Controlling Non-additional Credits from Nutrient Management in Water Quality Trading Programs Through Eligibility Baseline Stringency

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Abstract: A concern for any program that offers payment for environmental services is that those services be additional. Non-additional services are those that would have been provided without the payment. One source of non-additionality is farmer misrepresentation of their pre-program management. Farm management practices are often difficult to observe, particularly those that do not involve structural changes, such as nutrient management. If practices are difficult to observe, management oversight lax, and enforcement weak, the farmer has an incentive to provide biased information that increases the likelihood that he will receive a more favorable baseline for calculating services created, and a larger payment. This is a moral hazard problem. The presence of non-additional credits in a water quality trading program can result in the degradation of water quality. Point source discharges above permitted levels are replaced by equivalent reductions from unregulated nonpoint sources. If the abatement that point sources purchase from nonpoint sources is non-additional, discharges will be higher than if the abatement was truly additional. Preventing non-additional credits from entering a water quality trading market is one of the goals of program design. In this paper we assess how program eligibility baseline choice affects the incentive to misrepresent baseline nutrient management practices using data from the Chesapeake Bay Watershed.

Keywords: additionality; point-nonpoint water quality trading; baseline; nutrient management; moral hazard

Additionality is a measure of the extent to which a payment for an environmental service is necessary for its provision (Claassen et al., 2013; Gillenwater, 2011; Marshall and Weinberg, 2012). Non-additional services are those that would have been provided without the payment. Inclusion of non-additional services in a conservation program can result from a failure of the resource agency to accurately measure pre-program management, a failure to account for new, profit enhancing practices that are just starting to be implemented in the farming community, strategic actions by farmers to misrepresent their current management in order to obtain a larger payment, or through a policy choice by the resource agency.

The consequences of non-additionality depend on the type of program providing the economic incentive. For a cost-share program such as the Environmental Quality Incentive Program, paying for a practice that would have been adopted without the payment reduces the economic efficiency of the program; payments result in less environmental improvement than if all improvements were additional (Claassen et al., 2013). However, environmental quality itself is not threatened.

In the case of a water quality trading program, however, payments for non-additional practices can result in the degradation of water quality. In a point/nonpoint trading program a regulated point source is able to purchase abatement from unregulated nonpoint sources to offset abatement it would otherwise have to provide through enhanced treatment technologies (Ribaudo et al., 2008). In essence, the point sources are allowed to discharge more than their discharge permit would otherwise allow with the expectation that purchased nonpoint source reductions will provide the offsetting abatement. If the abatement that point sources purchase from nonpoint sources is non-additional, discharges will be higher than if the abatement was truly additional or if point sources provided the abatement themselves. Preventing non-additional credits from entering a water quality trading market is one of the goals of program design. In this paper we assess how baseline stringency can be used to reduce the incentive for strategic actions by farmers to misrepresent their management. .

1.1 Sources of non-additionality

Four general mechanisms lead to the creation of non-additional credits in a trading program. One is the intentional choice by a resource management agency to reward "good stewards" for previous adoption of management practices that provide environmental services. A point of contention in programs that pay for environmental services is how to reward "good stewards" who have been providing environmental services voluntarily, making investments in management improvements out of their own pocket (Ribaudo et al., 2008). Maryland's water quality trading program and USDA's Conservation Stewardship Program both allow payments for services generated by past actions. The presence of non-additional credits hurts program efficiency and in Maryland's case can result in water quality degradation unless compensating abatement is obtained elsewhere.

A second source is how expiring conservation contracts are handled. Conservation programs such as EQIP provide financial incentives to farmers for installing a variety of environmental quality-enhancing practices. When a contract expires the question is whether future environmental services are additional or not (Claassen et al., 2013). A resource management agency may reason that once the contract expires the farmer will stop following the practice and the environmental services will cease, so a payment allows the services to continue (Miller and Duke, 2013). However, a farmer may find the practice beneficial and continue to implement it after the contract expires (which is the intent of the conservation payment in the first place). In this case paying for environmental services would be non-additional.

A third possibility is a failure to account for adoption trends for new practices that increase net returns or provide other private benefits to farmers (Claassen et al., 2013; Mezzatesta et al., 2013). Farmers are most likely to voluntarily adopt practices that increase net returns. However, the adoption process can be slow. The environmental services from practices a farmer would have eventually adopted on his or her own are non-additional. Due to the heterogeneity of farms and farmers and the difficulty in obtaining privately held cost information, it would be very difficult for an agency to identify *a priori* whether an individual farm would benefit from a particular practice without a financial incentive.

A fourth possibility is that farmers misrepresent their management choices (Miller and Duke, 2013; Duke et al, 2012). Farm management practices are often difficult to observe, particularly those that do not involve structural changes (Jackson-Smith et al., 2010). Nutrient management is such a practice. Even on-field inspections will not reveal fertilizer application rates or timing. Since farmers are not generally required to report their practices to any government agency, the only way for a resource management agency to know whether a practice is current or new is through farmer self-reporting. If practices are difficult to observe, management oversight lax, and enforcement weak (asymmetric information), the farmer has an incentive to provide biased information that increases the likelihood that he will receive a more favorable baseline for calculating services created, and his payment (Gillenwater, 2012; Miller and Duke, 2013; Duke et al., 2012; Shabman et al., 2002).

Duke et al. (2012) used survey data from Maryland to estimate the potential incentive for farms that are below (meeting) a water quality baseline to misrepresent their use of annual management practices in a water quality trading program. They found that loose rules about additionality for annual practices and the difficulty of monitoring practice implementation leads to the potential for non-additional credits.

Giannakas and Kaplan (2005) empirically analyzed the economic determinants of producer noncompliance with the Highly Erodible Land Conservation provisions of the 1985 Food Security Act. They found that the lack of a strong auditing program induces producers that do not adopt necessary conservation practices to masquerade as adopters and claim government payments for which they are not entitled, assuming producers respond only to economic incentives. Noncompliance was shown to increase with the costs of adopting conservation practices.

Whether cheating is an issue in existing conservation or regulatory programs is largely unknown due to a lack of data. U.S. Department of Agriculture (USDA) has generally found high levels of adherence with the compliance provisions for highly erodible land and wetlands (which are generally much easier to detect than the use of nutrient management), but the U.S. General Accounting Office found deficiencies in the review process that brought into question USDA's assessment (U.S. GAO, 2003).

Maryland, Delaware, and Virginia all have requirements for nutrient management plans on at least some cropland. Compliance rates range from 65 percent in Maryland to 80 percent in Virginia and Delaware based on small samples (8 – 10 percent) of fields (Perez, 2011). However, adherence with nutrient management plans has generally been difficult to detect with on-farm inspections (Perez, 2011). Survey data from the Natural Resource Conservation Service's (NRCS) Conservation Effects Assessment Project for the Chesapeake Bay Watershed found that only about 10 percent of cropland was meeting NRCS criteria for good nutrient management in 2006 (USDA, NRCS, 2011). This finding suggests that nutrient management plans are inadequate or are being ignored.

The asymmetry in information between farmers and the resource management agency makes this a moral hazard problem (Hanley et al., 1997). Moral hazard occurs when the party with more information about its actions has an incentive to behave inappropriately from the perspective of the party with less information. In our example, the economic benefits of misrepresenting baseline practices with little risk of getting caught could lead to environmental harm (poorer water quality).

Motivated by the findings of Duke et al. (2012) and the role that point/nonpoint trading is expected to play in the Chesapeake Bay watershed, we extend this work by examining how baseline choice influences the incentive to misrepresent practices and offer non-additional credits in a trading program.

1.2 Point/nonpoint trading and additionality

In simple terms, trading programs provide a means of reallocating pollution control responsibility from dischargers with relatively high marginal abatement costs to those dischargers with relatively low marginal abatement costs, thus reducing total control costs for achieving a particular environmental goal. In a point/nonpoint trading program, point sources regulated through the National Pollutant Discharge Elimination System (NPDES) permit program of the Clean Water Act may be required to reduce pollution discharges because of a Total Maximum Daily Load (TMDL), which sets a pollutant discharge limit or cap for an impaired watershed. Without a trading program point sources would have to meet the new discharge limits through treatment technology upgrades. With trading, regulated sources can offset required abatement through purchases of abatement credits from unregulated nonpoint sources such as agriculture. Nonpoint sources can produce credits by adopting improved management systems. Abatement is generally certified by the resource agency and farms are awarded credits based on their level of abatement. Agriculture is widely believed to be able to abate pollution for a much lower unit cost than point sources (Van Houtven et al., 2012)

Credits from agriculture are usually calculated at the field level using a model such as the Maryland Nutrient Trading Tool (Maryland Dept. of Ag., 2013). The farmer inputs soil and field characteristics, “current” or baseline management, and which practices he intends to implement, and the model estimates the number of credits that would be produced. Most trading programs require some type of site visit to verify baseline practices and the model calculations.

Structural practices are relatively easy to verify in a baseline, many through remote methods. On the other hand, annual management practices such as nutrient management may be very difficult to observe. Such practices have relatively low upfront costs and the decisions of whether and how to implement them can be made annually, depending on economic and environmental conditions. A resource management agency generally has to rely on farmers' personal statements to determine whether a management practice is current or new.

Let's assume that a farmer has a nutrient management plan (NMP) and he has been following it for years. The opportunity arises to enter a water quality trading program and to produce and sell credits generated by reducing nitrogen losses from his fields. Even though he has been following a nutrient management plan, he may be tempted to claim that the NMP is a new practice. Perhaps this is seen as a way of finally receiving an award for past stewardship. At no cost to him he can then benefit by being awarded credits that he can sell to point sources. A lack of effective inspection and the nature of the practice make this a low-risk action. Otherwise, adding additional management on top of an existing NMP to reduce nutrient loss further will likely be expensive and produce little additional abatement, making it difficult for the farmer to be competitive in a credit market.

If there is a low risk to misrepresenting true baseline practices and claiming that nutrient management is being implemented to supply credits, farms that do so should be able to sell credits for a lower price than farms that must adopt nutrient management or other practices to create credits. If such misrepresentation is prevalent in a watershed a high proportion of credits entering a market may be non-additional, which could threaten water quality. This is an example of adverse selection, where the incentive tends to favor those supplying non-additional credits (Hanley et al., 1997).

1.2.2 Baselines and additionality

Eligibility baselines have been suggested as a means of increasing additionality in conservation programs by requiring farmers to have in place practices that are believed to be profitable over the long term (defined as “business as usual”) (Horowitz and Just, 2013). Business-as-usual can be incorporated into a trading program through an eligibility baseline that defines the practices or level of environmental performance a farm must attain before being able to receive payments for environmental services. Strict adherence to the additionality criterion requires that program managers determine whether proposed abatement goes beyond what constitutes current or projected “business-as-usual” reductions (Marshall and Weinberg, 2012). Research has shown that additionality in conservation programs is higher for practices that are unlikely to provide positive on-farm (private) benefits (Claassen et al., 2013; Mezzatesta, 2013). Setting a baseline that includes those practices with a high risk for non-additional credits (those which appear to provide net positive benefits to most farmers) would improve the cost-effectiveness of programs that pay for environmental services. In a similar vein, an eligibility baseline may be effective at reducing the incentive for misrepresenting baseline practices that are difficult to verify. Assume that a trading program establishes eligibility using a field-level model that estimates edge-of-field nitrogen losses and that a farmer is using nutrient management prior to the trading program. The following situations are possible after a trading program is introduced:

1. Meets the eligibility baseline without including nutrient management as a current practice (Farm 1 in figure 1). Given the difficulty in observing the practice and assuming lax inspection and enforcement, there is an economic benefit from misrepresenting nutrient management as a new practice. All credits are non-additional, and the cost to the farmer is 0.

2. Does not meet the trading eligibility baseline without including nutrient management as a current practice, but adding nutrient management drops N loss below the baseline (Farm 2 in figure 1). There is an economic benefit from misrepresenting nutrient management. Only that portion of abatement below the baseline can be sold as credits. These credits are all non-additional and the cost to the farmer is 0.

3. Does not meet the trading eligibility baseline with nutrient management included as a current practice (Farm 3 in figure 1). There is no economic benefit to misrepresenting nutrient management as a new practice. Nutrient management needs to be included as a current practice to get the field as close to baseline as possible. Additional practices would be required to create credits. Abatement beyond what is needed to meet baseline would be additional.

From these scenarios it is clear that a regulatory agency can reduce the likelihood of non-additional credits by increasing the stringency of the eligibility baseline. The more stringent the baseline, the less likely a farmer can benefit by misrepresenting his baseline practices. It should be noted that such an approach would only work when the baseline is defined in terms of environmental performance (e.g. edge of field nitrogen losses). A baseline based on specific practices (such as nutrient management) would not address farmer strategic behavior.

There is an important tradeoff in all this. The more farmers have to do in order to be eligible to trade (thus ensuring additionality), the less likely a farmer will find it profitable to enter a trading program. For the farmer to recoup the cost of meeting baseline, the price of a credit must be high enough that revenue from trading covers the cost of meeting baseline as well as the cost of the tradable credits. The more stringent the baseline, the more difficult it would be for those farms that have the poorest management (pollute the most) to enter the market, and the greater the percentage of cropland that would not meet the baseline (Ghosh et al., 2011; Ribaudo et al., 2014). Regulated point sources seeking offsets would be adversely affected by a reduction in credit supply and an increase in credit prices.

2. Data and procedures

We examine how baseline stringency protects against non-additional credits using data from the Chesapeake Bay watershed and a hypothetical trading program that contains features of Maryland's nutrient trading program that was established to offset future growth of point source discharges (Maryland Department of Agriculture, 2008). In our trading program farmers are allowed to sell credits to point sources by implementing practices that reduce nitrogen discharges to water. A farmer wishing to sell credits would identify the field and manually input land and agronomic management characteristics, current and future BMPs, and other details into a modeling tool. The resource management agency managing the trading program would verify the model results and certify the credits produced.

Before the farmer can sell credits, however, the field must meet a baseline water quality requirement. The baseline provides assurance that participants are at a minimum level of stewardship, and that any additional management is due to the trading program and not from "business as usual" decisions. In our example this is defined as a maximum level of edge of field nitrogen loss (as in Maryland's program). Practices implemented on a field meeting the baseline would produce credits. However, a field is not given credit for being "cleaner" than the baseline requires. Doing so would result in non-additional credits. If the field is not meeting the eligibility baseline (loading are above the baseline), edge of field losses must be reduced before credits are produced. Only reductions below the baseline can be sold as credits. The stricter the baseline, the less likely the practices adopted to produce credits could be considered business as usual.

The issue we are interested in is the possibility that nutrient management could be claimed as a new practice to produce credits when in fact it is actually a current practice. The difficulty of observing this practice would enable a farmer to benefit from misrepresenting his current practices and receive credits without changing management, even if a resource management agency attempted to verify current practices. These credits would be non-additional.

2.1 Data

We estimated field level nitrogen losses, nitrogen abatement and credits with data from the NRCS Conservation Effects Assessment Program (CEAP) study of the Chesapeake Bay Watershed. The CEAP assessment involved 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 over crop years 2001-2006. These observations represent the distribution of practices on all agricultural lands within the Bay watershed. In addition to the survey, NRCS simulated nitrogen losses of the pre-TMDL management (current practices) plus up to 7 different combinations of conservation systems that could be added to current practices to abate nitrogen:

- Cover crops
- Nutrient management practices

- 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

Details about the additional conservation systems are provided in the Appendix.

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). APEX is a field-scale model that simulates the 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 instream 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). HUMUS consists of: 1) 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); 2) a Geographic Information System to collect, manage, analyze and display the spatial and temporal inputs and outputs; 3) relational databases needed 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.

About 18 percent of cropland was under a nutrient management plan prior to the TMDL. We could not use these observations in our analysis because NRCS did not model these fields without nutrient management, which would be necessary to calculate the number of non-additional credits these fields could generate. For the purposes of this analysis we selected all observations that did not use nutrient management, representing 3,402,499 acres of cropland (82% of watershed cropland). We could then add nutrient management and observe the change in field-level losses and the number of credits that could be generated, given a particular eligibility baseline (assuming no trading ratios). Since we are interested in the potential for strategic behavior on the part of farmers currently using nutrient management to provide non-additional credits in a market, we treat the scenario with all cropland under nutrient management as business as usual.

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 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.

NRCS calculated 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 contain 28 unique crop rotations. We estimated the crop value based on reported

2010 state-level crop prices provided by USDA's National Agricultural Statistics Service (NASS). For some crops, state-level prices were not available (less than seven percent of 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 NASS. Nitrogen price reflects the U.S. average price ($499 per ton) for anhydrous ammonia, which is 82 percent nitrogen (N), or a price per active ingredient of $0.30 per lb.-N. Phosphorus price reflects the price per ton of superphosphate (46 percent 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) 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 Weiland 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 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 are maximizing 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 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 assured that the baseline scenario represents those practices that give 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.

2.2 Estimating the supply of credits in the Chesapeake Bay watershed

We defined an eligibility baseline in terms of nitrogen loss per acre of cropland, based on the approach Maryland is using in their trading program (Maryland Dept. of Ag., 2008). We examined eligibility baselines of 65, 45, 35, 25, and 15 lbs N loss per acre of cropland (Maryland's baseline ranges between 16 and 26 lbs of N per acre, depending on river basin). 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 meet baseline (if necessary) and to supply credits. 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 (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 for producing nitrogen loss reductions. 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 and overcoming inertia (ignoring any cost-share payments from conservation programs). If the observation meets the eligibility baseline, all subsequent abatement goes to the credit market. If the eligibility baseline is not met, subsequent abatement is allocated between meeting the baseline and the credit market. Adopting a single management system could often produce enough abatement to meet the baseline and to supply the credit market. If a producer misrepresents the use of nitrogen management (Farm 1 and Farm 2 in figure 1) the cost of credits is set to 0 as the producer is already using nutrient management and faces no additional management costs. Aggregating credit supply across all observations results in a sector credit supply curve for that baseline scenario. An advantage of this approach, made possible by the CEAP survey data, is that we can estimate rents for each observation given the price of a credit. This is in contrast to more aggregate modeling approaches that have recently been used to evaluate trading and other policies in the watershed, where each geographic sub-basin is treated as a farm. (Wainger et al., 2013; Van Houtven et al., 2012). It is this surplus that provides the incentive to misrepresent baseline.

For each baseline we estimated a credit supply curve assuming no misrepresentation of the use of nutrient management (all credits additional) and a supply curve assuming that those producers who would benefit misrepresent their use of nutrient management (some credits are non-additional). We assume two credit prices, $5 and $20, which bound the range of credit prices found for a hypothetical market in the Chesapeake Bay watershed (Ribaudo et al., 2014; Talberth et al., 2010a; 2010b). For each baseline we estimated the economic benefit from misrepresenting nutrient management for each observation, and averaged across cropland acres producing credits to come estimate the average incentive per acre of cropland.

3. Results

We start with a loading rate baseline of 65 lbs. N/acre (least stringent). About 90 percent of cropland in our sample would be able to meet this baseline without claiming nutrient management (table 1). This means that only 10 percent of crop acres already using nutrient management would be compelled to claim nutrient management as a current practice (Farm 3 in Figure 1).

What does this mean for credit supply? Ignoring trading ratios to account for uncertainty and assuming that there is no misrepresentation of baseline practices, the equilibrium quantity of credits supplied to the market is 2 million with a credit price of $5 (table 2). All of these credits would be additional. However, farmers meeting the baseline can gain, on average, an additional $62.01 per acre by misrepresenting baseline practices (table 3). If we assume that all farmers who benefit from misrepresenting their baselines cheat, the number of credits sold would increase to 38.9 million, 61 percent of which would be non-additional. This means that 23.8

million lbs. of N that point sources could discharge above their permit requirements would not be offset by additional or "real" reductions from agriculture.

With a credit price of $20 (higher demand for credits), the number of credits supplied when farmers accurately report baseline management increases to 17.1 million. However, the incentive for misrepresentation is strong, averaging $329.88 per acre (table 3). With misrepresentation, 43.4 million credits would be supplied, and about 55 percent would be non-additional. The number of non-additional credits is the same under both prices. Non-additional credits cost the farmer nothing, so they will always be offered for sale regardless of credit price.

Increasing stringency makes it less likely that a field will meet the eligibility baseline without claiming nutrient management as part of the baseline. With an eligibility baseline of 45 lbs. N/acre, only 0.5 million credits are supplied at a price of $5 per credit assuming no misrepresentation of baseline practices, a decrease of 75 percent from the 65 lbs/acre stringency level. This is the expected consequence of increasing the percentage of cropland that will need to install management practices just to be able to enter a trading market (Ghosh et al., 2011; Ribaudo and Gottlieb, 2010). With a potential economic gain of $41.23 per acre, on average, Farm 1 and Farm 2 producers in figure 1 have an incentive to misrepresent their management and offer non-additional credits. The number of credits supplied increases to 21.3 million. While the increase in baseline stringency reduces the supply of non-additional credits by 40 percent (a desirable outcome) the percentage of credits sold that are non-additional increases to 66 percent compared to the less stringent baseline. With increased stringency more fields must adopt practices just to enter the market (Farm 3 in figure 1), but with low credit prices few of these would profit by doing so. Since non-additional credits cost nothing, they make up a larger share of the market.

With a higher credit price more of the fields in the Farm 3 situation would be willing to enter the market, all providing credits that are additional. With misrepresentation, the percentage of credits that are non-additional falls compared to the less stringent scenario to about 41 percent of credits sold because of the increase in the supply of additional credits.

As the stringency level is further increased, the number of non-additional credits supplied under either credit price declines, as the percentage of fields characterized by Farm 1 and Farm 2 in figure 1 declines and the average return from misrepresenting baseline practices declines. With a credit price of $5, no fields can profitably produce credits without misrepresenting their use of nutrient management with stringency levels of 25 lbs. N/acre and less. However, with misrepresentation, about 1 million credits will be supplied under the most stringent baseline of 15 lbs. N/acre, all of them non-additional. At the higher credit price of $20, only 18 percent of credits supplied assuming misrepresentation would be non-additional. There are fewer Farm 1 and Farm 2 fields that can realize an economic benefit from misrepresenting their practices, and the higher credit price allows more of the Farm 3 types to profitably generate credits for the market that are additional.

4. Summary and discussion

When a farmer's actions cannot be monitored by a resource management agency (asymmetric information) for the purpose of assigning credits that can be sold in a point/nonpoint water quality trading market, the farmer has an economic incentive to misrepresent his management in order to increase the number of credits he is awarded. This is a moral hazard problem that leads to market failure and degraded environmental quality. Some non-structural management practices that are based upon the efficient management of inputs are nearly impossible to monitor. The inclusion of such practices in a point/nonpoint trading program where farmer participation is purely voluntary could lead to non-additional credits entering a market, which could threaten water quality. It is important to note that the presence of an incentive does not mean that farmers will necessarily misrepresent their management, but it creates the potential. Even if the probability of getting caught and sanctioned is low, it is difficult to believe all farmers would take advantage and misrepresent their management. We cannot estimate the propensity of farmers to cheat with the data we have. Such a line of research would shed light on how important this source non-additional credits might be.

We examined the use of an eligibility baseline to limit the incentive to misrepresent current practices. We showed that a stringent baseline does encourage farmers not to misrepresent management practices in their baselines for calculating credits. However, increasing baseline stringency makes additional credits more expensive, as abatement that is additional goes to meeting baseline rather than entering the trading market (Stephenson et al., 2010; Kramer, 2003; Ghosh et al., 2011; Ribaudo et al., 2014). Assuming standard downward sloping credit demand curves, equilibrium credit prices increase and trade volume decreases. Non-additional credits that are produced, even if in reduced amounts, will be able to outcompete additional credits in the market.

An alternative to using baseline stringency to assure additionality is to reduce information asymmetry through increased frequency of site audits and monitoring of farms and farmer records to establish pre-program management practices (Giannakas and Kaplan, 2005). Such an approach has drawbacks. One is high transaction costs, although these might be reduced by inspecting a random sample of farms.

Farmers may be unwilling to subject their operations to close inspection by a government agency and not enter a program that is voluntary (Mariola, 2012). Such inspections could be counter-productive when voluntary programs are the primary means of getting farmers to increase their supply of environmental services such as water quality. A potential solution would be to offer a financial incentive for on-site inspections (Ribaudo et al., 2014). Again, this might be costly way to compel farmers to participate.

Another option is to identify which practices are most susceptible to producing non-additional credits and exclude them from the trading market. In the case of the Chesapeake Bay, about 18 percent of cropland was using nutrient management prior to the TMDL (USDA, NRCS, 2011). Not allowing nutrient management as a practice that can produce credits would prevent non-additional credits from these fields, but the potential loss of additional credits from the remaining 82 percent of cropland not currently using nutrient management would likely be significant. Abatement could be achieved through more easily-observable structural practices such as cover crops, vegetative filters and constructed wetlands, but if nutrient management is the most efficient practice for reducing nutrient pollution, then the trading market would be adversely affected by the increased cost of abatement. Research has found that nutrient management is more cost-effective at reducing nutrients than vegetative buffers or restored wetlands (Ribaudo et al., 2001).

Appendix I – Model Management Practice Choices

Cover Crops – Cover crops are planted when the principal crops are not growing to provide soil surface cover and reduce soil erosion, and to remove excess nutrients remaining in the soil, preventing them from leaching or running off to surface water. For sample points in the baseline without a cover crop in the rotation, rye was planted as the cover crop. The cover crop was planted the day after harvest of the main crop, or the day after the last major fall tillage practice. The cover crop was not harvested for sale.

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

- All commercial fertilizer was applied 14 days prior to planting, except for acres susceptible to leaching loss
- For acres susceptible to leaching, nitrogen was applied in split applications
- Manure applications during winter months were moved to the spring
- All fertilizer and manure was incorporated or injected.
- All nitrogen application rates for all crops except cotton and small grains were limited to 1.2 times the crop removal rate. For small grains nitrogen applications were limited to 1.5 times the crop removal rate. For cotton, nitrogen applications were limited to 50 pounds per bale.
- Phosphorus application rates were adjusted to be equal to 1.1 times the amount removed in the crop at harvest

Water erosion control

- Terraces were added to all sample point with slopes greater than 6 percent, and to those with slopes greater than 4 percent and a high potential for excessive runoff (hydrologic soil groups C or D).
- Contouring or strip-cropping was added to all other fields with slope greater than 2 percent that did not already have those practices
- Fields adjacent to water received a riparian buffer
- Fields not adjacent to water received a filter strip
- No changes were made to tillage

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Table 1 – Percentage of crop acres in the Chesapeake Bay Watershed meeting eligibility baselines without claiming nutrient management.

Baseline	Acres meeting baseline without NM (1,000's)	Percent acres meeting baseline
65 lbs. N loss/acre	3,051.7	90
45 lbs. N loss/acre	2,879.6	85
35 lbs. N loss/acre	2,702.1	79
25 lbs. N loss/acre	2,252.7	66
15 lbs. N loss/acre	1,445.6	42

NM = nutrient management

Table 2 –Volume of additional and non-additional credits supplied in a trading market with and without misrepresentation (referred to here as cheating) for credit prices of $5 and $20.

	$5 per credit			$20 per credit		
Baseline	Credits supplied with no cheating	Credits supplied with cheating	Percentage of credits non-additional	Credits supplied with no cheating	Credits supplied with cheating	Percentage of credits non-additional
	millions			millions		
65 lbs. N loss/acre	2.0	38.9	61.0	17.1	43.4	54.7
45 lbs. N loss/acre	0.5	21.3	66.9	15.8	35.0	40.6
35 lbs. N loss/acre	0.1	10.5	85.6	13.1	27.4	32.7
25 lbs. N loss/acre	0	4.1	95.3	8.0	16.6	23.7
15 lbs. N loss/acre	0	1.0	100.0	3.0	5.6	18.3

Table 3 – Economic benefits to farmers for misrepresenting baseline nutrient management for different baseline requirements

	$5 per credit	$20 per credit
Baseline	Average per-acre returns from cheating	Average per-acre returns from cheating
	$/acre	
65 lbs. N loss/acre	62.01	329.88
45 lbs. N loss/acre	41.23	289.56
35 lbs. N loss/acre	29.22	243.50
25 lbs. N loss/acre	18.61	168.44
15 lbs. N loss/acre	12.32	96.06