sector.

Focus on Integrators

Many farmers in the Chesapeake Bay watershed produce for a few “integrators” – large companies that purchase farmers’ outputs while providing them with inputs. If it is infeasible to regulate or otherwise involve the small farmers in offset markets, it may be feasible to address the integrators.

Reduced to its biochemical essence, the problem with nutrient pollution in the Chesapeake Bay watershed is the imbalance between in and out-flows of reactive nitrogen and bioavailable phosphorus—that is, more nutrients flow into the confines of the Bay watershed than are removed through agricultural products exported out of the Bay watershed, immobilized in new soil, or converted through denitrification. With the exception of atmospheric deposition, the nutrients originate as protein content in livestock feed, as chemical fertilizer, and biosolids (sewage sludge) imported from areas outside the Chesapeake Bay watershed (NRC 2011). The soils and the plants and animals within the watershed can accommodate only so much nitrogen and phosphorus based upon the climate, exports of food and feed out of the basin or watershed, or denitrifying capacity of the land. The excess represents the nutrient imbalance that, depending upon the severity of storm events, becomes the nutrient load to the Bay. Moreover some nutrients embodied in crop or livestock produced in the Chesapeake Bay watershed are recycled through sewage sludge that is returned to the land. This recycling adds to the imbalance resulting from imported nutrients.

Since grain brokers or livestock integrators in large measure control the flow of feed into the Bay watershed, they control a major control point for nutrients. By reducing feed imports, they thereby also reduce total animal production – and wastes. Moreover, there are relatively few grain brokers or livestock integrators, making tracking of nitrogen and phosphorus material flows easier.

Thus, a regulatory option could be to establish a “deposit-refund” system. Whenever any nutrients – feed or fertilizer – are introduced into the watershed, the entity introducing them, in this case the integrators, would need to pay a deposit. A portion of the deposit would be refunded based on the amount of nutrients that are not released to the environment. The size of the deposit could be reduced if less fertilizer were used, feed reformulated to reduce nitrogen and phosphorus content, or actions undertaken on the land to increase net denitrification or reduction of bioavailable phosphorus, such as wetland rehabilitation or restoration. The size of the refund could also be increased if more nutrients in animal waste were processed to a chemical form that can be shipped out of the watershed as fertilizer.

Alternatively, rather than charging for net introductions of nutrients, integrators could be assigned numerical limits on the net amounts of nutrients they introduce. Such allocations would form the basis of an environmental market in net nutrients in which integrators might trade with one another, or with other polluters in the watershed.

While such a system might be more administratively tractable than one dealing directly with myriad farmers, it does present some challenges. One is that the approach we have described begs the question of leakage. The advantage of imposing the burden of compliance on the small number of large integrators is that it would be easier to keep track of what they are doing than of the farmers with whom the contract. At present integrators contract with farmers because there are cost advantages to them of doing so. If more independent farmers could avoid regulatory scrutiny, those cost advantages might be eroded, if not eliminated. It would be important to verify that this sort of atomization of the industry would not occur if a program of the type we have suggested were implemented.

Another related consideration is that, while regulators might shift the technical burden of compliance to large integrators, a large part of the program would still rely on verifying the performance of individual farms. It would still be important to monitor farm-level performance and enforce compliance.

Conclusion

There is a widespread consensus regarding two facts: the water quality of Chesapeake Bay is seriously degraded, and reductions in agricultural discharges are essential for attaining adequate improvement. The difficult question is how to reduce these discharges short of direct regulation of agriculture.

One approach would be to severely curtail allowances on current NPDES holders, especially WWTPs. Although it would be unrealistic for WWTPs to attain these reductions at a reasonable cost, in lieu of reducing their own discharges they could be offered the opportunity to pay agricultural sources to undertake relatively inexpensive discharge-reducing BMPs.

In this paper we examine the key policy decisions required to implement such an offset trading program in practice. We find that many face a dilemma. On the one hand, program rules can be specified in such a way that facilitates trade. The danger with this approach is that trades may result in little, if any environmental improvement. At the extreme, this path could result in a massive transfer of resources from municipalities to agricultural producers while water quality in the Bay continues to deteriorate.

On the other hand, program rules can be specified in a way that minimizes the risk of non-environmentally beneficial trades. The danger with this approach is that the cost of safeguards and administrative hurdles is so great that few if any trades occur. At the extreme, this path could result in a massive investment by municipalities in further treatment. Due to the relative impact of municipalities in total discharges, this treatment alone is likely to be insufficient to attain water quality goals in the Bay.

Navigating policy between these two dangers is not a simple task. Nonetheless, there is a common element at the root of most of the difficulties. The fundamental issue with the offset program is that, unlike successful policies such as the Acid Rain trading program, there is no strictly enforceable cap. We offer some tentative examples of how an offset program might be modified to incorporate a cap.[19] Programs that focus on trading between WWTPs and CAFOs may be promising, as well as those that focus on the possible role of integrators in the management of nutrients and animal wastes.

References

Abdalla, C., Borisova, T., Parker, D., Saacke Blunk, K. (2007) Water Quality Credit Trading and Agriculture: Recognizing the Challenges and Policy Issues Ahead. Choices 22 (2):117-124.

Batuik, R. (2010) Introduction to TMDLs with Examples from the Chesapeake Bay http://www.epa.gov/ocem/frrcc/pdf/2010_rich_batiuk_introduction_to_tmdls.pdf).

Breetz, H.L., Fisher-Vanden, K., Jacobs, H., Schary, C. (2005) Trust and Communication: Mechanisms for Increasing Farmers' Participation in Water Quality Trading. Land Economics 81(2): 170-190.

Crocker, T.D. (1966) The Structuring of Atmospheric Pollution Control Systems. In The Economics of Air Pollution Wolozin, H. ed. New York: W.W. Norton.

Dales, J. H. (1968) Pollution, Property and Prices. Toronto: University Press.

Federal Leadership Committee (FLC) (2010) Strategy for protecting and restoring the Chesapeake Bay watershed. http://executiveorder.chesapeakebay.net/file.axd?file=2010%2f5%2fChesapeake+EO+Strategy%20.pdf.

Freeman, J., Kolstad, C.D. (2007) Prescriptive environmental regulations versus market-based incentives. In Moving to Markets in Environmental Regulation: Lessons from twenty years of experience, Freeman, J., Kolstad C.D. eds. New York: Oxford University Press. Ch. 2.

Gale, J.A., Line, D.E., Osmond, D.L., Coffey, S.W., Spooner, J., Arnold, J.A., Hoban, T.J., Wimberly, R.C. (1993) Evaluation of the Experimental Rural Clean Water Program. National Water Quality Evaluation Project, NCSU Water Quality Group, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, NC. EPA-841-R-93-005.

[19] These ideas are discussion points rather than pronouncements on what is permissible under current statutory authority.

Hahn, R. (1989) Economic prescriptions for environmental problems: How the patient followed the doctor's orders. *Journal of Economic Perspectives* 3(2): 95-114.
Horan, R.D., Shortle, J.S. (2011) Economic and Ecological Rules for Water Quality Trading. Journal of the American Water Resources Association 47(1): 59-79.
Jepma, C.J. (2003) The EU emissions trading scheme (ETS): how linked to JI/CDM?. *Climate Policy* 3, 89-94.3.
Jones, C., Branosky, E., Selman, M., Perez, M. (2010) How nutrient trading could help restore the Chesapeake Bay. World Resources Institute Working Paper.
King, D.M., Kuch P.J. (2003) Will nutrient credit trading ever work? An assessment of supply and demand problems and institutional obstacles. Environmental Law Reporter News and Analysis 33(5): 10352-10368.
Kneese, A., Schultze, C. (1975) Pollution, Prices, and Public Policy. Washington, DC: The Brookings Institution.
MacDonald, J. (2008) The Economic Organization of U.S. Broiler Production. Economic Information Bulletin 38. Washington, DC: USDA Economic Research Service.
Montero, J.-P. (1999) Voluntary compliance with market-based environmental policy: Evidence from the U.S. acid rain program. *Journal of Political Economy* 107(5): 998-1033.
Montero, J.-P. (2000) Optimal design of a phase-in emissions trading program. Journal of Public Economics 75: 273-291.
Montgomery, W.D. (1972) Markets in Licenses and Efficient Pollution Control Programs. Journal of Economic Theory 5: 395-418.
Morgan, C., Wolverton A. (2008) Water quality trading in the United States: trading programs and one-time offset agreements. Water Policy 10(1): 73-93.
National Research Council (2011) Achieving Nutrient and Sediment Reduction Goals in the Chesapeake Bay: An Evaluation of Program Strategies and Implementation National Academies Press, Wsahington, DC.
Osmand, D.L. (2010) USDA water quality projects and the National Institute of Food and Agriculture Conservation Effects Assessment Project watershed studies. Journal of Soil and Water Conservation 65(6): 142A-146A.
Pigou, A.C. (1920) The Economics of Welfare. London: Macmillan.
Rentz, H. (1998) Joint implementation and the question of 'additionality': a proposal for a pragmatic approach to identify possible joint implementation projects. *Energy Policy* 26: 275-279.
Ribaudo, M.O., Gottlieb, J. (2011) Point-nonpoint trading: Can it work? *Journal of the American Water Resources Association* 47(1): 5 - 14.
Roberts, M.J., Bucholtz, S. (2005) Slippage in the Conservation Reserve Program or spurious correlation? A comment. American Journal of Agricultural Economics 87(1): 244-250.
Roberts, M.J., Bucholtz, S. (2006) Slippage in the Conservation Reserve Program or spurious correlation? A rejoinder. American Journal of Agricultural Economics 88(2): 512-514.
Salzman, J., Ruhl, J.B. (2007) "No net loss": Instrument choice in wetlands protection. In Moving to Markets in Environmental Regulation: Lessons from twenty years of experience, Freeman, J., Kolstad C.D. eds. New York: Oxford University Press. Ch. 12.
Selman, M., Greenhalgh, S., Branosky E., Jones, CY., Guiling, J. (2009)"Water Quality Trading Programs: An International Overview" *WRI Issue Brief* No. 1: 1-16.
Shabman, L. (2004) Compensating for the impacts of wetlands fill: The U.S. experience with credit sales. In Tradeable Permits: Policy evaluation, design and reform, Tietenberg, T.,

Johnstone, N. eds. Paris: Organisation for Economic Cooperation and Development. Ch.7.

Shabman, L., Stephenson, K. (2011) Rhetoric and reality of water-quality trading and potential for market-like reform. *Journal of the American Water Resources Association* 47(1): 15-28.

Smith, C.M., Peterson, J.M., Leatherman, J.C. (2010) Simulation of Factors Impeding Water Quality Trading Market Performance. Paper presented at Agricultural and Applied Economics Association Meeting.

US Environmental Protection Agency (2009). The next generation of tools and actions to restore water quality in the Chesapeake Bay: A revised report fulfilling section 202a of Executive Order 13508. http://executiveorder.chesapeakebay.net/file.axd?file=2009%2f11%2f202a+Water+Quality+Report.pdf

US Environmental Protection Agency (2011) Chesapeake Bay Program. http://stat.chesapeakebay.net/?q=node/59&quicktabs_3=2&quicktabs_10=2.

US Government Printing Office (GPO) (2009) Executive Order 13508: Chesapeake Bay protection and restoration. http://www.gpoaccess.gov/presdocs/2009/DCPD-200900352.pdf.

US Natural Resource Conservation Service (NRCS) (2010) 1997 National Resources Inventory: Highlights. http://www.nrcs.usda.gov/technical/NRI/pubs/97highlights.html.

Wara, M. (2006) Measuring the clean development mechanism's performance and potential. *UCLA Law Review* 55: 1759-1803.

Woodward, R. T. (2003) Lessons about effluent trading from a single trade. Review of Agricultural Economics 25(1): 235-245.

Wu, J. (2000) Slippage effects of the conservation reserve program. *American Journal of Agricultural Economics* 82(4): 979-992.

Wu, J. (2005) Slippage effects of the conservation reserve program: Reply *American Journal of Agricultural Economics* 87(1): 251-254.