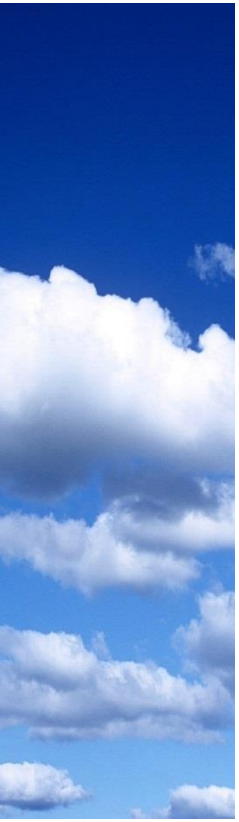

Agricultural BMPs and Cost-Sharing

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MACS cover crop program

- Cost sharing of agricultural best management practices (BMPs)
  - Maryland Agricultural and Water Quality Cost Sharing (MACS) program
    - MACS spent $26.7 million in 2013 (80% for cover crops)
  - Federal conservation programs
    - EQIP spent $1.38 billion in 2012

- Total Maximum Daily Load (TMDL) for Chesapeake Bay
  - Nitrogen (N), Phosphorus (P), and Sediment (Sed) reduction of 25%, 24% and 20% by 2025
  - Agriculture is a major source accounting for about 36% of N, 50% of P, and 50% of Sed reaching the Chesapeake Bay

Research Objectives

- Analyze the effectiveness of MACS cover crop program
  - **Direct effect** on cover crops
    - Change in proportion acreage in cover crop with versus without cost sharing for cover crops
  - **Indirect effect** on other field practices (no-till & contour/strip)
    - Change in proportion acreage in other field practices with versus without cost sharing for cover crops

- Effectiveness of MACS cover crop program to reduce nutrient and sediment loads in the Chesapeake Bay
  - Enrolled and unenrolled farmers
  - Variation by major river basin

Program evaluation for agricultural cost sharing

- Voluntary enrollment in cost share programs may result in self-selection bias
  - Mezzatesta, Newburn, and Woodward 2013
- Substitution (indirect) effects among practices
  - Lichtenberg 2004; Cooper 2003; Khanna 2001; Wu and Babcock 1998; Dorfman 1996

Outline

- Farmer survey in Maryland
- Regression analysis
  - Enrollment in cost share programs
  - Proportion acreage in BMP
- Average treatment effects
  - Enrolled farmers
  - Unenrolled farmers
- Chesapeake Bay Program (CBP) model and water quality
  - Nutrient and sediment reduction by major river basin
    - Eastern Shore
    - Potomac
    - Patuxent/Western Shore/Susquehanna

Farmer survey in Maryland

- Administered in 2010 by Maryland Agricultural Statistical Service (MASS)
- Random stratified sampling
- Original sample 1,000 farmers → 451 usable responses
- Practice types
  - cover crops, no-till, contour/strip

BMP Adoption and Cost Sharing

Practice type	Number of farms			
	No Adoption	Adoption without cost share	Adoption with cost share	Total
	[1]	[2]	[3]	[4]
Cover crops	301	57	93	451
No-till	205	219	27	451
Contour/Strip	359	82	10	451

Descriptive Statistics

N = 451 farmers	Mean	Std. Dev.	Min	Max
Distance to the nearest water body (miles)	0.56	2.1	0	35
Proportion income from farming	0.50	0.4	0	1
Proportion acres flat (< 2% grade)	0.50	0.4	0	1
Proportion acres moderately sloped (2-8% grade)	0.42	0.4	0	1
Proportion acres steeply sloped (>8% grade)	0.08	0.2	0	1
> 50 acres in corn, soybeans, or small grains	0.48	0.5	0	1
Operating acres (thousands)	0.46	0.9	0.001	9.78
Animal Units (thousands)	0.31	1.5	0	20.64
Proportion operating acres rented	0.26	0.3	0	1
Farmer age	62.44	12.3	22	89
Highest level of education attained Graduated high school	0.43	0.5	0	1
Some college	0.12	0.3	0	1
Completed comm. college	0.04	0.2	0	1
Bachelor's degree	0.16	0.4	0	1
Master's or Ph.D.	0.09	0.3	0	1

Erosion reduction cost variable

- Erosion reduction cost ($/lb) = $\frac{\text{BMP implementation cost per acre}}{\text{Erosion reduced per acre}}$

  - Erosion reduced per acre comes from Chesapeake Bay Program (CBP) data (Loads of sediment per acre x BMP erosion reduction efficiency)

Descriptive Statistics (cont'd)

N = 451 farmers	Mean	Std. Dev.	Min	Max
Erosion reduction cost ($ / pound reduced)				
Cover crops	0.022	0.016	0.003	0.069
Contour/Strip	0.025	0.021	0.003	0.090
No-till	0.009	0.006	0.002	0.024

Regression analysis

- Enrollment in cost share programs (first stage)
  - Simultaneously estimate the decision to enroll in cost share for each practice as a function of farm and farmer characteristics
  - Trivariate probit for cover crops, contour/strip, no-till
- Proportion acreage in each practice (second stage)
  - Simultaneously estimate the proportion of operating acreage adopted in each practice as a function of cost share enrollment, farm and farmer characteristics
  - Switching regression for the three practices

Treatment effects

- Calculate the effect of cover crop cost sharing on the acreage share of each practice
  - Direct effect = Acreage share in cover crop with vs. without cover crop cost sharing
  - Indirect effect = Acreage share in contour/strip and no-till with vs. without cover crop cost sharing
  - Total effect = Direct + Indirect effects
- Average treatment effects for enrolled and unenrolled farmers

Treatment effects: Acreage share in BMP with vs. without cover crop cost sharing

	Enrolled (N=93)	Unenrolled (N=358)
Avg. Farm Operating Acres	876.0	170.9
Cover Crop (Acreage shares)		
Without	0.031	0.026
With	0.317	0.087
Direct Effect	0.286**	0.061*

**Significant at the 99% level. *Significant at the 95% level.

Treatment effects: Acreage share in each BMP with vs. without cover crop cost sharing

	Enrolled (N=93)	Unenrolled (N=358)	
Avg. Farm Operating Acres	876.0	170.9	
Cover Crop (Acreage shares)			
Without	0.031	0.026	Direct effect
With	0.317	0.087	
Direct Effect	0.286**	0.061*	
Contour/Strip (Acreage shares)			
Without	0.196	0.054	Indirect effects
With	0.171	0.065	
Indirect Effect	-0.025**	0.011	
No-till (Acreage shares)			
Without	0.400	0.113	
With	0.462	0.179	
Indirect Effect	0.062**	0.066	

**Significant at the 99% level. *Significant at the 95% level.

Chesapeake Bay model and water quality

- Chesapeake Bay Program (CBP) model
  - Pollution loads of N, P and sediment by tributary
  - BMP pollution reduction efficiency for each practice
  - Delivery factors from each tributary to the Bay
- Link farmer survey to tributary using zip code
- Average abatement in the Bay and cost of abatement considering both direct and indirect effects

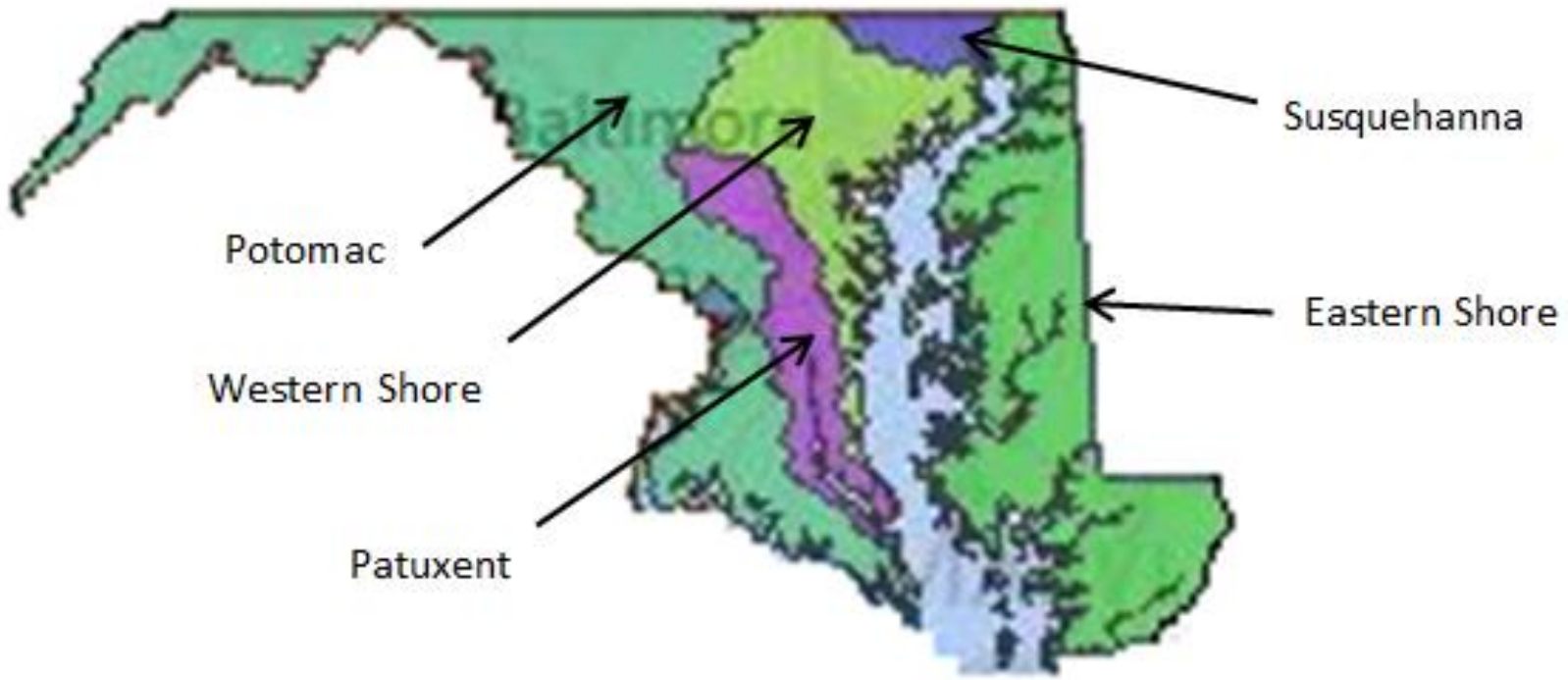
Average pounds abatement in each farm

	Enrolled	Unenrolled
Nitrogen (pounds)		
Direct Effect	1,504.4	119.5
Indirect Effect	-25.1	9.0
Total Effect	1,479.3	128.5
Phosphorus (pounds)		
Direct Effect	28.1	2.6
Indirect Effect	-4.8	1.3
Total Effect	23.3	3.8
Sediment (pounds)		
Direct Effect	32,576.8	3448.1
Indirect Effect	-5,205.4	1202.1
Total Effect	27,371.4	4650.2

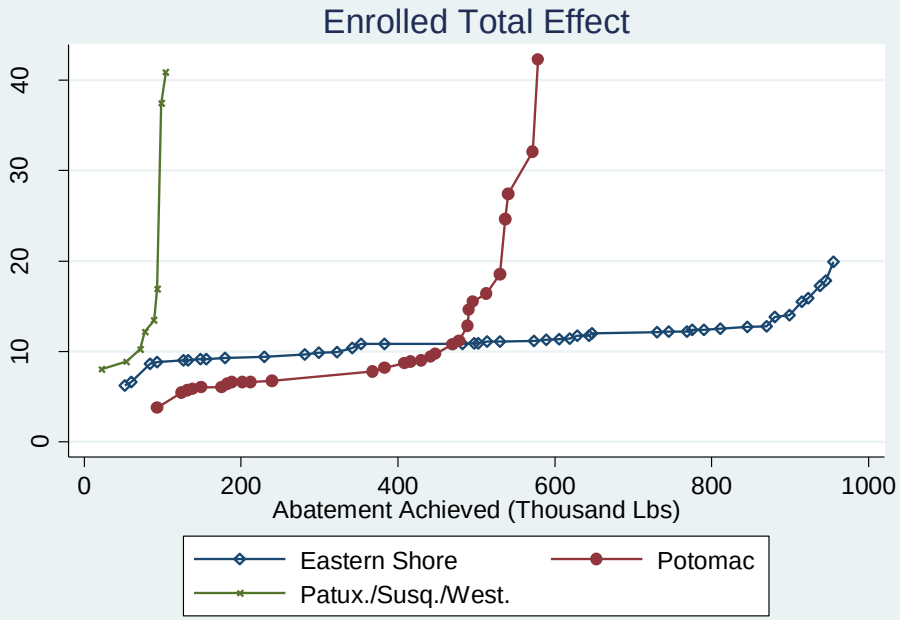
Average cost per pound abatement in each farm

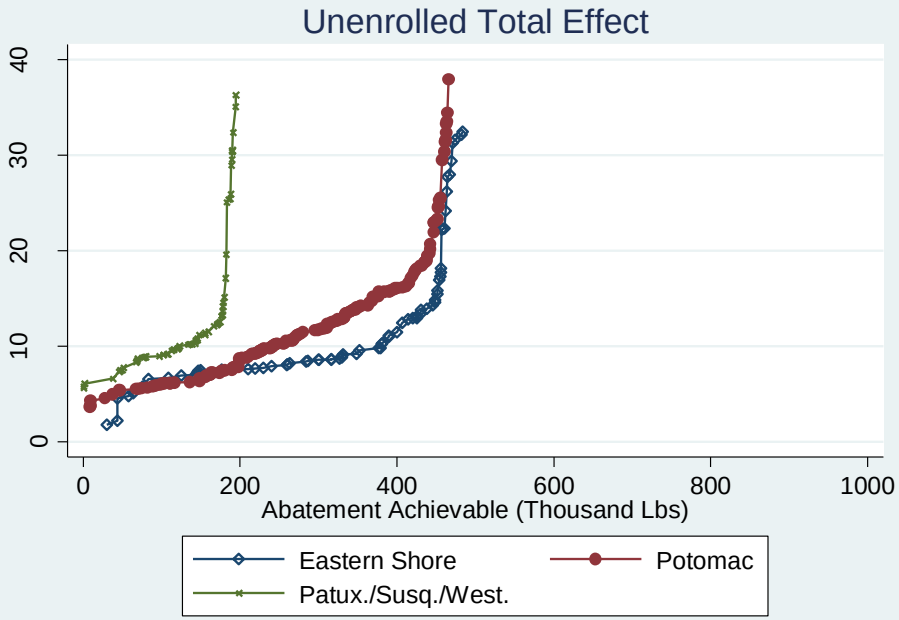
	Enrolled	Unenrolled
Nitrogen ($ / lb)		
Direct Effect	$11.96	$19.04
Indirect Effect		
Total Effect	$12.34	$17.40
Phosphorus ($ / lb)		
Direct Effect	$602.21	$738.76
Indirect Effect		
Total Effect	$936.62	$344.05
Sediment ($ / lb)		
Direct Effect	$0.84	$0.92
Indirect Effect		
Total Effect	$0.74	$0.41

Major river basins in Maryland

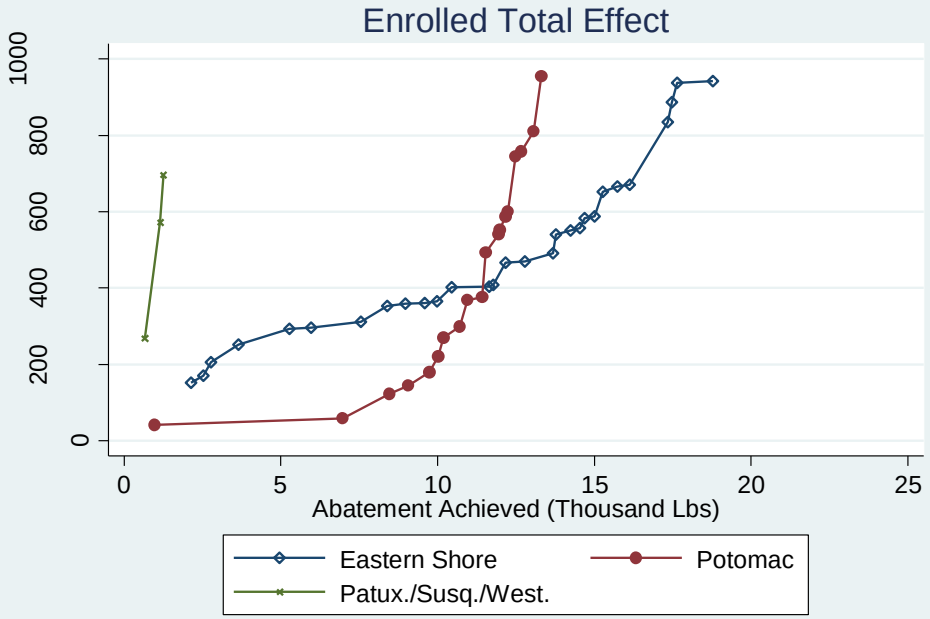


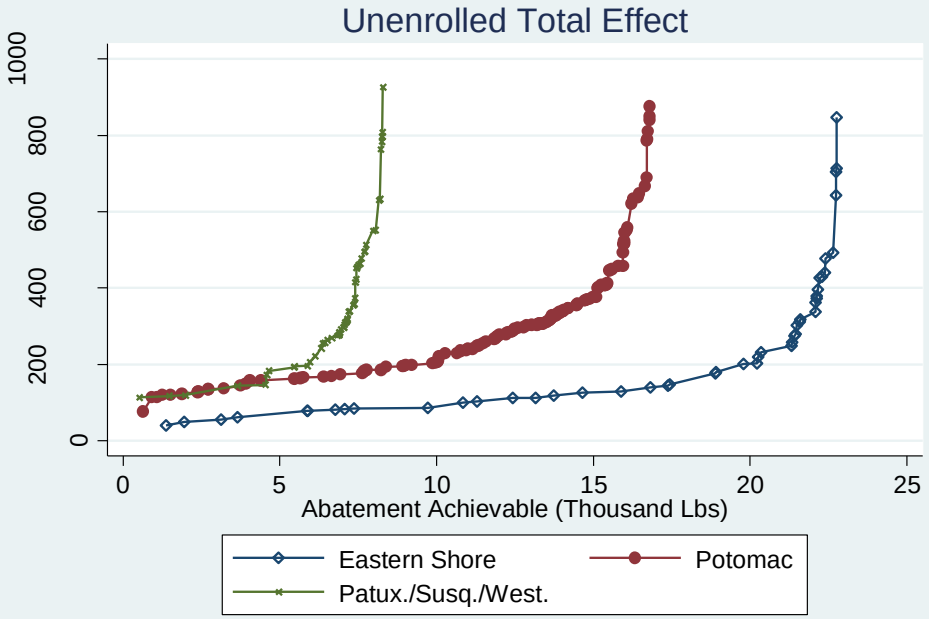
Marginal abatement cost by river basin - Nitrogen



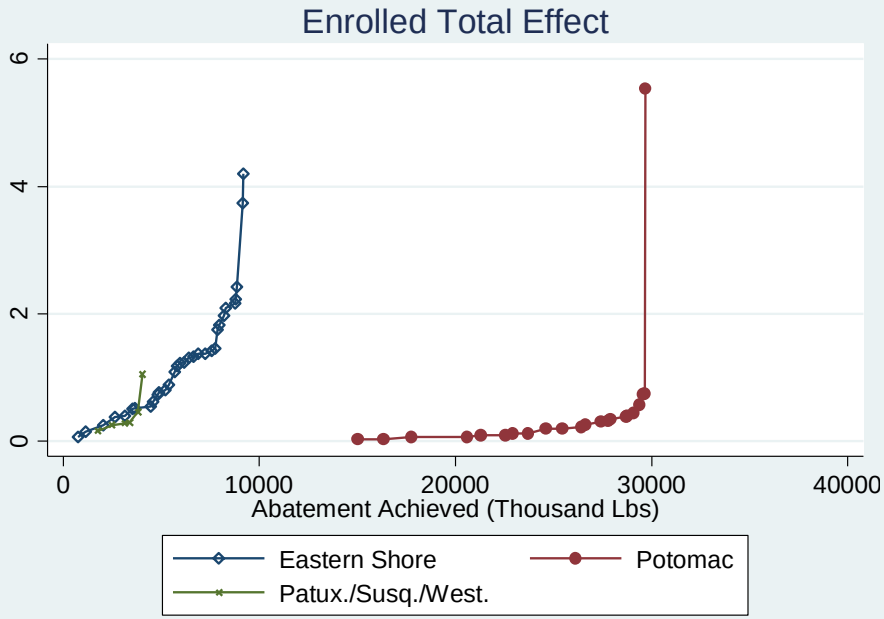


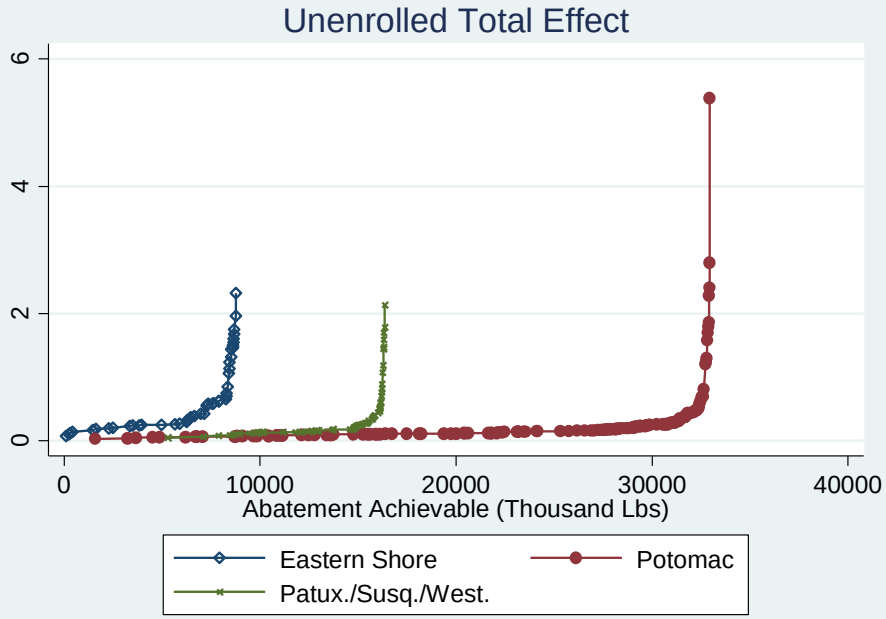
Marginal abatement cost by river basin - Phosphorus





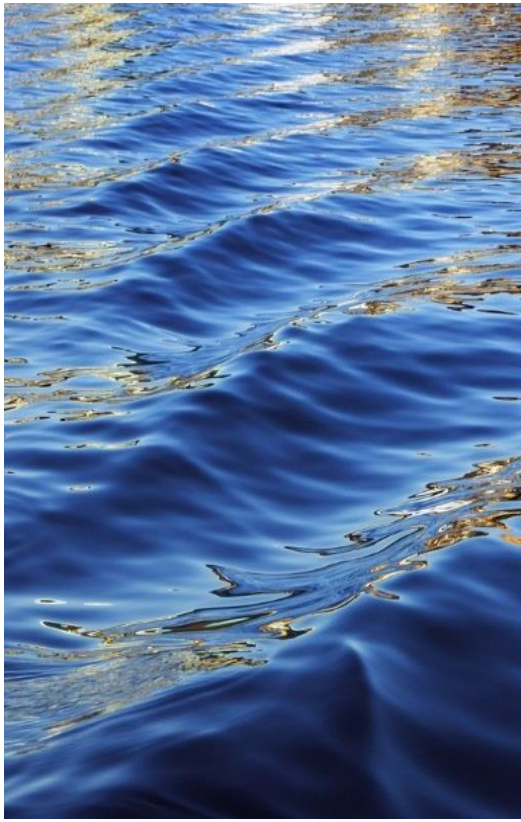
Marginal abatement cost by river basin - Sediment





Conclusion

- The additionality of the cover crop cost share program is high, reflecting a significant increase in cover crop acreage that otherwise would not have occurred
- Indirect effects on other practices partially offset the benefits of the program
- Abatement potential and marginal cost of abatement vary by river basin



Appendix: Results – Cost Share equations

Estimated marginal effects on cost share receipt

Multivariate Probit - Full Correlation

	Cost Share		
	Cover Crops (1=yes, 0=no)	Contour-Strip (1=yes, 0=no)	No-till (1=yes, 0=no)
Erosion reduction cost (Cover crops)	-0.1799**	-0.1926	-0.9294***
($ per lb. erosion reduced)	(0.13)	(0.26)	(0.49)
(Contour-strip farming) ($ / lb.)	0.2292***	0.1043	0.8672***
	(0.14)	(0.19)	(0.29)
(No-till) ($ / lb.)	0.3504	0.0961	-0.1053
	(0.48)	(0.20)	(0.50)
Proportion acres moderately sloped	0.0521*	0.029***	0.0646***
(2-8% grade)	(0.04)	(0.02)	(0.02)
Proportion acres steeply sloped	-0.0182	-0.0377	-0.0264
(> 8% grade)	(0.06)	(0.03)	(0.05)
Distance to the nearest water body	-0.0202***	-0.0001	-0.0014
(miles)	(0.01)	(0.00)	(0.01)
Proportion income from farming	0.1505***	0.01	0.0476***
	(0.03)	(0.01)	(0.02)
Observations	451	451	451

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Appendix: Results – BMP Acreage Share equations

Estimated marginal effects on BMP acreage share

Multivariate Tobit - Full Correlation

	Acreage share - *Switching based on cover crop cost share*					
	Cover crop		Contour-strip farming		No-till	
	(Cost Share = 1)	(Cost Share = 0)	(Cost Share = 1)	(Cost Share = 0)	(Cost Share = 1)	(Cost Share = 0)
Lambda (covariance w/ cover crop cost share)	0.158***	0.013	0.1043	-0.0352	-0.0328	-0.2146***
	(0.06)	(0.02)	(0.10)	(0.04)	(0.06)	(0.08)
Lambda (covariance w/ contour-strip cost share)	-0.0959***	-0.3013*	0.2472	0.2189	0.603	-0.1118
	(0.05)	(0.18)	(0.36)	(0.18)	(0.68)	(0.49)
Lambda (covariance w/ no-till cost share)	-0.0279***	0.0017	0.0939	-0.1202	0.0342	0.2297***
	(0.16)	(0.06)	(0.28)	(0.20)	(0.23)	(0.13)
Erosion reduction cost (Cover crops) ($ per lb. erosion reduced)	**-0.1052**	**-0.2028**	-0.1058	-0.3538	-0.1519***	-0.0331
	(0.20)	**(0.60)**	(0.08)	(0.32)	(0.76)	(0.67)
(Contour-strip farming) ($ / lb.)	-0.2681*	-0.3923	**-0.2839**	**-0.1125**	0.2121***	0.1556***
	(0.21)	(0.44)	**(0.70)**	**(0.40)**	(0.08)	(0.05)
(No-till) ($ / lb.)	-0.1423***	-0.1269	0.7842***	0.5383*	**-0.1841****	**-0.3807*****
	(0.07)	(0.26)	(0.35)	(0.38)	**(0.13)**	**(0.13)**
Contour-strip cost share (1=yes; 0=no)	0.2125	0.0438	0.2236	0.3533	-1.3662	0.2641
	(0.20)	(0.38)	(0.86)	(0.38)	(1.58)	(1.11)
No-till cost share (1=yes; 0=no)	0.5245**	0.251*	-0.0845	0.1835	0.1016	0.3858*
	(0.33)	(0.16)	(0.61)	(0.38)	(0.49)	(0.28)
Observations	94	348	94	348	94	348

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Appendix: Calculation of pollution reduction

- Direct effect: $\Delta_{ps} = (\widehat{ATT_1} \cdot \bar{z}_{ps} \cdot \theta_{1ps}) \cdot \delta_{ps}$, s $= 1 \ldots S$ river segments
  - $\bar{z}_{ps}$ is pollution load per acre from cropland,
  - θ_{mps} is pollution reduction efficiency (%) of BMP m
  - δ_{ps} is delivery ratio of pollution to the Bay from the river segment

- Indirect effect: $\Delta_{ps} = \sum_{m=1}^{3}(\widehat{ATT_m} \cdot \bar{z}_{ps} \cdot \theta_{mps}) \cdot \delta_{ps}$, s $= 1 \ldots S$ river segments.

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Appendix: Results – TMDL Goals

TMDL Progress and Targets for Agriculture in Maryland, by Major River Basin

	Nitrogen *(thousands of lbs. / year)*			Phosphorus *(thousands of lbs. / year)*		
	2013 Progress	2025 Target	Reduction required	2013 Progress	2025 Target	Reduction required
Eastern shore	8,825	7,435	1,390	860	783	77
Potomac	6,146	5,741	405	475	456	19
Patuxent	472	429	43	70	63	6
Susquehanna	717	651	66	42	37	5
Western shore	661	594	67	59	54	5
Maryland Total	**16,821**	**14,850**	**1,971**	**1,507**	**1,395**	**112**

Source: Based on data from ChesapeakeStat (http://stat.chesapeakebay.net/?q=node/130&quicktabs_10=2)