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Submitted Article

Encouraging Reductions in Nonpoint Source Pollution through Point-nonpoint Trading: The Roles of Baseline Choice and Practice Subsidies

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Abstract *Water quality regulations in the United States apply almost exclusively to point sources. In impaired watersheds where both point and nonpoint sources contribute to pollution, the U.S. Environmental Protection Agency (EPA) is encouraging the use of point-nonpoint trading to reduce the cost of point sources to meet their permit requirement, and to encourage nonpoint sources to voluntarily contribute more towards meeting overall water quality goals. The EPA guidance encourages trading programs to set a nonpoint source eligibility baseline that extracts some "extra" abatement from nonpoint sources. Research has shown that setting an eligibility baseline that is substantially more stringent than current management could discourage nonpoint source participation and significantly hinder trading. In this paper we examine how choosing the eligibility baseline for agricultural sources affects the efficiency goal of trading (reducing costs to point sources), as well as how it affects the EPA goal of encouraging nonpoint abatement. Using data from the Chesapeake Bay Watershed we find that eligibility baselines set to encourage additional nonpoint source abatement reduce the supply of credits in a market; the more stringent the baseline, the fewer the trades and the smaller the overall abatement from nonpoint sources. A subsidy to farmers for reducing the cost of meeting a baseline encourages greater nonpoint source abatement, but may not benefit the trading market.*

Key words: Nonpoint source pollution, Water-quality trading, Environmental markets.

JEL codes: Q15, Q20, Q58.

One major issue facing water resource managers is how to promote the adoption of water quality-protecting practices by nonpoint pollution sources. Water quality regulations in the United States are applied almost

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exclusively to point-source pollution (pollution discharged directly into surface water through a discrete pipe or other conveyance). Nonpoint source (NPS) pollution, on the other hand, enters water resources over a broad front, is largely unobservable, is stochastic in nature, and cannot easily be traced back to its source. Largely because of these characteristics, NPS is exempt from the regulatory instruments employed by the Clean Water Act (CWA).

Nutrients (nitrogen and phosphorus) are a major agricultural nonpoint source water pollutant. Indeed, nearly 7,000 water bodies are on the Environmental Protection Agency (EPA) Impaired Waters list because of nutrients, and agriculture is the primary source of nutrients in most (EPA 2013). Existing policy tools for reducing agricultural nonpoint source pollution have largely been limited to the voluntary adoption of best management practices, which are supported with technical and financial assistance, primarily from U.S. Department of Agriculture conservation programs.

While farmers have received significant financial support to promote the voluntary use of water quality practices, this approach has not been very successful at addressing specific water quality problems (Osmond et al. 2012; USDA, NRCS 2011). Rather, program incentives for farmers to adopt improved nutrient management practices have proven to be inadequate, and point/nonpoint trading is being promoted as a market-based approach that could provide the incentives necessary for farmers to reduce nutrient discharges. Allowing agriculture to supply credits in a market created by capping discharges from regulated point sources would serve two purposes. First, it would reduce the cost of meeting water quality goals by allocating abatement more efficiently among sources (the economic rationale for trading); second, it would provide a strong economic incentive for unregulated nonpoint sources to play a larger role in improving water quality (Shortle 2013). Some U.S. states are emphasizing the latter role by requiring nonpoint pollution sources to provide some "extra" abatement before being eligible to enter a trading program. In this paper we examine how choosing the eligibility baseline for agricultural sources affects the attainment of these two goals. This paper contributes to the literature by explicitly accounting for the amount of "extra" nonpoint source abatement that a resource management agency can extract from nonpoint sources, and how this is affected by the choice of a baseline.

Trading and the Role of Baseline

Under the Clean Water Act, point sources (e.g., factories, sewage treatment plants) are generally regulated through a non-tradable permit system, where annual permits set limits on how much a firm can discharge (U.S. EPA 2008). Trading pollution allowances is a mechanism to improve the efficiency of water pollution control allocations among regulated sources. A regulated firm's discharge permit can be met by installing abatement technology or purchasing pollution allowances from other firms willing to sell theirs. The theoretical promise of emissions trading, the success of trading in the air pollution realm, and a lack of progress in reducing nonpoint source pollution has led the EPA to encourage individual states to consider agriculture as a source of credits in water quality trading programs (which are equivalent to allowances). A number of states are either implementing or considering

water quality trading programs that allow point/nonpoint source trading (U.S. EPA 2004, 2008; Greenhalgh and Selman 2012; Shortle 2013).

The theory and efficiency of point/nonpoint emissions trading is well explored in the literature (Tietenberg 2006; Baumol and Oates 1988; Stavins 2005), as are the many problems encountered when trading is actually implemented (Hoag and Hughes-Popp 1997; King 2005; King and Kuch 2003; Woodward and Kaiser 2002; Ribaudo and Gottlieb 2011; Horan and Shortle 2011; Shortle 2013). We will not revisit these issues here, but will focus on one aspect of water quality trading design, the eligibility baseline, and how this choice affects economic performance and nonpoint source participation.

Because NPS pollution from agriculture is exempt from the regulatory provisions of the Clean Water Act, point/nonpoint trading is considered by the EPA as a means of obtaining NPS abatement (Wainger 2012). According to the EPA, "... WQT (Water Quality Trading) is one of the few current tools that EPA has to address unregulated discharges," (U.S. EPA 2008). Trading therefore serves the dual roles of reducing total abatement costs for meeting water quality goals and expanding abatement by nonpoint sources. The USDA also supports the development of trading programs, as they would provide additional income streams for farmers and complement traditional financial support for water quality practices through programs such as the Environmental Quality Incentive Program and Conservation Stewardship Program. In 2006 the EPA and USDA signed a Water Quality Credit Trading Agreement stating that point-nonpoint trading will complement existing USDA conservation programs (USDA 2006).

Almost all trading programs are driven by the Total Maximum Daily Load provisions of the Clean Water Act. For example, when a water body is listed as impaired under section 303(d) of the Clean Water Act and existing regulatory programs for point sources are inadequate for meeting water quality goals, the state must develop a Total Maximum Daily Load, which sets the allowable discharge limit for the watershed to ensure that water quality goals are met. The allowable load is then allocated between point sources (Waste Load Allocation) and nonpoint sources (Load Allocation). Waste Load Allocation is managed through the National Point Discharge Elimination System (NPDES) discharge permits that all point sources must have; each point source is assigned a portion of the Waste Load Allocation through its NPDES permit. In contrast, the Load Allocation is not allocated to individual farms, but is managed at the sector level, as no permit system exists for nonpoint sources and nonpoint loadings from individual farms are unobservable and impractical to measure. It does not matter where the nonpoint source reductions come from as long as the sector goal is met. In practice, because nonpoint sources are exempt from the regulatory portions of the Clean Water Act, Load Allocation is generally met through voluntary approaches such as education and financial assistance. Water quality trading is one approach for providing an incentive for nonpoint source pollution abatement, but it is important to note that since water quality trading offsets point source Waste Load Allocation with nonpoint source offsets, these offsets cannot count towards agriculture's Load Allocation.

The marginal cost of reducing nitrogen loss from cropland is generally less than the marginal cost of reducing nitrogen discharges from point sources. Thus, the expectation is that a high demand for nonpoint source abatement from agriculture would exist once trading is allowed (Faeth 2000;

Ribaudo et al. 2005; Camacho 1990; Friedman et al. 2007; Van Houtven et al. 2012; Shortle 1990). There appear to be many opportunities for point/nonpoint trading programs to be established. Indeed, almost 7,000 water bodies impaired by nutrients (pollutants produced by both point and nonpoint sources) have been listed under Section 303(d) of the Clean Water Act (EPA 2013). Agriculture is a major source of nutrients in most of the watersheds containing impaired waters, and it is impossible to meet TMDL goals without increasing abatement from nonpoint sources (Ribaudo and Nickerson 2009). To date, over 4,000 Total Maximum Daily Loads (TMDLs) have been developed to address nutrient-impaired waters.

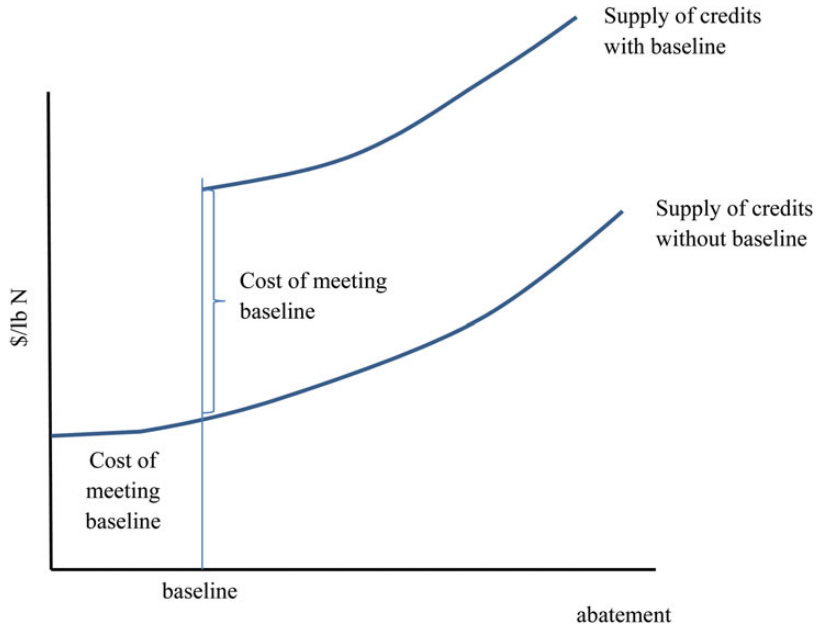
All point/nonpoint trading programs must establish a baseline for nonpoint sources. At a minimum, a baseline can be defined as a prediction of the quantified amount of the pollutant discharge that would have occurred in the absence of the trading program (EPA 2007). This definition ensures the additionality of credits sold to regulated sources (Marshall and Weinberg 2012). Fields not meeting the baseline criteria cannot produce credits for sale in a market until the baseline criteria are achieved. The EPA's Trading Policy states that where a TMDL is in place, the Load Allocation should serve as the baseline for nonpoint sources to generate credits (EPA 2007). In a sense, the baseline is a representation of the TMDL Load Allocation implemented at the field scale. When the Load Allocation is less than current loadings, such a baseline implies a higher level of management than current practices. It is important to note that this baseline is not legally binding, but rather only applies to nonpoint sources wishing to enter a trading program. The ability to sell credits is implicitly expected to be a strong enough incentive for farmers to be willing to meet the baseline in order to trade.

The abatement produced by meeting the baseline is considered a contribution towards meeting the Load Allocation, and therefore complements other policy approaches such as education and cost-sharing of management practices. A state could try to increase contributions to Load Allocation by manipulating the eligibility baseline. The more stringent the baseline, the greater the amount of cropland that would have to adopt practices to meet the baseline, and the greater the amount of "extra" abatement that farms would have to provide before being able to sell credits.

However, setting a baseline that is more stringent than current practices could come at the cost of point sources trying to reduce their own permit compliance costs. Such a baseline could significantly restrict credit supply by discouraging producers not meeting the baseline from voluntarily entering a market. This increases the price of credits, thus reducing the attractiveness of nonpoint source credits to point sources. In figure 1, a baseline based on a TMDL's Load Allocation increases the marginal cost of credits from a farm by the cost of attaining the baseline, shifting the farm's supply curve up. A farmer would only be willing to create and sell credits if the credit price is high enough to cover the cost of meeting the baseline *plus* the cost of an additional practice. In aggregate, the sector credit supply curve shifts to the left. The amount of the shift depends on the share of cropland not currently meeting the baseline and the amount of abatement that farmers must achieve before being eligible to trade.

Stephenson et al. (2010) found that when the eligibility baseline is more stringent than current practices, agricultural credit costs for nitrogen can surpass marginal abatement costs for point sources because the baseline has

Figure 1 Impact of baseline on credit supply from an individual field



claimed the lowest-cost pollutant reductions. Ghosh et al. (2011) found that Pennsylvania's baseline requirements significantly increased the cost of entering a trading program, making it unlikely that nonpoint sources that could reduce nutrient losses for the lowest unit costs would enter the market. Wisconsin has expressed concern that the EPA's approach to defining baselines could obstruct agricultural sources' participation in trading programs and possibly impede water quality improvements (Kramer 2003). The concern is that fewer nonpoint source credits would be purchased by point sources, and total abatement costs for regulated sources will be higher than they could have been. None of these studies examined the Load Allocation implications of the baseline.

An Empirical Examination in the Chesapeake Bay Watershed

We examine this tradeoff in the context of a stylized, hypothetical, watershed-wide point/nonpoint trading market simulated with data from the Chesapeake Bay watershed. The EPA established a TMDL for the Bay in 2010, requiring a 25% reduction of nitrogen deliveries to the tidal waters of the Bay from all sources (EPA 2010). The Load Allocation for cropland agriculture (the loadings goal from agricultural land that was established by the states) requires a 36% reduction in baseline agricultural nitrogen losses across the entire watershed (Commonwealth of Virginia 2010; New York State Department of Environmental Conservation 2010; Pennsylvania Department of Environmental Protection 2011; State of Maryland 2010; State of Delaware 2010; State of West Virginia 2010). (Note that the percentage reduction goals for each state vary). The Waste Load Allocation for point sources sets a cap that creates a demand for credits once trading is allowed.

We assume that all point sources in the watershed are allowed to seek credits from agricultural sources.

Agricultural sources are allowed to sell credits to point sources once a baseline requirement is met. In Maryland's trading program, the Chesapeake Bay Watershed Model was used to establish field-level nitrogen loss rates that are consistent with the Load Allocation for agricultural sources. We base our analysis on Maryland's approach, and examine a range of nitrogen loading rate baselines for their impact on the cost of credits in a trading market and contributions to Load Allocation. For this analysis we also assume that trading is allowed across sub-basins within the Bay watershed, which is not currently allowed. We examine the relationship between baseline stringency, credit market equilibrium price, abatement going to the credit market, and abatement going to TMDL Load Allocation.

We must emphasize that we are not trying to predict how a trading program would actually perform in the Chesapeake Bay watershed. Rather, we are assuming a basin-wide trading program that does not currently exist, and are ignoring the program goals of the individual watershed states. For example, Maryland is using trading only to offset future growth, not to help regulated point sources meet current Waste Load Allocations. We also ignore common features of trading programs that affect trades, such as trading ratios. However, our findings are relevant in that they guide the design of trading programs when trading is being considered as a means of providing an incentive to encourage agricultural nonpoint source abatement.

Data for Estimating Credit Supply

We estimated nitrogen abatement and credits with data from the NRCS Conservation Effects Assessment Program (CEAP) study of the Chesapeake Bay Watershed, which detailed a field-level survey of 771 cultivated cropland sample points of the National Resources Inventory (NRI) in the Bay watershed (USDA, NRCS 2011). The NRI is a periodic representative survey of land use and natural resource conditions and trends on U.S. nonfederal lands. The CEAP-NRI survey collected detailed production and conservation management data from crop years 2001–2006. These observations represent the distribution of practices on all agricultural lands within each four-digit hydrologic unit code (HUC) in the Bay watershed. We restricted our analysis to major field crops, which constituted 97.9% of crop acres. We excluded fields planted to vegetables, as we have less confidence that our cost data are representative of these specialized crops.

In addition to the survey, the NRCS simulated the environmental performance of the pre-TMDL management (current practices). This also included the following various conservation systems that could be added to each observation to abate nitrogen: current practices; cover crops; nutrient management; water erosion control; water erosion control plus cover crops; water erosion control plus nutrient management; nutrient management plus cover crops; nutrient management plus cover crops plus water erosion control.

It is important to note that water erosion controls and nutrient management are management systems, and the components of each differed for each observation depending on the physical characteristics of the field and the crops grown. Details about the additional conservation systems are

provided in the appendix. Less than 1% of cropland in the watershed was covered by all three management systems.

The water quality impacts of crop management choices were simulated by NRCS using the modeling system employed in their CEAP study (USDA, NRCS 2011). The field-level effects of current conditions and the alternative management scenarios on nitrogen, phosphorus, and sediment losses were assessed for each observation by NRCS with the Agricultural Policy Environmental Extender (APEX) (Williams et al. 2008; Gassman et al. 2009). The APEX is a field-scale model that simulates day-to-day farming activities, wind and water erosion, loss or gain of soil organic carbon, and edge-of-field losses of soil, nutrients, and pesticides. The impact of field-level losses on in-stream concentrations and loadings of nitrogen, phosphorus, and sediment within the watershed was simulated with the Hydrologic Unit Model for the United States (HUMUS) (Arnold et al. 1999; Srinivasan et al. 1998). The HUMUS consists of the following: a basin-scale watershed model (the Soil and Water Assessment Tool, or SWAT) that routes instream loads from one watershed to another (Gassman et al. 2007; Arnold and Fohrer 2005); a Geographic Information System to collect, manage, analyze and display spatial and temporal inputs and outputs; relational databases to manage the non-spatial data and drive the models. The modeling system accounts for any interactions from adopting multiple management systems. We define a credit as nitrogen abatement delivered to the tidal waters of the bay.

In addition to simulating environmental performance, we also estimated the cost of adopting the specified management systems for abating nitrogen losses. The cost of a management system to a farmer is the expected reduction in net farm returns from adopting it. These costs include annualized capital costs, changes in annual input costs (labor, fuel, chemicals, seed), changes to revenue due to changes in crop yields (including land taken out of production), plus an allowance for perceived risk of adoption. We assumed farmers would only add practices; current practices would not be removed.

The NRCS calculates fertilizer application rates, crop yield per acre, and the proportion of land cropped for each combination of practices for each observation. For each year in the crop rotation, we calculated the value of output and fertilizer input costs. These data were averaged to represent production costs as the average annual cost of implementing new practices. The data from CEAP contains 28 unique crop rotations. We estimated the crop value based on reported 2010 state-level crop prices provided by the USDA's National Agricultural Statistics Service (NASS). For some crops, state-level prices were not available (less than 7% of the total acreage in the watershed), so we represent the values of these crops using the U.S. price.

Fertilizer costs are based on reported 2010 prices by the NASS. The price of nitrogen reflects the U.S. average price ($499 per ton) for anhydrous ammonia, which is 82% nitrogen (N), or a price per active ingredient of $0.30 per lb./N. The price of phosphorus reflects the price per ton of superphosphate (46% phosphorus (P)), or an active ingredient price of $0.55 per lb./P.

We account for the opportunity cost of land taken out of production for soil erosion controls (filter strips and terraces) by using 2010 state-level land rental rates for irrigated and non-irrigated land reported by NASS. We obtained annualized, state-level installation and maintenance costs for

nutrient management, cover crops, grass buffers, terraces, and contouring from a variety of sources, including EQIP cost-share rates, Chesapeake Bay Program (CBC 2004), and Wieland et al. (2009). Because of variations in the components of a conservation system, differences in variable inputs, differences in the value of lost yields, and regional differences in practice costs, the farmer's per-acre cost to implement a particular conservation system varied considerably across observations.

When evaluating practice choice with an economic model, assuming that farmers have perfect information and maximize their expected profits should lead to a finding that observed practices are those that maximize net returns. However, we found that a portion of our sample could apparently increase net returns by adopting some of the improved management systems (because they reduced input costs or increased crop yields), implying that not all farmers maximize net returns (Diaz-Zorita et al. 2004; Pendell et al. 2006; Veith et al. 2004). We believe two factors are work here. First, we do not know the actual cost for each observation of adopting practices. All we have are regional averages. Second, we believe there are a variety of factors that operators treat as costs that are not captured by a simple accounting of implementation costs and returns. These factors include increased uncertainty about expected returns (risk), loss aversion (decisions are influenced more by a potential loss than an equal-sized potential gain), and behavioral inertia (Gillenwater 2012).

The data did not allow us to explore the cost and risk characteristics of each observation. Instead, we estimated what the implicit cost would have to be for the observed management to be the profit maximizing choice. For each modeled scenario we determined the largest increase in net returns from among all the observations. We then added this value as an implicit cost to adopting the conservation measures to each observation. This ensured that the baseline scenario represents those practices that provide farmers in the watershed maximum net returns in the absence of any policy, while preserving the rankings of observations in terms of implementation costs. Changes in management would therefore only be in response to the incentives offered by the trading policy, and not to any other economic factor.

Supply of Agricultural Nitrogen Credits in the Chesapeake Bay Watershed

With data on practice cost, yield, edge of field nitrogen loss, and nitrogen delivery to the tidal waters of the bay, we were able to estimate the least-cost option for each observation to supply credits for a market, subject to meeting the eligibility baseline. A credit is defined as a pound of nitrogen reduction delivered to the tidal waters of the bay. Each representative field could add new management systems (nutrient management, cover crops, or water erosion control practices) to its "current" set of practices, except for those observations implementing the full suite of management systems as current practices. We used integer programming in GAMS to find the least-cost management choice for each observation. Integer programming is appropriate when optimizing over a set of discrete, indivisible variables (conservation systems). Costs reflect the total costs to the farmer of adopting the practice set, including practice implementation costs, the opportunity costs of changes in nutrient applications and crop yields, and costs associated with increased risk (ignoring any cost-share payments from conservation programs). If the

observation met the eligibility baseline, all subsequent abatement goes to the credit market. If the eligibility baseline was not met, subsequent abatement was allocated between meeting the baseline (to the TMDL's Load Allocation, which is also measured in terms of N abatement measured at the tidal waters of the bay) and the credit market. Adopting a single management system could often produce enough abatement to meet the baseline and to supply the credit market. The cost of credits includes the cost of achieving the baseline. Aggregating the credit supply across all observations for a particular baseline results in a sector's credit supply curve for that scenario. We calculated nonpoint source nitrogen credit supply curves for a "current practices" baseline (the minimum baseline for assuring additionality of credits), and baselines of 65, 45, 35, 25, and 15 lbs. of nitrogen loss per acre of cropland, measured at the field.

Supply of Credits with Subsidies

If a baseline reduces the supply of credits in the market, the government could try to compensate by offering to subsidize practices necessary to meet the baseline. A state may feel that the benefits of trading, in terms of reducing point source costs and reducing nonpoint source pollution, are worth the taxpayer expense of the subsidies. This is currently an accepted use of conservation programs funds (American Farmland Trust 2013).

We examined this policy by calculating nonpoint source nitrogen credit supply curves when the costs of meeting baseline are not paid by the farmer. For simplicity, we assume a 100% cost-share, which differs from current conservation programs that typically offer 75% or less. This assumption does not change the nature of the results. We also assume that abatement generated by the subsidized practices is not eligible for sale as credits, even if the baseline is exceeded (consistent with rules against so-called double dipping). All abatement from subsidized practices goes to the nonpoint source Load Allocation of the TMDL.

Demand for Credits in the Chesapeake Bay Watershed

For this analysis we assume that demand for credits from agriculture will come from publicly-owned sewage treatment works (POTW). We used data from a subset of 176 significant wastewater treatment plants in the watershed to estimate potential demand for N credits in a trading market from all POTW in each of the Bay States. The basis of demand was the avoided costs of treatment upgrades that would be required to meet N discharge limits under the TMDL. Sources of cost data include the Maryland Department of the Environment (2010), the Pennsylvania General Assembly Legislative Budget and Finance Joint Committee (2008), and the Virginia Department of Environmental Quality (2010).

Cost elements include capital and operating costs for achieving nitrogen reductions consistent with a Waste Load Allocation for the TMDL. Reductions were calculated as a function of existing flows (3-year average) and both pre- and post-upgrade concentrations. For each plant, the costs of reducing nitrogen were modeled on a per pound basis. After all relevant data for each plant were compiled a demand curve for credits was plotted.

Results

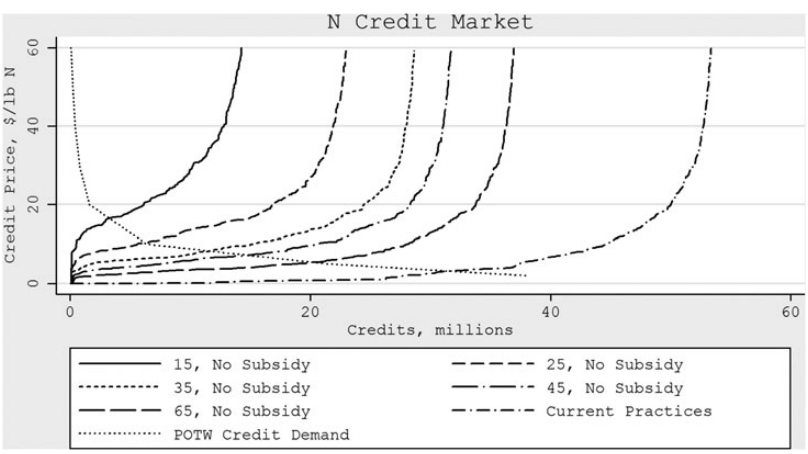
The credit demand curve and the credit supply curves without subsidies for the different baseline scenarios are shown in figure 2. For each scenario we calculated the equilibrium market price (where demand and supply curves intersected), the number of credits sold in the market, and the amount of abatement going to Load Allocation (abatement generated by adopting practices to meet the baseline). Pre-TMDL loadings of nitrogen to the bay from cropland were estimated from the CEAP data to be 120.8 million lbs. per year. Assuming the same 36% reduction in total, watershed-wide cropland nitrogen loads implied by the state watershed implementation plans, meeting Load Allocation for the watershed requires a reduction of 43.5 million pounds of N delivered to the bay.

Impact of Baseline Stringency on Trades and Load Allocation

The "current practices" baseline provides the most credits at lowest cost, as all fields are eligible to supply credits with the implementation of a practice. In this scenario 31.6 million lbs. of N are sold to POTWs at a price of $3.13/lb. (table 2). Since all the management actions that farms make generate credits, most of the credits come from fields with high N losses that are not covered by conservation systems prior to the trading program. Installing conservation measures on such fields produces high amounts of nitrogen reduction for a low per-unit cost. Fields already under conservation measures cannot provide as much additional abatement, and the abatement provided is more costly.

When an N loss eligibility baseline is used to provide more abatement for Load Allocation, credit supply curves shift to the left, as expected, since some fields cannot sell credits until the baseline is met. Since abatement going to meeting the baseline cannot be sold, there are fewer credits supplied. In addition, the cost of credits that are supplied reflects the cost of meeting the baseline, plus any additional measures taken to reduce N losses. The more stringent the baseline, the fewer the available credits (and the further left the supply curve shifts). Only 26% of cropland acres can meet the most stringent baseline of 15 lbs. N/acre under current

Figure 2 Offset demand and supply curves under different baselines, without practice subsidies



practices (table 1). The equilibrium price in the market would be $16.49, and 3.3 million credits would be traded (table 2). Some fields not meeting the baseline would still find it profitable to meet the baseline and sell credits in the market. The result is that 3.5 million lbs. of additional N abatement would go towards Load Allocation, which is one of the goals of an eligibility baseline. This is only 8% of what is required to meet Load Allocation. A total of 6.6 million lbs. of nonpoint source abatement is generated.

The amount of abatement going to Load Allocation increases as the eligibility baseline is relaxed. At the least stringent baseline we examined (65 lbs. N/acre), more total abatement is produced at the equilibrium price than under the "current practices" baseline. About 61% of the Load Allocation goal for the watershed would be met; the reason is that market prices are high enough to induce fields that do not quite meet the baseline, but can produce high levels of abatement at a low cost to adopt the necessary practices. However, the equilibrium credit price is higher than under the "current practices" baseline, and the economic benefits to regulated point sources are reduced.

Load Allocation and Welfare Implications of Baseline Subsidies

Providing a subsidy for meeting the baseline to stimulate supply did not have the expected impact on the credit market. We found that for all but the most stringent baseline, the provision of a subsidy actually reduces the number of credits going to the market (table 2, figure 3). The reason for this counter-intuitive result is our assumption that abatement generated by a practice cost-shared by the government cannot be sold as credits in the market to prevent "double dipping", even if the eligibility baseline is exceeded. Generally, the initial investment in practices produces the biggest "bang for the buck", so a substantial amount of abatement may be made ineligible for the trading market by the subsidy. As a result, some of the credits that were available to the market when the subsidy was not offered instead go to Load Allocation; the supply curve for that baseline level shifts to the left with the subsidy. Point sources do not benefit from the subsidy, but total nonpoint source abatement is higher with the subsidy for all baselines. With our least stringent baseline (65 lbs. N loss per acre) plus a subsidy, about 89% of the Load Allocation goal for agriculture is met in our example.

Under the most stringent baseline (15 lbs. N per acre loss), the subsidy results in an increase in credit supply, which results in a $21.8 million benefit to regulated treatment plants in reduced abatement costs (table 3). However, taxpayer costs for the subsidy are $143 million. Under less stringent baselines, subsidy costs decline as a higher percentage of fields meet

Table 1 Percentage of Cropland Acres Meeting Edge-of-field Loading Limits, before the TMDL

Edge of field nitrogen loss (pounds N/acre)	Percentage of watershed cropland
15	26.5
25	50.8
35	65.4
45	74.2
65	85.3

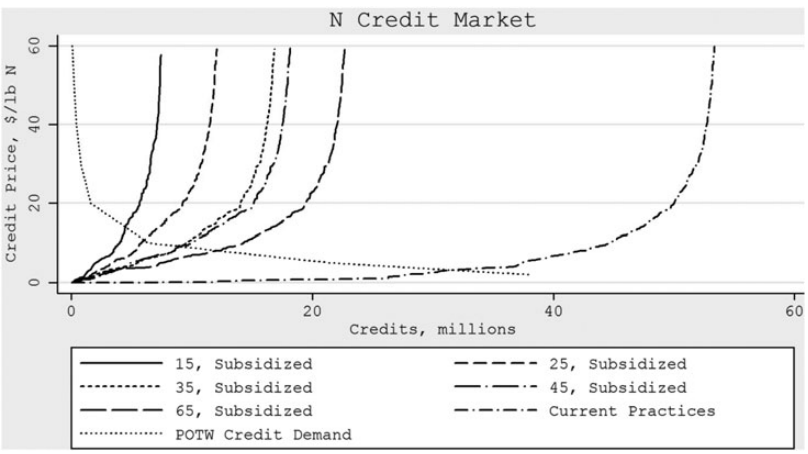
Note: Based on survey data from the NRCS CEAP, 2011.

Table 2 Comparison of Equilibrium Conditions under Alternative Baselines, with and without Practice Subsidies

Baseline	Equilibrium credit price ($/lb N)	Equilibrium quantity traded (1 million lbs. N)	Abatement towards Load Allocation (1 million lbs. N)	Total nonpoint abatement (1 million lbs. N)
Current practices	3.13	31.6	0	31.6
15, no subsidy	16.49	3.3	3.5	6.8
25, no subsidy	10.28	6.2	7.4	13.7
35, no subsidy	8.26	11.6	12.6	24.2
45, no subsidy	7.23	14.7	18.1	32.8
65, no subsidy	5.41	20.2	26.4	46.6
15, subsidized	13.93	4.5	19.8	24.4
25, subsidized	10.65	6.1	32.2	38.2
35, subsidized	9.18	8.8	33.1	41.9
45, subsidized	9.09	9.1	33.9	43.1
65, subsidized	8.09	12.1	38.5	50.7

Note: The 15, 25, 35, 45, and 65 refer to lbs. N loss per acre of cropland.

Figure 3 Offset demand and supply curves under different baselines, with practice subsidies



the baseline, but point sources see a decrease in credit supply, thus increasing their abatement costs relative to the no-subsidy case. Whether the additional abatement spurred by the subsidy that goes to Load Allocation is worth the cost to taxpayers and to point sources would depend on the costs of alternative policy approaches for meeting Load Allocation goals. In our particular example, taxpayer subsidy costs are not offset by reduced costs for point sources.

It is important to note that these results are driven in part by the limited number of management options in our model. With more management choices available to farmers, the impact of the subsidy on credit supply in the market would probably be reduced; more abatement would go to the market and less to Load Allocation.

Table 3 Welfare Implications of a Subsidy to Meet Baseline

Baseline	Point source cost from subsidy (Million $)	Taxpayer cost of subsidy (Million $)
15, subsidized	-21.8	143.8
25, subsidized	0.5	138.0
35, subsidized	8.5	105.2
45, subsidized	17.5	76.0
65, subsidized	26.4	38.4

Note: The 15, 25, 35, 45, and 65 refer to lbs. N loss per acre of cropland.

Discussion and Conclusions

Credit trading is a policy approach used for reducing the cost of meeting regulated reductions in pollutant loadings. It is also being used as a way to incentivize reductions in nonpoint source pollution when regulatory means are unavailable for achieving nonpoint source abatement goals, such as those defined by the Load Allocation of a TMDL. An eligibility baseline, defined in terms of pollutant loss rates, requires that farms with pollutant loss rates exceeding the baseline reduce pollution loss before being allowed to trade. This abatement counts towards meeting the TMDL's Load Allocation for agricultural sources.

Using data from the Chesapeake Bay watershed, we found that an eligibility baseline that requires a contribution to Load Allocation before being able to sell credits in a trading market has the *potential* to provide both nonpoint source abatement for Load Allocation and more total nonpoint source abatement (credits plus load allocation) than a current-practices baseline. However, this potential comes at the expense of reduced benefits to point sources. A baseline defined as current practices provides the greatest benefit to point sources, but does not obtain any additional nonpoint source reductions that can be credited towards the Load Allocation of a TMDL.

However, making the baseline more stringent (fewer farmers meet the baseline) to acquire more abatement for Load Allocation makes trading less attractive to farmers because of the high cost of achieving the baseline; trading becomes less profitable for most farmers. The result is that both Load Allocation goals and the credit market suffer. A *less* stringent baseline that makes it easier for farmers to participate in the trading market provided more abatement for Load Allocation, as well as more credits for point sources (but still less than under a current-practices baseline). A resource management agency would have to balance the competing goals of increasing nonpoint source abatement and reducing the costs to point sources of meeting discharge limits when selecting an eligibility baseline. Given that abatement costs are private information, it would be very difficult to identify the "optimal" baseline that balances both objectives.

Using conservation program payments to help farmers meet a baseline is seen as one way to reduce the cost of participating in a trading program with a stringent baseline, and presumably as a way to increase the potential supply of credits. However, our findings indicate that a subsidy that covers the cost of meeting a baseline may not necessarily have the desired effect. While a subsidy increases total nonpoint source abatement, rules to prevent double dipping may actually reduce the amount of credits in a market, thus

reducing the benefit to point sources; in this case, both taxpayers and point sources bear a cost from providing a subsidy. On the other hand, the subsidy increased the supply of abatement going to Load Allocation. It may be possible to partially subsidize practices based on the amount of abatement that goes to baseline, and to allow more abatement to go to the credit market, but this would be very difficult to estimate for each field (high transaction costs). A more practical approach may be to use separate programs to address Load Allocation goals. This would favor a baseline that is closer to "business-as-usual" practices and provide the best opportunity for point sources to benefit from trading while meeting overall water quality goals.

In our example the demand for credits relative to the supply resulted in the *potential* for baseline choice to make an important contribution to meeting Load Allocation for cropland agriculture (assuming all the impediments to trading can be addressed). This may not be the case elsewhere, but given the lack of a regulatory option for nonpoint source control, resource managers might at least consider the possibilities offered by the incentives of a trading program. Project-by-project assessment would be required to ascertain whether baseline stringency is a worthwhile design feature, and what level of stringency is most beneficial.

Appendix

Cover Crops are planted after the principal crops are harvested to provide soil surface cover and reduce soil erosion, and to remove excess nutrients remaining in the soil, thereby preventing them from leaching or running off to surface water. For sample points not currently using a cover crop in the rotation, the environmental performance of adding a cover crop was simulated, assuming rye as the cover crop. The simulation assumes the cover crop was planted the day after harvest of the main crop, or the day after the last major fall tillage practice, and that the cover crop was not harvested for sale.

Nutrient management is defined in terms of the appropriate rate, timing, and method of application for all crops in the rotation:

- All commercial fertilizer is applied 14 days prior to planting, except for acres susceptible to leaching loss.
- For acres susceptible to leaching, nitrogen is applied in split applications.
- Manure applications are moved to the spring.
- All fertilizer and manure is incorporated or injected.
- All nitrogen application rates for all crops except cotton and small grains are no more than 1.2 times the crop removal rate. For small grains nitrogen application rates are no more than 1.5 times the crop removal rate. For cotton, nitrogen application rates are no more than 50 pounds per bale.
- Phosphorus application rates are no more than 1.1 times the amount of phosphorus removed in the crop at harvest.

Water erosion control consists of structural and vegetative practices that slow runoff and capture contaminants that it may carry. Approaches include the following:

- Terraces are added to all sample point with slopes greater than 6%, and to those with slopes greater than 4% and a high potential for excessive runoff (hydrologic soil groups C or D).

- Contouring or stripcropping is added to all other fields with a slope greater than 2% that do not already have those practices.
- Fields adjacent to water receive a riparian buffer.
- Fields not adjacent to water receive a filter strip.
- No changes are made to tillage.

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