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Short communication

Voter evaluations regarding the tradeoffs between agricultural production and water quality in Lake Erie

Richard T. Melstrom [a,*], Trey Malone [b]

[a] School of Environmental Sustainability, Loyola University Chicago, USA
[b] Department of Agricultural Economics and Agribusiness, University of Arkansas, Fayetteville, USA

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A B S T R A C T

This research note examines public support for policies to regulate and incentivize pollution control in the farm sector to protect water quality in the western basin of Lake Erie. We conducted an experiment in which local residents indicated whether a policy was fair depending on whether it targeted waste from animal feeding operations or fertilizer runoff from crop farms and if it used regulations or incentives. We then asked how they would vote in a referendum on the policy. Our results show that while support for such policies is widespread, residents are most willing to support regulating fertilizer runoff (i.e. nonpoint source pollution) from crop farms.

1. Introduction

Runoff pollution from agriculture is a hotly debated source of water quality problems. Excessive sedimentation and nutrient levels from runoff can contribute to toxic, harmful algal blooms (HABs), leading to depleted oxygen levels and, consequently, loss of aquatic habitat. HABs also risk contaminating drinking water and disrupting recreation (Weirich and Miller, 2014; Zhang and Sohngen, 2018; Wolf et al., 2019; Boudreaux et al., 2023). Policymakers have attempted to respond to these problems by funding programs that use subsidies to incentivize best management practices and agricultural water conservation (Shew et al., 2021). By contrast, agricultural runoff has been expressly excluded from regulations such as the Clean Water Act (CWA) (Laitos and Ruckriegle, 2012). Policymakers could consider expanding regulations to penalize harmful practices, but agricultural stakeholders often fiercely oppose the regulatory approach (Farm Bureau, 2022).

Current U.S. water quality policy places much of the burden for cleaning up water pollution on discrete, point sources generally regulated under the Clean Water Act. This includes some agricultural point sources such as animal feeding operations. While reducing agricultural point source pollution is important, agricultural *nonpoint* source pollution due to soil erosion and fertilizer runoff is *also* a major concern (U.S. Department of Agriculture, 1986; Zaring, 1996). Nevertheless, regulating agricultural nonpoint source pollution remains politically controversial.

Absent from the debate over how to reduce agricultural source pollution is information about what people think about policies to influence agricultural practices, using either incentives (i.e. subsidies) or regulations backed by the threat of penalties. Some may view restrictions as an unfair legal burden that could reduce farm income or an infringement of farm operator rights. In contrast, others might consider the same restrictions as a critical legal tool to protect water quality. Furthermore, these two types of people might hold divergent views on the desirability of incentive-based policies. The first type might dislike restrictions but support subsidies encouraging practices to reduce nutrient runoff, which the second type might oppose because they see subsidies as rewarding practices farmers should be doing anyway. Of course, many people have more nuanced opinions, but it is not difficult to find such opposing “straw man” positions staked out in lobbying and media.

* Correspondence to: BVM Hall 424, School of Environmental Sustainability, Loyola University Chicago, 6349 N. Kenmore Ave., Chicago, IL 60660, USA.
E-mail address: rmelstrom@luc.edu (R.T. Melstrom).

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This article uses policy examples to examine public support for managing agricultural source pollution in the western Lake Erie basin. Our focus on Lake Erie is important because nutrient pollution has contributed to large, recuring HABs in the lake, which borders two countries and five U.S. states and serves as a drinking water source for more than 10 million people. Nutrient loading in the western basin has contributed to HABs that have forced lakeshore communities to seek alternative drinking water treatments and avoid the lake for recreation. For example, a 2014 HAB left residents in and around Toledo, Ohio, without water for drinking, cooking, or bathing for three days when toxin concentrations exceeded safety levels at the local water treatment plant (U.S. Action Plan for Lake Erie, 2018). Both point and nonpoint sources contribute significantly this problem. Point sources contribute more nutrients to Lake Erie than to any other Great Lake (Robertson and Saad, 2011).[1] Nevertheless, agriculture accounts for approximately three-quarters of total nutrient loading, mainly from fertilizers (Robertson and Saad, 2011). This means any policy aimed at reducing Lake Erie HABs will need to address agricultural management practices.

Our paper extends agricultural water policy research in two ways. First, we compare policy designs that use regulations and incentives to reduce animal waste and fertilizer runoff to achieve HAB reductions. Minimizing HABs through nutrient load reductions has become a priority for U.S. federal and state partners (U.S. Action Plan for Lake Erie, 2018). Incentive-based policies, which are expected to reduce compliance costs, have received considerable support among economists and policy scholars (Randall and Taylor, 2000). Nevertheless, regulation-based policies remain crucial to controlling nutrient pollution from agricultural point sources, and the relative desirability of these policies among the public is unknown. We also examine whether public support strengthens or weakens as a function of how the policy affects farm income, if it affects it at all.

Second, we measure public support by surveying opinions about the fairness of a policy rather than constructing a measure of environmental attitudes (Rohrschneider, 1988; Johnson et al., 2005; Portney et al., 2018) or estimating willingness to pay. A large literature in economics uses contingent valuation and choice experiments to measure public values for protecting and restoring water quality (Carson and Mitchell, 1993; Choi and Ready, 2021). Valuation studies are important because they can inform policymakers about whether policies are worth the cost and create a net social welfare gain. However, the level of support absent payment, or the shift in support as the policy moves from incentive-based to regulation-based, or from targeting animal operations to crop farms, remains unclear. The sharp distinction between point and nonpoint sources in the Clean Water Act suggests that social and economic pressures are compelling policymakers to burden point sources, which includes animal operations, with regulations. Our survey data allows us to test the hypothesis that the public supports regulating animal operations but not crop farms, for which we in fact find no empirical support.

2. Material and methods

This article measures public support for policies protecting water quality from agricultural pollution in the western Lake Erie basin. Each policy scenario involved a point or nonpoint source contributing to HABs, a policy action to reduce HABs, and an effect on farm income. To gauge support, we developed a survey that asked residents living in the basin their opinion on the fairness of a policy scenario and whether they would vote for or against it in a hypothetical referendum.

We conducted a web-based survey taken remotely by participants in two areas near Lake Erie. We surveyed residents in the Toledo, Ohio, and Detroit, Michigan, metropolitan areas in May 2022 using an online panel recruited by Qualtrics. Toledo-area residents have experienced direct economic losses from HABs, as evidenced by local property value reductions (Wolf and Klaiber, 2017; Wolf et al., 2022). Detroit-area residents may be farther from and thus less impacted by Lake Erie HABs, but are likely at least aware of Lake Erie's water quality problems due to media attention that major HAB events in the lake have received. In any case, the survey instrument provided respondents with information about Lake Erie water quality, HABs, and the role of runoff from crop farms and wastewater from animal feeding operations. After reading this information, respondents were informed about the ability of state and federal agencies to reduce HABs through regulations or market-based incentives. Forty-nine percent of respondents reported that they were confident or very confident that state and federal agencies could influence HABs in Lake Erie, while 36% were somewhat confident. Respondents were then told that their responses could help policymakers make informed decisions to encourage respondent consequentiality (Carson et al., 2014). A copy of the survey instrument can be found in Appendix A.

The survey instrument consisted of four policy scenarios that described an action by a state environmental agency to reduce HABs in western Lake Erie. Respondents were told that each scenario would reduce pollution contributing to HABs by the same amount.[2] The first scenario required farmers to reduce fertilizer applications. The second scenario used subsidies to incentive reductions in fertilizer. The third scenario switched the focus to animal feeding operations by requiring producers to reduce wastewater releases. Finally, the fourth scenario used subsidies to incentive producers to reduce wastewater releases. Each scenario also described the effect of the policy on farm income. If the policy was regulation-based, the income change varied randomly among 0% (no change), a 5% reduction, and a 10% reduction. If the policy was incentive-based, the difference took the values of 0%, a 5% increase, or a 10% increase.

After each scenario, the survey asked respondents to indicate whether they felt the policy was very fair, fair, unfair, or very unfair. The survey then asked how the respondent would vote if the policy was put on the ballot and that a majority voting in favor would make it law. Following the four policy scenarios, respondents were asked how much they agreed or disagreed with a series of statements about HABs and the consequentiality of the survey before being asked about their recreation and work-related visits to Lake Erie, household size and composition, and employment industry.

The survey was pretested in a small group of scientists and economists to provide feedback on the water quality information and the framing of the policy scenarios. We then pretested the survey instrument with ten undergraduate students in Michigan who were majoring in agriculture or environmental science. Each pretest was conducted in an individual interview setting that explored subjects' comprehension and recall of the source of water quality problems and policy actions immediately after the policy scenarios. These tests indicated that respondents understood the link between agriculture and HABs and found

[1] To be clear, effluent from sewage treatment is a major point source of nutrients in the basin. However, since 1985, governments have spent several billion dollars improving treatment plants and sewer infrastructure (Hartig et al., 2020), and many treatment plants now discharge at rates below permitted levels (U.S. Action Plan for Lake Erie, 2018).

[2] In principle, different policies could achieve the same HAB reductions in Lake Erie. There is substantial loading from fertilizers and manure in the basin, which suggests large reductions in either source could reduce HABs (Robertson and Saad, 2011). Farmers in the basin are also willing to participate in incentive-based programs to reduce runoff (Wilson et al., 2018). Whether in practice different policies could achieve equivalent reductions would depend on the structure of incentive-based programs (e.g., payment amounts, contract length), the stringency of regulations and the efficacy of point versus nonpoint source management practices. To be clear, support for policies will likely vary with the expected amount of HAB reduction, which is a criteria our experiment does not test.

each scenario attribute to be salient.

We use linear probability models to estimate the effect of the scenario attributes and respondent characteristics on two different binary measures of support.[3] First, we define support as believing that the policy is either fair or very fair; second, support is equivalent to voting yes if the policy was put on a ballot. We describe the estimates of these models in the next section. In Appendix B, we present estimates from a set of analogous logit models; the interpreted results are essentially the same as the linear probability models, so we do not discuss them here. In Appendix C, we probe the sensitivity of the estimates to beliefs about policy consequentiality.[4] The estimates in Appendix C provide evidence that respondents with consequential beliefs (which includes most of the sample) drive the significance of our results.

3. Results

We received 1011 responses to the survey. The median time to complete was 6 min. We were left with 910 responses after dropping those that took less than 3 min or more than one hour, which are the 5% and 95% duration percentiles, plus one individual who reported visiting Lake Erie more than once per day for a year. Across the four policy scenarios, this provides 3640 observations for analysis. The upper panel of Table 1 describes the key variables used in our analysis. By design, half of the policy scenarios are incentive-based, and half focus on reducing runoff. In addition to Lake Erie visits, we collected information on whether the respondent is concerned about Lake Erie HABs, water quality near their home, and their type of work. Table 1 shows that concern about Lake Erie HABs is nearly universal in our sample.

The responses indicate broad support for policies to protect water quality from agricultural source pollution. In 82% of observations, the respondent viewed the policy in front of them as fair, and in 81% of observations, they would vote to make it law. The lower panel of Table 1 breaks down support by policy type and individual characteristics. If a policy is regulation-based, then 77% view it as fair and would vote in favor. However, if a policy is incentive-based, 87% view it as fair, and 84% would vote for it. In results not shown but available upon request, if a policy reduces farm income (and is, therefore, a regulation-based policy), 72% view it as fair and would vote to make it law, while 87% view it as fair and 84% would vote in favor if it raises farm income. Thus, support is sensitive to whether a policy uses regulations or incentives, with a decline in support if regulations reduce farm income, though a majority still support regulations-based approaches with a modest negative effect on income.

We find support is consistently high across individual characteristics, although there can be important differences between groups. Those who visit Lake Erie are more likely to view the policy they saw as fair or vote in favor compared to those who do not visit (84% and 82% versus 78% and 77%, respectively; both $p < 0.001$). We also find large differences based on industry category and concern about water quality and HABs. Although they make up a small portion of the sample, workers in the agricultural and natural resources sector are significantly more likely to view a policy as fair (94% versus 82%; $p = 0.004$) and vote in favor (89% versus 80%; $p = 0.041$) compared to workers in other industries. This difference could be driven by the former working in proximity to and knowledge of agriculture as the primary contributor to nutrient loading in Lake Erie. Finally, the largest relative difference in support occurs between those concerned about both water quality and Lake Erie HABs and those not concerned, with the latter significantly more likely to view a policy as fair or vote in favor (83% and 82% versus 73% and 69%, respectively; both $p < 0.001$). Nevertheless, it is important to emphasize regardless of group that large majorities support policies to reduce agricultural pollution contributing to HABs.

Table 2 presents the results from our econometric models. The first column shows the parameters when modeling beliefs about fairness. Although the model includes controls for individual characteristics, including visit status, employment category and water quality concern, our primary interest is in the three variables controlling for the policy attributes shown in the table. The parameter on *incentive* indicates that support increases by 4% points if a policy is incentive-based rather than regulation-based. In comparison, the parameter on *fertilizer runoff* indicates support increases by 3% points if the policy targets crop farms rather than animal feeding operations. The estimate for *income change* indicates that support increases by 0.7% points for every percentage point increase in farm income due to the policy. Fig. 1 illustrates changes in support associated with these attributes; note the large change when the policy has a nonmarginal effect on farm income.

The second column shows the results when we model how a respondent would vote for a policy. The parameter on *fertilizer runoff* indicates that support increases by 7% points if the policy targets crop farms. This could be because many residents in the study region are aware that most nutrient pollution comes from fertilizers (Robertson and Saad, 2011). The estimate for *income change* indicates that support increases by 0.5% points for every percentage point increase in farm income due to the policy. The parameter on *incentive* implies that support increases by 3% points if the policy is incentive-based, which is slightly lower than the effect of *incentive* on beliefs about fairness; however, this estimate is not significantly different from zero. Important caveats, though, include that the parameter is just insignificant at a conventional level ($p = 0.125$), the precision of which is affected by a strong correlation between *incentive* and *income change* (correlation coefficient = 0.77), and a joint test shows that the two parameters are highly significant together ($p < 0.001$). So we should not yet rule out the importance of incentive-based policies on voter support. Nevertheless, these results suggest that when support is measured in terms of voting behavior, a larger increase in support occurs when a policy moves from reducing animal waste to one focused on fertilizer. We do not see as large a difference when support is measured in terms of fairness, which implies that whether a policy targets animal waste or fertilizer plays more of a role in voter support than in opinions about fairness.

The next two columns in Table 2 show the estimates when we replace the individual variables with fixed effects that control for *any* individual-specific effects that could be correlated with support, including a tendency to just support every policy in the experiment, regardless of design. The parameters on *fertilizer runoff* and *income change* are largely the same as those in the first two models, although the effect of income change in the vote model implies a more substantial 0.8% point increase for every percentage point increase in farm income. The main difference is that the parameter on *incentives* moves toward zero in both models, which provides weaker evidence that support increases moving from a regulation-based to an incentive-based policy.

The last four columns in Table 2 presents the estimates when we include fixed effects along with different sets of interaction variables. The first set tests for heterogeneity in support for incentive-based policies through an interaction between *incentive* and *fertilizer runoff*. This variable does not qualitatively change the interpretation of the fairness model. By contrast, in the vote model, the parameter on the interaction is significantly negative, the parameter on incentive is now significantly positive, and the parameter on fertilizer has moved further away from zero. These estimates imply that support is highest when the policy targets fertilizer runoff using regulations, and lowest when it targets animal waste using regulations. The typical resident in our study region prefers regulations to incentives when addressing runoff from crop

[3] The specification is $y_{ip} = \beta_0 + \beta_1 incentive_p + \beta_2 runoff_p + \beta_3 incomechange_p + \gamma x_i + \epsilon_{ip}$, where y_{ip} indicates if person i supports policy p, $incentive_p$ is an indicator for incentive-based policies, $runoff_p$ is an indicator for policies targeting fertilizer runoff, $incomechange_p$ is change in farm income, x_i are respondent controls, and ϵ_{ip} is the error.

[4] Prior research finds that respondents are more likely to reveal their preferences truthfully in the presence of consequentiality. See, for example, Vossler et al. (2012) and Carson et al. (2014).

Table 1
Summary statistics.

Variable name	Description	Mean	St. Dev
Incentive	= 1 if policy used incentives to reduce agricultural pollution	0.500	0.500
Fertilizer runoff	= 1 if policy used focused on reducing runoff pollution from farms	0.500	0.500
Income change	Percent change in farm income due to policy	0.034	6.442
Fair	= 1 if respondent believed policy was fair or very fair	0.822	0.383
Vote	= 1 if respondent would vote in favor of policy	0.805	0.396
Visit	= 1 if respondent visited Lake Erie in past year	0.688	0.463
Ag and resources	= 1 if respondent is employed in the agricultural and natural resources sector	0.023	0.150
HAB concerned	= 1 if respondent is somewhat concerned, concerned, or very concerned about HABs in Lake Erie	0.976	0.154
WQ concerned	= 1 if respondent is somewhat concerned, concerned, or very concerned about water quality near where they live	0.915	0.278

Fairness and vote shares by policy type and individual characteristics

	Incentives = 1	*Fertilizer runoff = 1*	*Visit = 1*	*Ag and resources = 1*	*HAB and WQ concerned = 1*
Fair	0.875	0.839	0.839	0.940	0.831
Vote	0.845	0.838	0.821	0.893	0.818

Table 2
Regression estimates from the linear probability and logit models.

	Benchmark estimates		Individual fixed effects		Attribute interaction		Group-specific effects	
	Fairness	Vote	Fairness	Vote	Fairness	Vote	Fairness	Vote
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Incentives	0.040 * *	0.025	0.027 *	0.004	0.043 * *	0.038 *	0.050 *	0.007
	(0.016)	(0.016)	(0.016)	(0.017)	(0.019)	(0.020)	(0.027)	(0.028)
Fertilizer runoff	0.034 * *	0.065 * *	0.034 * *	0.065 * *	0.050 * *	0.098 * *	0.046 * *	0.086 * *
	(0.011)	(0.011)	(0.011)	(0.011)	(0.016)	(0.016)	(0.022)	(0.022)
Income change	0.007 * *	0.005 * *	0.008 * *	0.008 * *	0.008 * *	0.007 * *	0.008 * *	0.007 * *
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.003)
Incentives ×Fertilizer runoff					-0.031	-0.067 * *		
					(0.020)	(0.020)		
Incentives ×Ag and resources							0.039	0.073
							(0.102)	(0.117)
×*Visit*							-0.035	-0.007
							(0.034)	(0.035)
Fertilizer runoff ×Ag and resources							0.042	0.116
							(0.053)	(0.071)
×*Visit*							-0.018	-0.035
							(0.025)	(0.026)
Income change ×Ag and resources							-0.012	-0.003
							(0.008)	(0.009)
×*Visit*							0.0006	0.0003
							(0.003)	(0.003)
Constant	0.519 * *	0.443 * *	0.791 * *	0.771 * *	0.783 * *	0.754 * *	0.791 * *	0.771 * *
	(0.078)	(0.080)	(0.010)	(0.010)	(0.012)	(0.012)	(0.010)	(0.010)
Individual characteristics	X	X						
Fixed effects			X	X	X	X	X	X
R-squared	0.044	0.038	0.471	0.480	0.471	0.482	0.471	0.482
Observations	3640	3640	3640	3640	3640	3640	3640	3640

Standard errors clustered on respondents. * and * * indicate significance at 0.1 and 0.05 levels.

farms, but prefers incentives to regulations when addressing manure from animal operations. This heterogeneity could be driven by perceptions that crop farms are less regulated when it comes to fertilizer applications (although Ohio restricts applications on frozen ground) relative to animal operations and manure, that incentives are relatively less effective at reducing runoff than wastewater, or both.

The next set of interactions tests for group-level heterogeneity in support by multiplying each policy attribute by an indicator for working in the agricultural and natural resources industry, and an indicator for visiting Lake Erie. This heterogeneity could arise if individuals that benefit from a policy in ways other than their residential location (i.e., through work or leisure) are more likely to support the policy. However, none of the interaction effects are significant. We also found insignificant estimates for other interactions tested but not shown in the table. Thus, the effect of specific policy attributes on support appears unrelated to individual characteristics.

4. Conclusion

We investigated public support to reduce harmful algal blooms in Lake Erie by limiting agricultural source pollution using policy scenarios that differentiated between point and nonpoint sources, use of regulations versus incentives, and changes in farm income. We measured support in terms of whether residents living near Lake Erie believed a policy was fair or they would vote to make it law. We found strong evidence that support increases if the policy targets fertilizer runoff from crop farms rather than manure waste from animal feeding operations, as well as if the policy increases farm income through the use of incentives.

Among all respondents, support increased by 3–7% points if the policy targeted fertilizer runoff rather than animal waste. When we

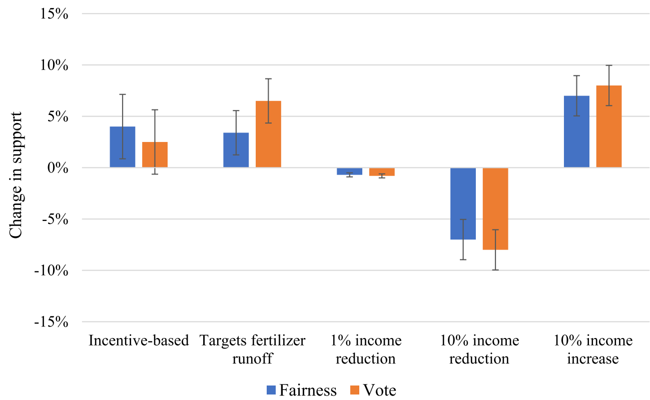

Fig. 1. Change in support as a function of policy attributes to address agricultural-source pollution. Estimates based on the benchmark linear probability model specifications. Standard error bars shown.

allowed support for these targets to vary by whether or not the policy used incentives or regulations, we found support increased by a more substantive 5–10% points when it targeted fertilizer runoff using regulations. This result implies that support among those living in communities adjacent to Lake Erie is broadest when the policy uses regulations to reduce fertilizer runoff, and narrowest when the policy uses regulations to reduce wastewater from animal feeding operations. To be clear, though, on average about three-quarters of respondents indicated that they would vote in favor of a policy to control agricultural source pollution. Changes in support of 5–10% points due to policy design are thus not enough to shift voter preferences from majority support to majority oppose. Likewise, while we found evidence that public support in the region depended on whether farm income is affected, modest (i.e., 5–10%) reductions in farm income lowered support by a similar proportion (i.e., 5–10% points), which is not enough that a majority would oppose regulations.

The Clean Water Act in essence regulates point source pollution from agriculture, which includes animal feeding operations but not nutrient runoff from crop farms. This distinction creates a burden that varies systematically by farm type and limits the effectiveness of the law. Our results showed that support for policies to reduce agricultural source pollution is widespread, with a large majority in favor, regardless of the design considered. However, support was greatest when the policy controlled fertilizer pollution using regulations. This result implies that, in the western Lake Erie study area, the public is most supportive of policies to control nonpoint source pollution, perhaps because runoff from crop farms is the largest contributor to nutrient loading in Lake Erie.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests. Richard T. Melstrom reports financial support was provided by National Oceanic and Atmospheric Administration (grant #NA19OAR4170388). Trey Malone reports financial support was provided by National Oceanic and Atmospheric Administration (grant #NA19OAR4170388).

Data Availability

Data will be made available on request.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.agwat.2023.108449.

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