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Additionality of Conservation Cost Sharing

Erik Lichtenberg

Department of Agricultural and Resource Economics
University of Maryland, College Park
elichten@umd.edu

Abstract. Subsidizing the adoption of on-farm conservation practices on working farmland has become the major policy instrument for addressing soil erosion, water quality impairments, and other environmental externalities from the farm sector. The additionality of these conservation cost sharing programs—and thus the extent to which they contribute to environmental quality improvements—is open to question. Many farmers adopt conservation practices voluntarily, making it likely that some farmers receive cost share awards for actions they would have taken without subsidization. On the opposite side of the coin, cost sharing for some conservation practices can have positive spillovers by inducing farmers to use complementary conservation practices they would not have used otherwise. We investigate the effect of cost sharing on overall conservation effort as measured by the number of conservation practices used. We use data from a 2010 survey of Maryland farmers. We model the number of conservation practices used as a function of the number of conservation practices for which cost sharing was received and farm and operator characteristics using a two-stage control function model to control for potential selection bias. We use the estimated coefficients of the model for the number of practices adopted to estimate counterfactuals and thus additionality. We find very high levels of additionality for farmers who received cost sharing and much lower additionality for farmers who did not receive cost sharing, suggesting diminishing environmental improvements from expanding cost share spending. That finding suggests further that gains from voluntary programs like water quality trading may be limited.

Keywords. Additionality, agricultural conservation, Chesapeake Bay, cost sharing, voluntary environmental programs, water quality trading.

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Introduction

Subsidizing the adoption of on-farm conservation practices on working farmland has become the major policy instrument for addressing soil erosion, water quality impairments, and other environmental externalities from the farm sector. At the federal level, the most recent three farm bills have authorized dramatic increases in spending on programs like the Environmental Quality Investment Program (EQIP) and the Conservation Stewardship Program (CSP) that subsidize conservation practice adoption while shrinking expenditures on the Conservation Reserve Program and other land retirement programs. At the regional level, efforts to meet water quality goals in the Chesapeake Bay and other watersheds have relied overwhelmingly on cost sharing to reduce nutrient runoff from agriculture.

The additionality of these conservation cost sharing programs—and thus the extent to which they contribute to environmental quality improvements—is open to question. Many farmers adopt conservation practices voluntarily because it protects the value of their land by reducing erosion or otherwise improving soil quality or because of a stewardship ethic or other pro-social preferences (see for example Schaible et al. 2015). Since participation in cost sharing programs is voluntary (and costly—see Peterson et al. 2014), it is likely that some farmers receive cost share awards for the adoption of practices would have used without subsidization. In fact, since all farmers are offered the same cost share subsidies, some non-additionality is inevitable (Horowitz and Just 2013). At the same time, cost sharing for some conservation practices can have positive spillovers by inducing farmers to use complementary conservation practices they would not have used otherwise (Lichtenberg 2004, Fleming 2017).

The literature to date has measured additionality of cost sharing in terms of effects on the use individual conservation practices (see for example Lichtenberg and Smith-Ramirez 2011, Mezzatesta et al. 2013, Chabé-Ferret and Subervie 2013, Claassen et al. 2013, Fleming 2017, and Fleming et al. 2017). In contrast, this paper studies the effect of cost sharing on overall conservation effort as measured by the number of conservation practices used. Conditions within individual farming operations typically vary in terms microclimate, topography, soils, terrain, proximity to water, and other landscape features that influence selection of crops and farming practices. That heterogeneity can make it efficient to implement more than one conservation practice on a farm (or even an individual field) to achieve adequate levels of soil and environmental quality protection. In such cases the number of conservation practices used is a good metric of overall conservation effort.

We use data from a 2010 survey of Maryland farmers. We estimate the number of conservation practices used as a function of the number of conservation practices for which cost sharing was received together with farm and operator characteristics using a negative binomial model to allow for overdispersion. We use a two-stage control function model that includes the residuals from a model of the number of practices for which cost sharing was received as a regressor to control for potential selection bias (Wooldridge 2010). We use the estimated parameters to construct counterfactual estimates of the expected number of practices adopted by each farm with and without cost sharing. We then use the difference between the observed and expected to estimate additionality attributable to receipt of cost sharing. Estimated additionality for those receiving cost share funds was quite high, ranging from 71% to 98%. Estimated additionality for those not receiving cost share funds was much lower, 56%, suggesting that extending cost share funds to those currently not participating the cost share programs would have a much lower return on investment.

Agricultural Conservation Cost Sharing Programs

Environmental policies affecting most industries in the US have been primarily regulatory, implemented by requiring emitters to engage in specific pollution control measures or through performance based approaches like the acid rain cap and trade program. Environmental policies in agriculture, by contrast, have taken the form of paying farmers to install conservation structures or adopt conservation measures that reduce emissions of pollutants like nutrients and sediment or protect wildlife habitat.

Prior to 2002, the primary vehicle for agri-environmental policy in the US was the Conservation Reserve Program (CRP), under which the US Department of Agriculture enters into long term contracts in which farmers agree to convert highly erodible cropland to conservation uses like grassland or trees in return for annual rental payments and partial subsidization of establishment costs. Beginning with the 2002 farm bill, the emphasis shifted from land retirement to subsidization of conservation practices on working farmland. The cap on acreage to be enrolled in the CRP was cut while existing programs based on sharing the cost of implementing conservation measures on working farmland were expanded and new cost share programs aimed at working farmland were created. As a result, by 2016 CRP spending accounted for only about half of USDA conservation spending, down from 99% twenty years earlier (Lichtenberg 2017).

The main vehicle for conservation cost sharing has been the Environmental Quality Incentives Program (EQIP), created in 1996 by consolidating earlier conservation cost sharing programs. EQIP provides subsidies of up to 75% of the cost of installing new conservation structures or purchasing new equipment needed for implementing conservation practices. The 2002 farm bill increased authorized funding for EQIP markedly, from $400 million in FY 2002 to $1.3 billion in FY 2007. The 2008 farm bill increased authorized EQIP spending to $7.325 over FY 2008-2012 up from $4.92 billion over FY 2002-2007. In line with reductions in overall federal spending, the 2014 farm bill cut authorized EQIP spending, albeit by an average of only $50 million annually.

In 2002, Congress added a new program to subsidize conservation on working farmland, the Conservation Security Program. The Conservation Security Program featured long term contracts in which farmers in selected watersheds were paid to utilize conservation practices that might or might not require new equipment—including maintaining conservation practices already in use. Farmers entering into contracts to maintain or expand conservation practices on their working farmland received payments ranging from 5% to 15% of the national average rent for land in similar use (subject to payment caps ranging from $25,000 to $45,000), depending on the level of conservation effort to be expended. The 2008 farm bill replaced the Conservation Security Program with a revised version, renamed the Conservation Stewardship Program (CSP). The CSP replaced the Conservation Security Program’s tiered payments based on national average rental rates with payments based on the cost of the conservation measures to be implemented and the environmental benefits to be gained from those conservation measures. The 2008 farm bill authorized the CSP to enroll 12.77 million acres annually at an average cost of $18 per acre. The 2014 farm bill reduced CSP authorized spending by cutting the cap on enrollment to 10 million acres.

EQIP and CSP funds are allocated to states according to formulas based largely on the amount of farming activity in each state. Funds in each state are then distributed among counties, again on the basis of formulas that measure the amount of agricultural activity. County committees composed of representatives elected by and from farm businesses in each county allocate those funds among project proposals that have been reviewed and approved by local USDA Natural Resource Conservation Service technicians (Lichtenberg 2017).

As a small state, Maryland gets relatively little in the way of federal conservation funds. But cost sharing has played a large role in its efforts to address agricultural contributions to water quality problems from nutrient pollution nonetheless. In 1983, the states of Maryland, Virginia, and Pennsylvania, the District of Columbia, and the US Environmental Protection Agency (EPA) signed an agreement to reduce nitrogen and phosphorus levels in the Chesapeake Bay by 40% by the year 2000. A subsequent agreement in 2000 renewed that goal and provided means of participation by the upstream states of West Virginia, New York, and Delaware. EPA is currently in the process of formulating water quality regulations for the Bay based on total maximum daily loads (TMDLs) from all sources, including nonpoint sources like farming, stormwater, and septic systems in addition to point sources like sewage treatment plants, industrial dischargers, and large confined animal feeding operations.

Maryland in particular has been relatively aggressive in using cost sharing of conservation practices to reduce nutrient runoff from agriculture as part of its effort to meet Chesapeake Bay water quality goals. The Maryland Agricultural Cost Share (MACS) program, established in the mid-1980s, reimburses farmers for up to 87.5% of the cost of installing conservation structures like grass waterways or establishing conservation practices like contour farming and stripcropping. Between 1984 and 2016, an average of 806 such project were completed each year with MACS funding. Grass waterways were the most commonly cost shared conservation measure over that period, accounting for about a quarter of all projects completed during that time. Watering facilities, waste storage structures, and grade stabilization structures each accounted for about 8% of all projects completed during that time, while vegetated treatment areas and riparian forest buffers each accounted for about 6% of all projects completed during that time.

MACS also pays farmers a flat rate to plant winter cover crops in order to take up nitrogen left over from the growing season before it runs off into the Bay or its tributaries. In 2005, MACS starting using supplemental funds (first from NRCS, subsequently from the Chesapeake Bay 2010 Trust Fund and Chesapeake Bay Restoration Fund) to expand the cover crop program. Acreage planted in cover crops under this program grew from under 30,000 acres in 2004 to over 500,000 acres in 2016. Finally, MACS has provided subsidies to help farmers prepare nutrient management plans required under Maryland's 1998 Water Quality Improvement Act and, more recently, to purchase equipment for injecting or incorporating manure to prevent runoff. Total MACS spending grew from an average of $3.8 million during 1984-2004 to $32.6 million in 2016, due largely to the expansion of the cover crop program, which has accounted for about 80% of MACS expenditures since 2011 (Maryland Agricultural Cost Share Program 2004-2016).

Previous Literature

Only a handful of studies to date has investigated additionality of cost sharing. All of them have focused on how cost sharing influences the use individual conservation practices.

Lichtenberg and Smith-Ramirez (2011) use data from a 1998 survey of Maryland farmers to study the effect of cost share receipt. Using a switching regression model to control for selection bias and a tobit specification of the extent of conservation practice use, they investigate (a) the probability that a Maryland farmer planted cover crops or used contour farming/stripcropping and (b) the share of farm area on which each of those practices was used.

They find that receipt of cost sharing for any one of almost two dozen conservation measures influenced the probability that farmers used either cover crops or contour farming/stripcropping but not the share of acreage on which they were used, suggesting a high level of additionality. They also find that receipt of cost sharing was associated with substantial reductions in vegetative cover, which would at least partially offset any reductions in nutrient emissions from increased cover crop or contour farming/stripcropping use.

Mezzatesta et al. (2013) use data from a 2009 survey farmers in the Greater Miami River watershed in Ohio to study the effect of cost sharing on the use of six conservation practices: conservation tillage, cover crops, hayfield (or grassland) establishment, grid sampling, grass waterways, and filter strips. Using propensity score matching, they find high levels of additionality for hayfield establishment, cover crops, and filter strips but low levels of additionality for conservation tillage and grass waterways.

Chabé-Ferret and Subervie (2013) use data from Ministry of Agriculture surveys conducted in 2003 and 2005 combined with information from the 2000 Census of Agriculture to study the effects of agri-environmental subsidies on the use of conservation practices, conversion to organic farming, and other farm activities. In terms of conservation practices, they use a difference-in-difference matching model to estimate how participation in France’s agri-environmental subsidy program affects French farmers’ use of cover crops and grass buffer strips. They find high levels of additionality for buffer strips but low levels of additionality for cover crops.

Claassen et al. (2013) use data from the Agricultural Resource Management Surveys for wheat (2009), corn (2010), and barley and sorghum (2011) to study the effects of participation in EQIP, CSP, CRP, and other federal programs on the use of four classes of conservation measures (buffers, soil conservation structures, conservation tillage, and nutrient management plans) on individual fields. Using propensity score matching, they find additionality ranging from 54% (for conservation tillage) to 83% (for nutrient management plans).

Fleming (2017) uses data from the 2010 survey of Maryland farmers used in this paper to investigate the effects of participation in Maryland’s cover crop program on the use of three conservation practices: cover crops, conservation tillage, and contour farming/stripcropping. Following Lichtenberg and Smith-Ramirez, he estimates a switching regression model of cover crop program participation combined with a tobit model of the shares of operating acreage on which these conservation practice are used. He finds positive spillovers between practices, specifically, that receipt of cost sharing for cover crops led farmers to use cover crops and conservation tillage on substantially larger shares of acreage than they otherwise would have.

Fleming et al. (2017) extend Fleming’s (2017) study to consider the effects of cover crop program participation on vegetative cover, conservation tillage, and water quality. The find high levels of additionality, on the order of 97% for current cover crop program participants and 90% for current non-participants. They also find slippage large enough to reduce reductions in nitrogen runoff by close to 50%. Like Fleming (2017), they find substantial complementarity between cover crop and conservation tillage use; that complementarity translates into very little impact on nitrogen runoff, however.

Data

We use data from a 2010 survey of Maryland farmers drawn from the Maryland Agricultural Statistics Service (MASS) master list of farmers. The survey was administered by mail with telephone follow up using a stratified random sampling design in order to obtain a sufficient number of responses from large operations. Sampling weights were based on annual sales categories reported in the 2008 Census of Agriculture. The survey questionnaire was mailed to 1,000 farm operations with telephone follow-up administered by MASS in 2010. Stratified random sampling ensured sufficient response from large operations, and expansion factors were provided by MASS for deriving statewide population estimates. A total of 523 responses were received; of those, 458 provided information sufficient to be used in this analysis.

The survey instrument asked farmers whether they used each of 13 categories of conservation practices in 2010[1]; the acreage served by each practice used; whether they had ever received cost sharing for each practice; and the most recent year in which cost sharing had been received. The questionnaire also asked for information on the farm operation (acreage operated, owned, rented in and out; acreages in major crops; livestock numbers), farm finance (farm sales in 2009, share of household income from farming), demographics (age, education level, years managing a farm), proximity to water bodies, topography, and nutrient management.

The survey sample is broadly representative of Maryland farms as characterized by the 2012 Census of Agriculture (Table 1). The share of farms in our sample with crops is roughly equal to that in the Census, as are the shares growing corn and raising cattle or horses. The shares of farmers in our sample growing soybeans, small grains, hay, and vegetables are slightly higher than those in the Census while the shares of farmers raising broilers or sheep and goats are correspondingly smaller. Acreage owned by the farms in our sample is somewhat lower than the average acreage in farms calculated from the Census. Average acreages in corn, soybeans, small

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[1] The 13 conservation measures included in the survey are cover crops, conservation tillage, contour farming, stripcropping, forested riparian buffers, grass riparian buffers, vegetative cover, wetland restoration, water conveyance and storage practices, waste storage structures or lagoons, heavy use poultry area concrete pads, and retirement of highly erodible land.

grains, and vegetables are higher than the Census averages. Farmers in our sample are older on average than those in the Census as well.

The survey asked farmers whether they used each of 13 different classes of conservation practices during 2010 and, if so, whether they had received cost sharing for each one used. Table 2 shows the joint distribution of number of practices used and number of practices cost shared. Use of these conservation practices is quite common in Maryland: An estimated two-thirds of Maryland farmers use at least one of these practices and 45% use two or more. Roughly one quarter are estimated to have received cost sharing for one or more conservation practices, about half of whom received cost sharing for one practice only. Most farmers who received cost sharing reported using a larger number of practices than they received cost sharing for.

Summary statistics for the 458 observations used in the econometric analysis, weighted using the revenue-based expansion factors provided by MASS, are shown in Table 3.

Econometric Model Specification and Estimation

Our goal is to estimate how cost sharing affects overall conservation effort as measured by the number of conservation practices a farmer uses. We therefore model the expected number of conservation practices used by farmer j, NU_j, as a function of the number of conservation practices for which cost sharing was received, NCS_j, characteristics of the farm operation and farm operator, X_j, including the log of acreage operated, the share of operated land rented, the share of household income from farming, the farmer's education level, the shares of moderately and highly sloped land on the farm, the number of animal units on the farm, whether the farm had 50 or more acres of corn, soybeans, and small grains, and annual sales of farm products (which is measured categorically):

$$NU_j = \alpha NCS_j + X_j\beta + u_j$$

It is likely that unobserved factors influence both the number of conservation practices used and the number receiving cost sharing, as both decisions are likely made simultaneously. We use two measures of environmental benefits—whether the farm is adjacent to a water body and the distance to the nearest water body for farms that are not adjacent to a water body—as instruments for the number practice receiving cost sharing on the grounds that these proxies for water quality risk matter to MACS but not to the farmer, who treats water quality benefits as externalities (see for example Lichtenberg and Smith-Ramirez 2011, Fleming 2017, and Fleming et al. 2017):

$$NCS_j = \gamma\mathbf{1}[Adjacent_j] + \theta Distance_j + Z_j\delta + v_j$$

The set of explanatory variables Z_j influencing the number of conservation practices for which cost sharing was received include all of the regressors in the equation for the number of conservation practices used with annual sales of farm products omitted (i.e., the model includes the log of acreage operated, the share of operated land rented, the share of household income from farming, the farmer’s education level, the shares of moderately and highly sloped land on the farm, the number of animal units on the farm, and whether the farm had 50 or more acres of corn, soybeans, and small grains).

We use a two-stage control function model that uses the residuals from a model of the number of practices for which cost sharing was received to control for potential bias (Wooldridge 2010). The second stage estimating equation is thus

$$NU_j = \alpha NCS_j + X_j\beta + \rho\hat{v}_j + u_j$$

The coefficient of the estimated first stage residual, ρ, measures the correlation between unobserved variables influencing both the number of practices used and the number of practices cost shared.

Both the number of practices used and the number of practices for which cost sharing was received are assumed to have a truncated negative binomial distribution. The negative binomial is a discrete distribution that allows for overdispersion. The distribution is truncated at 13 since the survey only asks about 13 different classes of conservation practices. The log likelihood associated with farmer j's receipt of cost sharing for NCS_j practices is thus assumed to be (Cameron and Trivedi 2013)

$$\begin{aligned}
\ln\big(L_j\big) = {} & \sum\nolimits_{k=0}^{NCS_j-1} \ln(k+\sigma^{-1}) - lnNCS_j! - \big(NCS_j+\sigma^{-1}\big)\ln(1+\sigma\exp(\gamma\mathbf{1}[Adjacent_j] \\
& + \theta Distance_j + Z_j\delta) + NCS_j\big[ln\sigma + (\gamma\mathbf{1}[Adjacent_j] + \theta Distance_j + Z_j\delta)\big] \\
& - ln\Big(\sum\nolimits_{m=0}^{13}\Big\{\sum\nolimits_{k=0}^{m-1} ln(k+\sigma^{-1}) - lnm! - (m+\sigma^{-1})ln(1 \\
& + \sigma exp(\gamma\mathbf{1}[Adjacent_j] + \theta Distance_j + Z_j\delta) \\
& + m\big[ln\sigma + (\gamma\mathbf{1}[Adjacent_j] + \theta Distance_j + Z_j\delta)\big]\Big\}\Big)
\end{aligned}$$

Similarly, the likelihood associated with farmer j's use of NU_j conservation practices is

$$\begin{aligned}
\ln\big(L_j\big) = {} & \sum\nolimits_{k=0}^{NU_j-1} \ln(k+\psi^{-1}) - lnNU_j! - \big(NU_j+\psi^{-1}\big)\ln(1+\sigma\exp(\alpha NCS_j + X_j\beta + \rho\hat{v}_j) \\
& + NU_j\big[ln\psi + (\gamma\alpha NCS_j + X_j\beta + \rho\hat{v}_j)\big] \\
& - ln\Big(\sum\nolimits_{m=0}^{13}\Big\{\sum\nolimits_{k=0}^{m-1} ln(k+\psi^{-1}) - lnm! - (m+\psi^{-1})ln(1+\psi exp(\alpha NCS_j \\
& + X_j\beta + \rho\hat{v}_j) + m\big[ln\psi + (\alpha NCS_j + X_j\beta + \rho\hat{v}_j)\big]\Big\}\Big)
\end{aligned}$$

The residual from the first stage model is the difference between the observed and expected number of practices cost shared:

$$\hat{v}_j = NCS_j - exp\left(\gamma \mathbf{1}[Adjacent_j] + \theta Distance_j + X_j \delta\right)$$

Both the first and second stage models are estimated by maximum likelihood in Stata using the Newton-Raphson algorithm in the *trncregress* routine. All observations are weighted using the expansion factors provided by MASS.

Estimated Negative Binomial Models

The regressors in both the first stage model of the number of conservation practices receiving cost share funds and the second stage model of the number of conservation practices used have substantial explanatory power, as indicated by respective χ^2 statistics of 2903.1 and 5237.44 for the hypothesis that their coefficients are all equal to zero. Both equations exhibit overdispersion, as indicated by dispersion parameters significantly different from zero at a 5% level (Tables 4 and 5). The signs of the estimated coefficients are in accord with findings from the literature. Farmers with larger crop and animal operations, those with higher levels of education, and those with larger shares of acreage with moderate slopes receive cost sharing for larger numbers of conservation practices. Farmers who own larger shares of the land they operate and who have grain operations use larger numbers of conservation practices. Interestingly, both commercial size operations (those with annual sales of farm products of $100,000 or more) and very small operations (those with annual sales of farm products between $2500 and $20,000) use larger numbers of conservation practices as well; this latter group likely consists of hobby farmers with substantial non-farm incomes.

The indicator for whether the farm is adjacent to a water body and the distance to the closest water body for farms not adjacent to a water body are both good instruments for the number of conservation practices receiving cost share funding. The coefficients of both are significantly different from zero in the first stage equation both individually (Table 4) and simultaneously (with a likelihood ratio test statistic of 5.19 and a corresponding p-value of 0.07). Their coefficients are not significantly different from zero in the second stage equation for the number of conservation practices used: their respective individual t-statistics are 0.81 and 0.37 with corresponding p-values of 0.42 and 0.71 while the likelihood ratio test statistic for the hypothesis that both are simultaneously equal to zero is 0.66 with a corresponding p-value of 0.72.

The coefficient of the number of conservation practices for which cost share funds were received is positive and significantly different from zero in the second stage equation for the number of conservation practices used, indicating that receipt of cost share funds increases overall conservation effort. The coefficient of the first stage residual is not significantly different from zero at any reasonable significance level, indicating the absence of correlation between unobservables affecting both cost share receipt and overall conservation effort.

As a robustness check, we estimate both the first and second stage models without weights and using a non-truncated negative binomial with and without weights. We also estimate all four specifications (truncated/non-truncated, weighted/unweighted) using a specification with an indicator for the presence of a livestock enterprise in place of the size of the livestock enterprise (number of animal units). The coefficient estimates are highly robust across specifications. The estimated coefficients of the truncated and non-truncated models are almost identical in both the weighted and unweighted versions. The estimated coefficients in the unweighted versions have the same signs and are close in magnitude to the weighted versions. Treating livestock qualitatively (using an indicator of whether livestock are present) rather than quantitatively (as the number of animal units) has virtually no effect on the estimated coefficients.

Additionality

The goal of this paper is to estimate the additionality of cost share receipt, i.e., the effect of cost sharing on overall conservation effort as measured by the number of conservation practices used. We use the estimated coefficients of the second stage model for the number of practices adopted to estimate counterfactuals and thus the effect of cost sharing on the total number of conservation practices used (i.e., the effect of treatment on both the treated and untreated) as a measure of additionality. The estimated effect of cost share receipt on those who received it (i.e., the expected effect of treatment on the treated) is

$$\Delta_j = NU_j - exp\left(X_j\hat{\beta} + \hat{\rho}\hat{v}_j\right), \qquad j \in \{NCS_j > 0\}$$

The corresponding effect of cost sharing receipt on those who did not receive it (i.e., the expected effect of treatment on the untreated) is

$$\Delta_j = exp\left(\hat{\alpha}NCS_j + X_j\hat{\beta} + \hat{\rho}\hat{v}_j\right) - NU_j, \qquad j \in \{NCS_j = 0\}$$

Finally, we calculate additionality associated with each number of practices cost shared as the weighted average of the expected effects of cost share receipt using the expansion factors provided by MASS, ω_j, as weights:

$$Additionality_n = \sum_{j \in \{NCS_j = n\}} \omega_j \Delta_j$$

These calculations indicate that additionality has been extremely high on average among Maryland farmers who have received cost share funds (Table 6). Our estimates indicate that farmers who received cost sharing for a single conservation practice, for instance, would have used an average of 0.03 conservation practices had they not received cost sharing, corresponding to additionality of 97%. Among those receiving cost sharing for 2-6 conservation practices, estimated additionality ranged from 71% to 93%. Additionality was lowest for farmers receiving cost share awards for 2-3 conservation practices and higher for those receiving cost share funding for 4-6 conservation practices.

Additionality was considerably lower on average for farmers who did not receive cost share awards, only 56%, suggesting decreasing marginal returns to cost share spending. Low average expected additionality for those currently not participating in cost share programs suggests further that would result in smaller gains in environmental quality, corresponding to smaller gains in additional conservation effort. This finding indicates that simple extrapolation from current spending is likely to be a poor predictor of the impact of expanding voluntary conservation programs in agriculture. One should not expect increases in budgets to achieve as much conservation for the buck as at present. Instead, inducing participation from current non-participants is likely to achieve much lower levels of additional conservation effort, with correspondingly lower improvements in environmental quality.

More generally, this finding suggests that low cost supplies of nutrient reductions from implementing agricultural conservation practices are likely to be quite limited—which implies in turn that cost reductions from water quality trading are likely to be correspondingly limited. Analyses of nutrient reduction measures from agriculture frequently assume the same average nutrient reduction level and implementation cost for the use of any given conservation measure.

Our findings indicate that payments likely exhibit decreasing marginal returns in the sense that a payment of any given size will achieve smaller and smaller additional reductions in nutrient emissions as cumulative adoption of conservation measures increases, implying increasing marginal cost of nutrient reductions. As additionality falls, the marginal cost of achieving nutrient reductions from voluntary adoption of conservation practices will rise, shrinking any difference between the marginal cost of nutrient reduction in agriculture and other sources like sewage treatment.

For Maryland and the Chesapeake Bay, that finding suggests further that expanding agricultural conservation programs in which participation is voluntary—including water quality trading—is unlikely to provide sufficient reductions in agricultural nutrient emissions to meet water quality goals for the Bay. The Chesapeake Bay Program (2016), for example, estimates that nitrogen emissions from agriculture in all states in the Bay watershed needed to be lowered by 18% from 2015 levels to meet 2017 interim target levels and by 34% to meet 2025 target levels. Progress in Maryland has been greater than elsewhere but the state still needs to lower agricultural nitrogen emissions by 6% from 2015 levels to meet the 2017 interim target and 16% to meet the 2025 target. The state of Maryland has introduced a limited program of payments for water quality credits while the Bay Program is in the process of devising a trading system to help meet water quality goals under TMDL regulations. The additionality estimates from this study suggest that it will be difficult to meet those targets relying on water quality trading unless farmers have to meet relatively stringent mandatory baselines for nutrient reductions before they can sell nutrient reduction credits.[2]

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[2] Horowitz and Just (2013) show theoretically that it will be optimal to set baselines resulting in payment for some non-additional reductions in nutrient emissions as long as participation is voluntary and the government can only offer a uniform subsidy level. Our findings provide empirical support for that conclusion.

Conclusion

Voluntary payment for ecosystem services (PES) programs have been the principal means of addressing environmental externalities from agriculture, most notably in developed countries like the US. The most recent three US farm bills, for example, have authorized large increases in spending on programs that pay farmers to adopt conservation practices, to the point where expenditures on these programs equal those for land retirement. Cost sharing adoption of conservation practices has also been the principal policy instrument used in efforts to to reduce nutrient runoff from agriculture in the Chesapeake Bay and other watersheds

Questions have been raised as to the additionality of these conservation cost sharing programs. Many farmers adopt conservation practices voluntarily. Since participation in cost sharing programs is voluntary, it is likely that some farmers are awarded cost share funds to implement conservation practices would have adopted without cost sharing. We investigate the additionality of conservation cost sharing using data from Maryland, a state that has used cost sharing aggressively to reduce agricultural nutrient emissions into the Chesapeake Bay and its tributaries. We estimate the number of conservation practices used as a function of the number of conservation practices for which cost sharing using a two-stage control function approach to control for potential bias. We estimate additionality using the estimated parameters of the second stage model to construct counterfactual estimates of the expected number of practices adopted by each farm with and without cost sharing.

Estimated additionality for those receiving cost share funds was quite high, ranging from 71% to 98%. Estimated additionality for those not receiving cost share funds was much lower, 56%, suggesting that extending cost share funds to those currently not participating the cost share programs would achieve less reduction in nutrient emissions, implying diminishing marginal returns to expanding voluntary cost sharing programs and thus increasing marginal costs of agricultural nutrient reductions from voluntary programs, including water quality trading with no or low regulatory baselines farmers must meet before they can sell water quality credits.

Studying additionality of conservation cost sharing has been feasible in Maryland because of the state's aggressive use of cost sharing to address nutrient runoff from agriculture into the Chesapeake Bay. Maryland is unusual in having high levels of unsubsidized conservation practice use among farmers: Data from the survey used in this study indicate that almost 40% of Maryland farmers use at least one of the classes of conservation practices included in the survey. The state's varied topography and the sandy soils of the state's major agricultural areas presumably make investments in soil conservation profitable; the prominence of Chesapeake Bay water quality in state politics may make some investment in farm conservation measures expedient as well.

The experience of other states is likely quite different than Maryland's. Within the Chesapeake Bay watershed, for instance, Pennsylvania lags far behind Maryland in addressing agriculture nutrient emissions into the Bay. The situation in the states of the Mississippi River watershed whose agricultural nutrient emissions contribute to the dead zone in the Gulf of Mexico is likely more similar to Pennsylvania than Maryland. It would be interesting to investigate additionality of conservation cost sharing in these other states; the expansion of EQIP and CSP in recent farm bills may have made it feasible to do so.

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Table 1. Comparison of Survey Sample (2010) with All Maryland Farmers (2012) and Descriptive Statistics of Explanatory Variables

	2012 Census of Agriculture	**Survey Sample** [a]
Share of Farms with		
Cattle	0.285	0.317
Sheep or Goats	0.128	0.112
Horses	0.266	0.243
Broilers	0.064	0.021
Crops	0.757	0.748
Corn [b]	0.289	0.314
Soybeans	0.205	0.287
Small Grains [c]	0.147	0.260
Forage [d]	0.358	0.455
Vegetables	0.064	0.105
Average Acres in		
Farm	166	137
Corn [b]	135	218
Soybeans	189	222
Small Grains [c]	99	119
Forage [d]	41	44
Vegetables	36	46
Other Farm Characteristics (Average)		
Operator Age (Years)	59	63

[a] Sample survey statistics weighted using revenue-class-based expansion factors from the Maryland Agricultural Statistics Service.

[b] Sum of corn for grain and silage in Census of Agriculture. Overlap not accounted for.

[c] Sum of wheat and barley in Census of Agriculture. Overlap not accounted for.

[d] Sum of hay and haylage in Census of Agriculture. Overlap not accounted for.

[e] Acreage operated includes acreage rented in/out and used free. Farm acreage includes only acreage owned.

Table 2. Number of Conservation Practices Used versus Number of Practices Cost Shared

Number of Practices Used	**Share of Maryland Farmers Receiving Cost Sharing by Number of Practices Cost Shared**									
	0	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***Total***
0	0.355	-	-	-	-	-	-	-	-	***0.355***
1	0.169	0.030	-	-	-	-	-	-	-	***0.199***
2	0.063	0.029	0.021	-	-	-	-	-	-	***0.112***
3	0.060	0.020	0.017	0.005	-	-	-	-	-	***0.103***
4	0.036	0.020	0.011	0.007	-	-	-	-	-	***0.073***
5	0.035	0.011	0.005	0.009	0.007	0.003	-	-	-	***0.070***
6	0.016	0.007	0.010	0.003	0.004	0.002	-	-	-	***0.042***
7	0.004	0.004	0.001	0.002	0.006	0.003	0.002	-	-	***0.022***
8	0.004	0.002	0.002	0.001	0.002	0.002	-	-	-	***0.014***
9	-	-	-	-	-	0.002	0.002	0.001	-	***0.005***
10	-	-	-	-	-	0.001	-	0.001	-	***0.001***
11	-	-	-	-	-	-	0.001	-	-	***0.001***
12	-	-	-	-	-	-	-	-	0.002	***0.002***
Total	***0.741***	***0.124***	***0.067***	***0.026***	***0.020***	***0.013***	***0.005***	***0.001***	***0.002***	
Share of farmers in each cell calculated from full sample of 523 respondents using survey weights.										

Table 3. Descriptive Statistics of the Farm and Farm Operator Characteristics Used in the Econometric Model

Variable	**Mean**	**Standard Deviation**
High School or Some College (0/1)	0.57	0.50
Completed College or Postgraduate Degree (0/1)	0.29	0.45
Log Acres Operated	4.93	1.67
Share of Operated Acreage Rented In	0.17	0.31
Percent of Household Income from Farming	34	41
Has 50 Acres or More of Corn, Soybeans, and Small Grains (0/1)	0.44	0.50
Animal Units of Cattle, Sheep, Goats, Horses, and Poultry	65	40
Percent of Land with Moderate Slope	40	
Percent of Land with Steep Slope	9	21
Distance to Closest Water Body (Miles)	0.53	1.78
Adjacent to a Water Body (0/1)	0.77	0.42
Percent with Annual Farm Sales:		
Less than $1,000	20.15	
$1,000-2,499	21.13	
$2,500-4,999	8.69	
$5,000-9,999	9.18	
$10,000-19,999	7.75	
$20,000-39,999	6.76	
$40,000-99,999	5.83	
$100,000-249,999	8.90	
$250,000-499,999	6.12	
$500,000-999,999	3.41	
$1,000,000 or more	2.48	

Sample survey statistics weighted using revenue-class-based expansion factors from the Maryland Agricultural Statistics Service. Acreage operated includes acreage rented in/out and used free.

Table 4. Estimated Coefficients of the First Stage Truncated Negative Binomial Model of Cost Share Receipt

Explanatory Variable	**Coefficient**	**Standard Error**
Adjacent to Water Body (0/1)	0.5543894	0.275835***
Distance to Closest Water Body (Miles)	0.0890941	0.051107*
Share of Operated Acreage Rented In	0.0883394	0.331523
Log Acreage Operated	0.3843072	0.108147***
Percent of Household Income from Farming	0.0033412	0.002771
Animal Units of Cattle, Sheep, Goats, Horses, and Poultry	0.0008823	0.000456*
Has 50 Acres or More of Corn, Soybeans, and Small Grains (0/1	0.5320765	0.295659*
High School or Some College (0/1)	1.099051	0.408608***
Completed College or Postgraduate Degree (0/1)	1.874585	0.452909***
Percent of Land with Moderate Slope	0.0060219	0.002388**
Percent of Land with Steep Slope	0.0084517	0.006834
Constant	-5.102532	0.693105***
Dispersion Parameter	1.16783	0.240259***
*** Significantly different from zero at a 1% level. ** Significantly different from zero at a 5% level. * Significantly different from zero at a 10% level. Standard errors are heteroscedasticity-robust.		

Table 5. Estimated Coefficients of the Second Stage Truncated Negative Binomial Model of Number of Practices Used

Explanatory Variable	Coefficient	Standard Error
Number of Practices Cost Shared	0.2884419	0.043586***
First Stage Residual	-0.0002435	0.003084
Share of Operated Acreage Rented In	-0.2708868	0.123724**
Log Acreage Operated	0.0628319	0.053929
Percent of Household Income from Farming	-0.0005765	0.001354
Animal Units of Cattle, Sheep, Goats, Horses, and Poultry	0.0000113	0.000109
Has 50 Acres or More of Corn, Soybeans, and Small Grains (0/1	0.6569495	0.133573***
High School or Some College (0/1)	-0.113333	0.185952
Completed College or Postgraduate Degree (0/1)	0.0312653	0.226495
Percent of Land with Moderate Slope	0.0016964	0.001182
Percent of Land with Steep Slope	0.0014055	0.002573
Annual Farm Sales		
$1,000-2,499	0.3532147	0.274044
$2,500-4,999	0.7221335	0.297083**
$5,000-9,999	0.6465693	0.276081**
$10,000-19,999	0.5809173	0.278033**
$20,000-39,999	0.4059621	0.274198
$40,000-99,999	0.3568822	0.282808
$100,000-249,999	0.6307111	0.285569**
$250,000-499,999	0.6507128	0.277121**
$500,000-999,999	0.5915634	0.32906*
$1,000,000 or more	0.5648431	0.383492
Constant	-0.5224554	0.359257
Dispersion Parameter	0.1907586	0.083942**

*** Significantly different from zero at a 1% level.
** Significantly different from zero at a 5% level.
* Significantly different from zero at a 10% level.
Standard errors are heteroscedasticity-robust.

Table 6. Estimated Additionality of Conservation Cost Sharing

Number of Conservation Practices Cost Shared		Estimated Additionality	Number of Observations
Actual	***Expected***		
0	0.5616325	56%	270
1	0.9729941	97%	73
2	1.675667	84%	44
3	2.143284	71%	20
4	3.519568	88%	16
5	4.633061	93%	11
6	5.24725	87%	6
Too few farmers (1-2 only) received cost sharing to permit calculation of average additionality.			