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Too Burdensome to Bid: Transaction Costs and Pay-for-Performance Conservation

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Abstract

In a world free of transaction costs, reverse auctions can cost-effectively allocate payment for environmental service contracts by targeting projects that provide the most benefit per dollar spent. However, auctions only succeed if enough farmers choose to bid so that the auctioneer can evaluate numerous projects for targeted funding. A 2014 conservation auction to allocate payments for phosphorus reduction practices in NW Ohio experienced very thin bidding. According to a follow-up survey, auction participation was deterred by the complexity of the bidding process and the need to negotiate with renters. Due to low participation, the actual conservation auction made payments for phosphorus reduction that were surprisingly costly at the margin. Applying a farmer behavioral model to the Western Lake Erie Basin, we simulate participation choice and cost-effectiveness of environmental outcomes in reverse auctions and uniform payment conservation programs. Results reveal that when perceived transaction costs of bid preparation are high, reverse auctions are less cost-effective than spatially targeted, uniform payment programs that attract higher participation.

Keywords: reverse auctions, transaction costs, cost-effective, conservation programs, endogenous participation

Reverse auctions promise to procure environmental benefits cost-effectively by paying farmers to use beneficial management practices (BMPs) where the environmental return on investment is highest (Hellerstein, Higgins and Roberts 2015; Latacz-Lohmann and Schilizzi 2005; Hill et al. 2011; Iftekhar, Hailu and Lindner 2012). In a reverse auction, program administrators solicit bids for the lowest payment that farmers would require to adopt a BMP. By competing for scarce agri-environmental program funds, farmers reveal private information about their costs of BMP adoption (Latacz-Lohmann and Van der Hamsvoort 1997). Program administrators can then use biophysical models to evaluate the bids submitted and weigh the expected environmental benefits against the required BMP payment. To cost-effectively allocate conservation funding, bids can be selected using simple cost-benefit (CB) rankings or more sophisticated optimization algorithms (Messer and Allen III 2010).

Reverse auctions have been touted as being more cost-effective than uniform payment programs because funding is targeted to projects that generate the most environmental benefit per dollar spent (Latacz-Lohmann and Schilizzi 2005; Selman et al. 2008; Rolfe and Windle 2011). However, previous research has also identified potential disadvantages of auctions due to adverse selection (Arnold, Duke and Messer 2013), strategic bidding (Glebe 2013; Cason, Gangadharan and Duke 2003), and low participation (Glebe 2013; DePiper 2015). Additionally, auctions can be administratively burdensome because the agency conducting the auction must have tools to reliably predict environmental benefits generated by the proposed BMPs. This is particularly important when funding is allocated to BMPs on working lands, because the wide array of management practices increases the heterogeneity of possible benefits from BMP adoption (Hellerstein et al. 2015).

Generating sufficient participation from land managers has been identified as a key requirement for successful auctions (Glebe 2013; Whitten et al. 2013), but few studies have explicitly examined what causes low participation and the resulting impact on auction performance. Additionally, most of the theoretical and empirical literature has assumed that participating in reverse auctions is costless (Latacz-Lohmann and Schilizzi 2005), which likely overestimates participation rates that would occur in reality. Recent research suggests that transaction costs faced by farmers can greatly affect their willingness to participate in conservation programs (Peterson et al., 2014), but to our knowledge no research has explicitly examined the role of transaction costs on reverse auction programs.

Reverse auctions for BMPs on working lands (e.g., cover crops, conservation tillage) have primarily been tested on a pilot scale with relatively low participation levels (Whitten et al. 2013; Smith, Nejadhashemi and Leatherman 2009). If participation in reverse auctions is low, there are declining gains from using auctions rather than offering a uniform payment, because having fewer candidate projects increases the odds of funding projects with high CB ratios.

In 2014, reverse auctions were used to allocate payments for BMPs that reduce agricultural phosphorus runoff in two Ohio counties in the Tiffin River Watershed, situated within the larger Maumee Watershed (Palm-Forster 2015). Land management practices in this watershed affect water quality in the Western Lake Erie Basin (WLEB). In particular, agricultural runoff has been identified as the primary source of phosphorus contributing to frequent and intense harmful algal blooms over the past five years (Michalak et al. 2013; International Joint Commission 2014). Participation in the reverse auctions was thin, with only one percent of invited landowners submitting bids. Payments were awarded for phosphorus abating BMPs that were surprisingly costly at the margin because some BMPs were predicted to provide very little benefit. A follow-up survey revealed barriers and deterrents to participation, including high transaction costs of bidding as perceived by landowners. A critical question that arises from this work is how the outcomes of a uniform payment program would have compared relative to the reverse auctions.

The objectives of this article are 1) to develop an empirically grounded farmer behavioral model to simulate participation choice, and 2) to assess the cost-effectiveness of simulated environmental outcomes from auctions as compared to uniform payment programs. We analyze the impact of transaction costs faced by land managers on their decisions to bid in reverse auctions relative to other types of programs. Results reveal that when perceived transaction costs of bid preparation are high, low participation in reverse auctions makes them less cost-effective than spatially targeted, uniform payment programs.

Tiffin Watershed BMP Auction Project

In collaboration with the local Soil and Water Conservation Districts (SWCDs), the Tiffin Watershed BMP Auction Project was implemented in Defiance and Fulton counties in NW Ohio during the summer of 2014. Letters announcing the auction project were mailed to 1,085 agricultural landowners in June, 2014. A website was established for the project and announcements were widely distributed via SWCD and Farm Service

Agency (FSA) newsletters, local farm newspapers, and flyers posted at local grain elevators. Private, sealed bids were accepted between July 21 and September 30, 2014 for three eligible BMPs, 1) cover crops, 2) filter strips, and 3) subsurface drainage control structures. Thirty-six bids for new BMPs were initially submitted by 10 farmers (although one farmer withdrew three bids prior to evaluation).

The Soil and Water Assessment Tool (SWAT) model (Gassman et al. 2007) was used to evaluate and rank bids by predicting the expected annual reduction in bioavailable phosphorus (P) runoff per dollar of funding awarded (LimnoTech 2013).[1] In mid-November, acceptance decisions were announced privately to each bidder and contracts were offered to fund BMPs on 29 parcels. After five additional bids were withdrawn from the program[2], 24 contracts were signed by the end of December. Additional information about the implementation and outcomes of the auctions is available in Palm-Forster (2015).

Costs per pound of reduction in bioavailable P runoff ranged from $25 to $2,310 for accepted projects. The high marginal cost to reduce bioavailable P runoff was not caused by high bids, but rather by low reductions in predicted runoff on certain parcels. If more bids had been submitted, funding could have been allocated to more cost-effective projects.

In order to identify factors that contributed to low participation in the auction, a follow-up survey was mailed to landowners who did not submit a bid. The survey response rate was 42%. Three key barriers to participation were identified as: 1) lack of knowledge about the BMP auction (30%), 2) perceived ineligibility to submit a bid (26%), and 3) lack of interest in submitting a bid (44%). Among individuals who knew about the auction and felt eligible, four key factors deterred participation: 1) the auction seemed complicated (32%), 2) they did not want to adopt any of the three eligible practices (26%), 3) land rental agreements complicated participation (23%), and 4) they perceived a low probability of bid acceptance (13%)[3] (Palm-Forster, 2015).

Conceptual model of conservation program participation decisions

Land managers decide to participate in a conservation program if their expected utility of participating is higher than their status quo utility, u_0. Assume a risk neutral land manager whose utility is derived from expected income π (including conservation payments θ) and stewardship satisfaction $v(a)$ that is gained from aligning management actions a with personal stewardship values. Disutility is derived from the transaction costs (TC) of applying for a program and complying with rules and regulations, $\psi(\boldsymbol{\rho})$. Assuming additive separability, the indirect utility of participating in conservation program j can be written as,

$$u_j(a_j, \theta_j, \boldsymbol{\rho_j}, m) = m\big(\pi(a_j) + \theta_j\big) + v(a_j) - \psi(\boldsymbol{\rho_j}) \tag{1}$$

where, m is the marginal utility of income, and $\boldsymbol{\rho_j}$ is the set of rules and regulations for program j. TC disutility is made up of two components: $\psi(\boldsymbol{\rho_j}) = \psi_1(\boldsymbol{\rho_j}) + \psi_2(\boldsymbol{\rho_j})$, where $\psi_1(\boldsymbol{\rho_j})$ is disutility associated with applying for the program, and $\psi_2(\boldsymbol{\rho_j})$ is the disutility from complying with rules and regulations once accepted into the program. Assuming $v(a_0) = 0$, status quo utility is $u_0 = m\,\pi(a_0)$.

Acceptance in a conservation program is not guaranteed, particularly when funding is allocated by reverse auction. But regardless of whether an application is successful, the applicant incurs TC disutility $\psi_1(\boldsymbol{\rho_j})$ in applying for the program. Let σ

be the probability that the application is accepted and funding is awarded. Expected indirect utility from applying to undertake conservation action a_j can be written as,

(2) $$E(u_1) = \left[m\left(\pi(a_j) + \theta_j\right) + v(a_j) - \psi_2(\boldsymbol{\rho_j})\right]\sigma + m\,\pi(a_0)[1-\sigma] - \psi_1(\boldsymbol{\rho_j}) \,.$$

An individual will apply for funding from a conservation program if,

(3) $$E(u_1) - u_0 \geq 0.$$

Uniform payment programs

In a uniform payment incentive program, a uniform price is offered to land managers in exchange for adopting a specific practice. Funds can be allocated on a first-come, first-served basis or projects can be scored based on environmental metrics and the highest scoring projects can be funded.

Consider a program in which funding is allocated in the order of enrollment until the budget is exhausted. We assume that applications are submitted one at a time and that the announcement of program closure is perfect information. In this case, $\sigma = 1$ and the individual will enroll if the payment offer (θ_j) is no less than their minimum willingness to accept (WTA).

(4) $$\theta_j \geq WTA_j = \pi(a_0) - \pi(a_j) + \frac{\psi_1(\boldsymbol{\rho_j}) + \psi_2(\boldsymbol{\rho_j}) - v(a_j)}{m}$$

Participation in a reverse auction

Participation in a reverse auction involves submitting a bid (offer) to adopt one or more BMPs. When projects have heterogeneous environmental impacts, bids are evaluated and selected based on a scoring metric that accounts for both the payment requested (bid) and the level of environmental benefits targeted. The most cost-effective projects are selected for funding until the budget is exhausted. Numerous selection criteria have been proposed for auctions, including optimization algorithms and more simple metric-based ranking procedures (Messer and Allen III 2010). For this analysis, consider a cost-benefit ranking metric, $\beta = {}^{\theta}/_{e}$, where θ is the bid submitted and e is the predicted environmental benefit from the proposed project.

The land manager chooses a bid to maximize the difference between their expected utility and their status quo utility. Conservation auctions are typically discriminatory price auctions in which selected bidders are paid the amount of their bid (Hellerstein et al. 2015), thus bids are influenced by the probability of bid acceptance. Since bidder decisions can influence both the likelihood of bid acceptance and the level of payment, individuals have an incentive to bid strategically based on how they believe their bid and predicted level of environmental benefits will compare to others (Glebe 2013; Hellerstein et al. 2015; Cason et al. 2003; Jacobs, Thurman and Marra 2014).

In choosing a bid, the manager considers their perceived probability that the bid will be accepted. This perceived probability depends on beliefs about the predicted environmental benefits of BMPs on their land (often unknown) and beliefs regarding bids and benefits of competing projects. Payment (bid) caps are commonly used to prevent funding excessively high bids (Hellerstein et al. 2015). Caps may or may not be announced. Either way, individuals form a subjective belief about the range of βs (bid/benefit) that will be accepted.

Without specifying a functional form for the perceived probability of bid acceptance, the optimal bid (conditional on bidding) can be written as,

(5) $$\theta_k^* = \pi(a_0) - \pi(a_k) + \frac{\psi_2(\rho_k) - v(a_k)}{m} - \frac{\ddot{\sigma}(\theta^*)}{{}^{\partial\ddot{\sigma}}/_{\partial\theta^*}},$$

where, ${\theta_k}^* \geq 0$ since otherwise, the farmer would have adopted the BMP voluntarily without the presence of any incentive program. The full derivation of the optimal bid is presented in Appendix A.

The bid is influenced by 1) the change in expected profit reflected by the full cost of BMP adoption, 2) transaction costs of program compliance, 3) utility provided by environmental stewardship, and 4) the ratio between the probability of bid acceptance $\ddot{\sigma}(\theta^*)$ and the partial derivative of the probability of bid acceptance with respect to a change in one's bid $\partial\ddot{\sigma}/_{\partial\theta^*} \leq 0$. Notice that the bid θ^* looks similar to the individual's WTA for a uniform payment in Eq. (4), but there is an extra quantity subtracted at the end $\left(\frac{\ddot{\sigma}(\theta^*)}{\partial\ddot{\sigma}/_{\partial\theta^*}}\right)$. As the probability of bid acceptance increases, the bid increases; therefore, if the individual thinks that their bid is particularly competitive, they will increase it in an attempt to extract information rents. Information rent is defined as the portion of the payment that exceeds the minimum payment necessary for the manager to participate – i.e., the portion of the payment that exceeds the minimum WTA.

Individuals submit an application only if $E[u_1(\theta_k^*, a_k, a_0, \rho_k, \ddot{\sigma})] \geq u_0(a_0)$, which accounts for the TC of application (See Eq. (2)). Since the cost of application $\psi_1(\boldsymbol{\rho_j})$ is incurred regardless of bid acceptance, this cost does not influence the optimal bid amount; however, it does influence the participation decision. Additional information, like details about baseline agricultural practices or management records, is often required in order to predict the benefits of new BMPs, but these requirements increase $\psi_1(\rho_j)$.

Aggregate supply of benefits affects cost-effectiveness

In the previous section, a participation decision framework was presented for a single individual. At an aggregate level, these decisions can affect the relative cost-effectiveness of different conservation incentive programs. Consider a scenario in which multiple land managers affect water quality in a watershed and suppose that the WTA and predicted environmental benefits can be known for each manager and parcel. By dividing the individual's parcel-specific WTA by the predicted environmental benefits of the BMP, a cost-benefit (CB) ratio can be computed for each potential project. Suppose that all land managers are willing to participate if the payment offered is at least as great as their WTA. Figure 1 depicts the contract supply curve that would result from ranking all projects by their CB ratio such that $CB = \frac{WTA}{e}$, where e is the environmental benefit generated by each BMP. The associated contract curve is represented by CB[1].

A uniform payment program offering price p would generate benefits e_f and make payments that total $p * e_f$. Holding the budget fixed ($Budget = p * e_f$), but using a reverse auction to allocate payments equal to the WTA of individual farmers, would result in an increase of benefits procured to e_a and payments would equal the area *0,a,b,*e_a. Assuming that the pool of participants has the same CB contract curve, the cost-effectiveness of the auction is greater than that of the uniform payment program because more environmental benefits are generated from the same conservation budget.

However, as shown in the previous section, the amount that an individual bids can differ from their minimum WTA. Thus the contract curves for the two programs will deviate. Deviations can be driven by differences in bids resulting from different TC between the programs or from strategic bidding to extract information rents in the auction. Lack of knowledge about a program and other participation barriers can also affect the slope of the CB contract curves.

The contract supply curve represents numerous individuals with heterogeneous costs and benefits. For any type of conservation program, one can imagine a line of points that comprise the supply curve, but some of the potential participants may not apply for a program either because they are, 1) not knowledgeable, 2) not eligible, or 3) not interested in applying for another reason. Nonparticipants could be those with the lowest WTA, the highest WTA, or they may be scattered across the length of the supply curve. It is sensible to hypothesize that individuals with the lowest WTA may not be eligible for conservation programs because they already use the BMP, but this would affect all programs that require additionality, not only reverse auctions.

If there are systematic differences in the supply curves between different types of programs, there may be substantial differences in the quantity of environmental benefits that can be procured with a given budget. Figure 2 shows how a contract curve for a reverse auction (represented by CB^2) might differ from CB^1. One reason for different contract curves could be a situation in which the pool of participants is the same, but individuals strategically inflate their bids if they think they have valuable projects that will be desirable even at higher payment levels, which is behavior that has been observed in previous studies (Cason et al. 2003; Cason and Gangadharan 2005). Another possibility is that the pool of participants may differ between those willing to engage in a conservation auction and those willing to participate in a uniform payment program. In a reverse auction for fishing license buybacks, DePiper (2015) found that individuals with low willingness-to-accept (WTA) participated in the auction at lower rates than other eligible individuals. If the contract curve is higher for the group willing to bid in the auction, cost-effectiveness will decline as the environmental benefits affordable with the same fixed budget declines from e_f to e_a.

Simulation Model

A simulation model is constructed to analyze how outcomes might differ among reverse auctions and uniform payment conservation programs. We compare three incentive programs that pay farmers to adopt cover crops, 1) a reverse auction program, 2) an untargeted uniform payment program, and 3) a targeted uniform payment program. Simulated outcomes from the three programs are compared to a first-best scenario in which we assume that the administrator knows the true WTA for all decision-makers. Figure 3 illustrates the basic structure of the simulation model.

Although many land management practices are possible, we focus on one in particular: winter cover crops that reduce soil erosion and associated P loss. Cover crop decisions are simulated for 933 agricultural parcels in Defiance County, Ohio within the Tiffin River Watershed (Figure 4). The Soil and Water Assessment Tool (SWAT) is used to predict the amount of bioavailable P runoff generated by 933 agricultural parcels in Defiance county that lie within the Tiffin watershed (LimnoTech, 2013). We assume that cover crops reduce per acre bioavailable P runoff by 6.9% for fields in the simulation. This assumption is based on the average predicted reduction of bioavailable P runoff generated by cover crop bids in the Tiffin Watershed BMP Auction Project.[4]

One decision-maker is assigned to each parcel and characteristics of that decision-maker are randomly generated for each simulation, including: 1) the cost of using cover crops, 2) TC of applying to the program, 3) stewardship attitude, 4) land rental agreement, 5) knowledge of the auction, and 6) eligibility based on current BMP usage. In the auction simulation, additional characteristics are 1) beliefs about phosphorus reduction from adopting cover crops on the individual's land and 2) beliefs about the range of CB scores that will be accepted in the auction. Parameters and their associated ranges are presented in Table 1.

To reflect the heterogeneity of farms, cover crop costs are independently drawn from a uniform distribution with a support of $20 and $60 per acre. This range of costs was selected based on interviews with farmers at the 2013 Michigan Ag Expo, and it aligns with cost-share payments available through government programs. For fiscal year 2015, the NRCS Environmental Quality Incentives Program (EQIP) offered Ohio farmers a 100% cost-share of $44.24/acre for winter-kill cover crops and $60.20/acre for cover crops that overwinter and are killed chemically or mechanically in spring (Natural Resources Conservation Service 2015).

Transaction costs involved with applying for a conservation program are distributed uniformly on the interval [142,1420], which represents a range of 4 to 40 hours of application time (following Peterson et al., 2014) with time valued at $35.50/hr.[5] The TC associated with implementing the BMP and complying with program requirements are not expected to differ among program types, thus they would not differentially impact program performance. Without loss of generality, we do not incorporate these TC, but they could easily be included if data were available.

We assume that 20% of individuals gain utility from taking stewardship actions that align with their environmental attitudes. This assumption is motivated by results from the follow-up questionnaire in which 21% of respondents indicated that they *strongly agree* with the statement, “I feel good about using management practices that improve water quality.” For stewardship-minded individuals, WTA for cover crops is reduced by $6.32/ac. This value originates from experimental auctions held in 2013 in which farmers who were members of environmental organizations (a proxy for stewardship attitudes) bid, on average, $6.32/ac. less to plant a cereal rye cover crop (Palm-Forster 2015).

We assume that one-third of parcels are rented, thus the decision-maker would have to coordinate with another manager (owner or renter) to participate. Without data about TC and rental agreements, we assume that TC of application and bid preparation increase by 50% for rented land.

To participate in a conservation program, decision-makers must be both knowledgeable about the program and eligible to receive funding. Thirty-percent of survey respondents reported having no knowledge of the BMP auction, thus in the model we assume that 30% of decision-makers do not know about conservation programs and thus do not apply. Land is considered eligible if cover crops are not currently being grown. LimnoTech (2013) reports that stakeholders have estimated that cover crops are adopted on 5-10% of the agricultural acreage within the Tiffin and nearly 8% of questionnaire respondents reported using cover crops on all of their acreage, while 36% reported using cover crops on at least a portion of land that they manage (Palm-Forster 2015). In the simulation of all conservation programs, we assume that 10% of parcels are ineligible because cover crops are already grown on those fields.

The behavior of land managers that are knowledgeable and eligible to participate in the conservation program is simulated based on a participation decision rule. The manager decides to apply for program j if expected utility from participating in the program exceeds baseline utility, which is assumed to be zero. In Eq. (2), utility from conservation is comprised of three components, 1) income that includes the BMP payment, 2) disutility from transactions cost associated with applying for and participating in the program, and 3) utility from aligning conservation actions with one's environmental stewardship ideals. In the simulation, all components of utility are converted to money metric units assuming that farmers share the same marginal utility of income, m. Each program simulation is repeated 1000 times using new random draws for all decision-maker characteristics for each of the 933 parcels.

Conservation auction

Individuals will only participate in the auction if the expected utility of participating exceeds their status quo utility. To compute the expected utility of bidding, two additional decision-maker beliefs are required for the auction simulation. First, managers have a belief about how much their parcel's P runoff will be reduced by planting a cover crop. This belief is randomly drawn from a uniform distribution over the range of potential runoff reductions (predicted by SWAT) for the 933 parcels in the watershed. Second, each manager has a belief about the highest CB score (highest bid to benefit ratio, $\tilde{\beta}$) that will be accepted in the auction, depending on the expected bids and benefits of proposals submitted by other farmers. We assume that CB scores are nonnegative, which requires that cover crops do not increase runoff and that bids are nonnegative. Individuals do not submit a bid if they believe their CB score exceeds the threshold. This belief may depend on the payments offered in existing programs. Current uniform payment programs in the Tiffin offer land managers between \$25 and \$60 per acre, so we assume that beliefs about the highest acceptable bid will fall in this range. The denominator of the CB score (e.g., the runoff reduction associated with the largest bid) is set at 0.115lb/ac., which is the 50th percentile of beliefs about runoff reduction on one's own field. We conduct sensitivity analyses to test the robustness of these assumptions.

Assuming that each manager knows their costs to adopt a BMP, they formulate their bid using the optimal bidding strategy described in the Appendix, which requires a distributional assumption regarding $\tilde{\beta}$. Conditional on bidding, the optimal bid is presented in Eq. (A.15) and is solved for each decision-maker using the constrained non-linear maximization routine in MATLAB. Next, the individual determines if that bid would generate positive net utility ($E[u_1] - u_0 \geq 0$) and if they think their CB score is below the maximum acceptable CB score, $\tilde{\beta}$. If both requirements hold, the individual submits a bid in the auction.

All submitted bids are evaluated to determine the cost per pound of reduced bioavailable P. Then, bids are ranked from lowest CB score (most cost-effective) to highest CB score (least cost-effective). Total payment required is calculated for each bid by multiplying the bid per acre by the total number of acres in that parcel. Bids are accepted in ranked order until the cumulative payment required exhausts the budget constraint, set at $100,000.[6]

Uniform payment conservation programs

In the uniform payment conservation program, individuals receive a payment of p per acre if they enroll in the program. If the payment offered by the program is at least as great as their minimum WTA, the individual will apply for the program.

Two types of uniform payment programs are simulated. The first targets environmentally vulnerable areas of the watershed, while the second is an untargeted program for which all parcels are eligible for payment. Participation in the targeted program is limited to individuals that manage highly vulnerable parcels while the untargeted program covers all parcels, regardless of vulnerability status.

Each of the 933 parcels is assigned a vulnerability index score, $I \in \{1,2,3\}$, by dividing the parcels into three quantiles based on the baseline amount of bioavailable P runoff (See Figure 4). Parcels with a score of I=3 represent the most vulnerable parcels with SWAT predicted bioavailable P runoff between 0.73 and 3.27 lbs./ac./yr. Parcels with a vulnerability score of I=1 represent less vulnerable parcels with SWAT predicted runoff between 0.25 and 0.57 lbs./ac./yr. In the targeted program, only the most vulnerable parcels (I=3) are eligible for the program.

As in the auction, the budget for the uniform payment program is constrained to $100,000. Participants are enrolled on a first-come, first-served basis depending on a randomly generated application order. The program is simulated for eight different per acre payment levels, $p \in \{ \$25, \$30, \$35, \$40, \$45, \$50, \$55, \$60\}$. Other uniform payment programs have offered payments in this range, including the Lake Erie Nutrient Reduction Program (LE-NRP) that offers $25/ac. for cover crops and NRCS EQIP that pays $60/acre for cover crop species that are killed chemically or mechanically (e.g. cereal rye) (Natural Resources Conservation Service 2015)

First-best program

To generate a best-case scenario reference point, a “first-best” conservation program is simulated in which land managers are paid exactly the amount that makes them indifferent between participating or not (i.e., they are paid their minimum WTA). This scenario assumes that the administrator knows all land manager costs and preferences and can exactly price discriminate and thus pay zero information rent. Using the same budget constraint and assumptions about the portion of knowledgeable and eligible participants, this scenario represents the most cost-effective outcome that would only be possible with perfect information.

Simulation experiments

Using the simulation model, we analyze the performance of reverse auctions compared to targeted and untargeted uniform payment programs. Transaction costs of bidding in a reverse auction are varied on a spectrum of equal to (1X), double (2X) and quadruple (4X) the cost of applying for the uniform payment programs. Five key conservation program outcomes are compared in each experiment: 1) number of applications submitted, 2) total funding awarded, 3) bioavailable P runoff reduction, 4) information rents extracted, and 5) cost-benefit ratio (cost per pound of bioavailable P runoff reduction). For each of the three TC levels, these five outcomes are compared among the reverse auction and targeted and untargeted uniform payment programs offering eight different levels of payments. In addition to the main experiment, we also examine the sensitivity of the results to variation in beliefs about the highest acceptable CB score.

Results

Results from the simulations illustrate how transaction costs reduce participation in reverse auctions and thereby undermine their cost-effectiveness compared to the uniform payment programs. The simulation also highlights how beliefs about the probability of bid acceptance can further erode the cost-effectiveness of auctions by reducing participation and promoting strategic bid inflation.

Equal transaction costs

In the first analysis, TC of submitting a bid are equal to the TC of applying for a uniform payment program. Relative to the first-best policy, the auction scenario and uniform payment schemes all enroll fewer people and pay more for each unit of bioavailable P reduction. Figure 5 presents a comparison of the average cost-effectiveness (measured in $/lb. bioavailable P reduction) across 1000 simulations for 12 programs (first-best outcome, BMP auction at three TC levels, and untargeted and targeted uniform payment programs at four payment levels). Recall that the first-best outcome is achieved by price discriminating with perfect information. In the first-best scenario, cost-effectiveness averages $341/lb. reduction in bioavailable P, while allocating funds with an auction results in a cost per pound of bioavailable P reduction of $593/lb. (Fig.5, columns 1 & 2).

Performance of the uniform payment programs varies by payment level (Table 2) and two patterns are evident. First, as expected, the untargeted payment program is less efficient than the targeted program at reducing P runoff at every payment level-- 41% more costly, on average. Second, in both uniform payment programs, the cost per pound of P abated decreases with lower uniform payment levels. But this benefit is partially offset by fewer applications submitted when lower payments are offered, which means fewer total benefits are procured. At the lowest payment levels, there are too few applications to exhaust the available program funds (Table 2).[7]

Figure 6 shows the number of simulated land managers who were eligible and willing to enroll their land in each conservation program. At the highest uniform payment level analyzed ($p = 60$), 373 (40%) of land managers are willing to enroll their parcels in the uniform payment program relative to 249 (27%) who are willing to submit a bid in the auction when TC are equal between the two programs. As the offered payment declines, fewer people are willing to enroll in a uniform payment program, with only 10 and 35 people willing to enroll for $25/acre and $30/acre, respectively. At these payment levels, so few people enroll in the two uniform payment programs that the conservation budgets are not fully utilized and runoff reduction is minimal (Table 2).

At higher fixed prices, cost-effectiveness of uniform payment programs is reduced because the benefit of greater participation is offset by the high information rents and lack of cost-benefit ranking of applicants. As shown in Table 3, high information rents are also paid in the auction program, but the ability to rank and select parcels makes auctions more cost-effective than both targeted and untargeted uniform payment programs paying above $40/ac. and $30/ac., respectively (Figure 5).

Transaction costs vary by policy

In the previous section, we reported results when TC of application are held constant across programs, but survey findings indicate that many farmer respondents perceived TC of submitting a bid to be daunting. In the follow-up questionnaire after the BMP auctions, 28% of respondents agreed with the statement that, “conservation auctions take more time to participate in than other conservation programs.” Additionally, 34% of respondents who were aware of the auction reported not submitting a bid because “the auction seemed complicated or time consuming.” These findings, along with the existing literature about transaction costs associated with conservation programs (Peterson et al. 2014) motivated experimental treatments that vary transaction costs of participation (measured in hours to submit a bid packet) by two (2X) and four (4X) times the participation cost of the uniform payment programs.

As the TC of auction participation increase, the number of people willing to submit a bid declines from 249 when TC are 1X greater to 164 when TC are 2X greater, and to 80 people when TC are 4X greater (Figure 6, columns 2 & 3). This decline in participation results in fewer high-impact bids being received, thus the average cost to reduce a pound of bioavailable P via reverse auctions increases from $579/lb. to $670/lb. when TC are double (2X), and $835/lb. when TC are quadruple (4X) the baseline (Figure 5). Even at the conservative estimate that TC participation costs are twice as high for an auction as for a uniform payment program, the reverse auction is less cost-effective and reduces P runoff less than targeted uniform payment programs offering $40/ac.

Sensitivity Analysis

The general finding that reverse auctions are less cost-effective than some uniform payment programs when bidding is costly is robust to a wide range of parameter adjustments. However, bidder beliefs about the maximum acceptable CB score deserve additional attention as they impact the perceived probability of bid acceptance that can result in censoring participation and strategic bidding. Beliefs about the maximum CB score pivot on the perceived ratio of the maximum acceptable bid amount to the lowest associated level of environmental benefit. Sensitivity analyses were conducted by evaluating these parameters over a range of values.

In the baseline analysis, the belief about the maximum acceptable bid was randomly varied between $38 and $90/ac, and the lowest associated level of runoff reduction was set at the 50th percentile of beliefs about one's own runoff reduction.

Holding TC at the 2X level, a sensitivity analysis was conducted by varying the expected per acre maximum acceptable bids across four levels ($25, $40, $60, and $80/ac). Participation increased when the expected maximum was higher, but so too did strategic bidding to extract information rents. When the expected maximum bid was $25, information rents were $4/ac., but only nine individuals submitted bids, on average. At $80 per acre, 230 bids were submitted, but information rents increased to $15/ac., on average. The most cost-effective outcome was achieved by setting beliefs about the maximum acceptable bid at $60/ac., which resulted in 152 bids submitted, a cost of $659/lb. of bioavailable P abated, and $11/ac. in information rents, on average.

A similar finding exists when beliefs about the lowest environmental benefit accepted are adjusted. Figure 7 shows the how bids submitted (a) and cost per pound of bioavailable P reduction (b) change across five TC levels and five levels of beliefs about the maximum acceptable CB score. If bidders believe only low CB scores (e.g., low bids, high benefits) will be accepted, fewer bids are submitted, especially when TC are high. Although participation increases when people believe higher CB scores will be accepted, strategic rent seeking also occurs, which reduces cost-effectiveness.

Discussion

Federal spending on conservation programs is projected to be $28.2 billion between 2014 and 2018, and an increasing proportion of funding is allocated to working lands programs (Lubben and Pease 2014). It is important to identify strategies to allocate funding cost-effectively among projects that provide environmental benefits. Conservation auctions have been identified as a key policy tool, but to be cost-effective they must attract a population of participants who are willing to submit bids. If participation is thin, projects may be funded with high costs per unit of environmental benefit procured. The objective of this article was to analyze the relative cost-effectiveness of auctions compared to uniform-price conservation programs when the transaction costs of bidding make participation in auctions costly. Results from this research suggest that high transaction costs of bid submission limit participation and cost-effectiveness of conservation auctions.

Lowering TC and reducing inflated perceptions of high TC involves familiarizing potential bidders with the auction process through straightforward advertising, information sessions, and working with leaders in the community to spread the word about the program. Whitten et al. (2013) propose a framework to help design conservation auctions to achieve greater participation that includes steps like building awareness, as well as educating and communicating with the eligible landowners. Streamlining the bidding process and reducing the time and effort required to participate may also reduce perceived TC and improve cost-effectiveness by increasing participation.

As participation increases, auctions become more attractive because the auctioneer can price discriminate among projects to select the most cost-effective ones. Auctions may also be preferred if land managers with high priority parcels have high costs of BMP implementation thus requiring payments that exceed the levels offered in a uniform program, but this assumes that managers are educated about their ability to generate environmental benefits using BMPs and that they believe that submitting a bid is worth their time. However, previous research suggests that as bidders become more familiar with reverse auctions, they learn about the highest acceptable CB score or bid cap (if one exists) and can bid strategically to extract rents from the auctioneer (Kirwan, Lubowski and Roberts 2005). For example, bidders with high value projects in lab experiments have strategically inflated bids to extract information rents (Cason and Gangadharan 2005). Results suggest that a tradeoff exists between boosting participation levels and minimizing rent seeking in discriminatory reverse auctions.

In some circumstances, it may be more cost-effective to use a targeted uniform-price program in lieu of an auction. More analysis is needed to identify preferred design parameters for targeted uniform payments and the associated conditions under which such a program is preferred to an auction, but results from the simulation model suggest that targeted uniform payment programs may perform better when high TC reduce auction participation. Given that conservation auctions can be administratively burdensome, administrative cost savings may be another benefit of using a uniform program. In this article, we do not explore differences in administrative costs among alternative conservation programs, but this is an important consideration for conservation agencies.

Figures

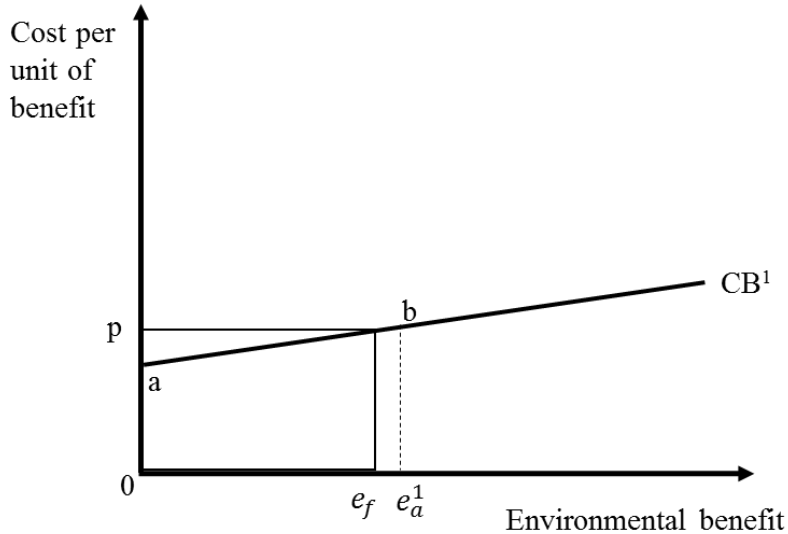


Figure 1. Environmental supply curve (contract curves) with full participation

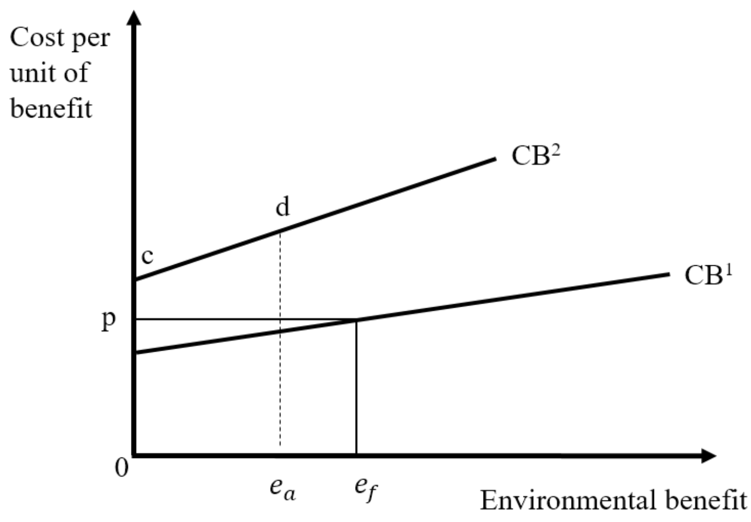


Figure 2. Contract curves for two different conservation programs may differ, thus affecting the benefits that can be procured with a given budget.

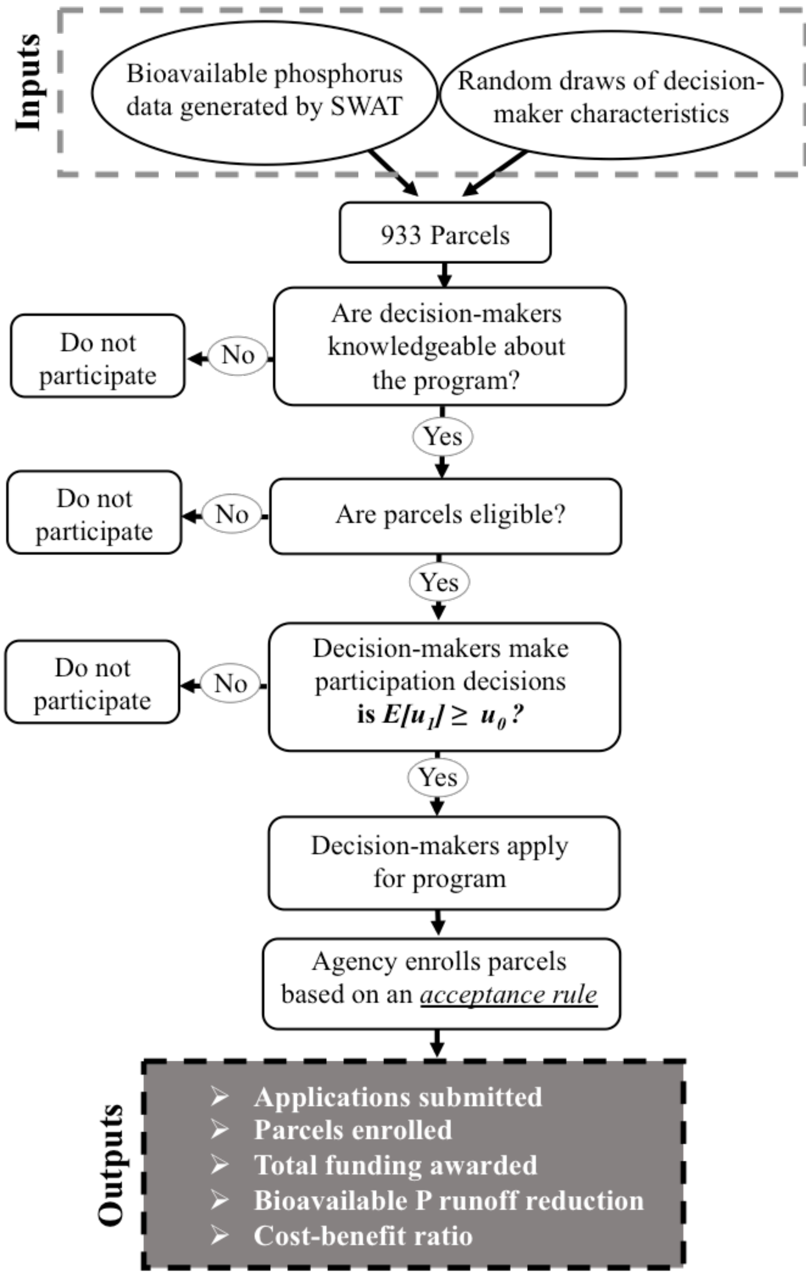


Figure 3. Policy simulation framework.

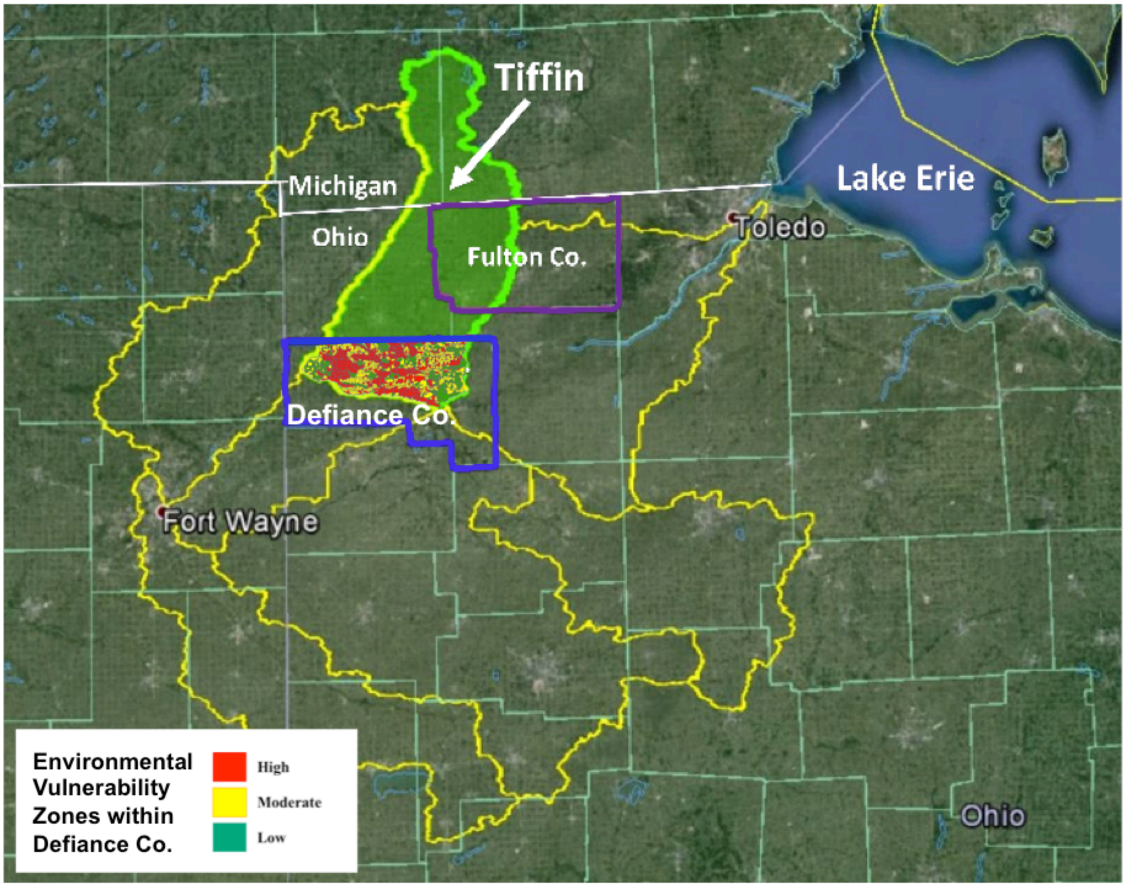


Figure 4. Map of the Tiffin Watershed and the three vulnerability areas for 933 parcels in Defiance County that were included in the simulation.

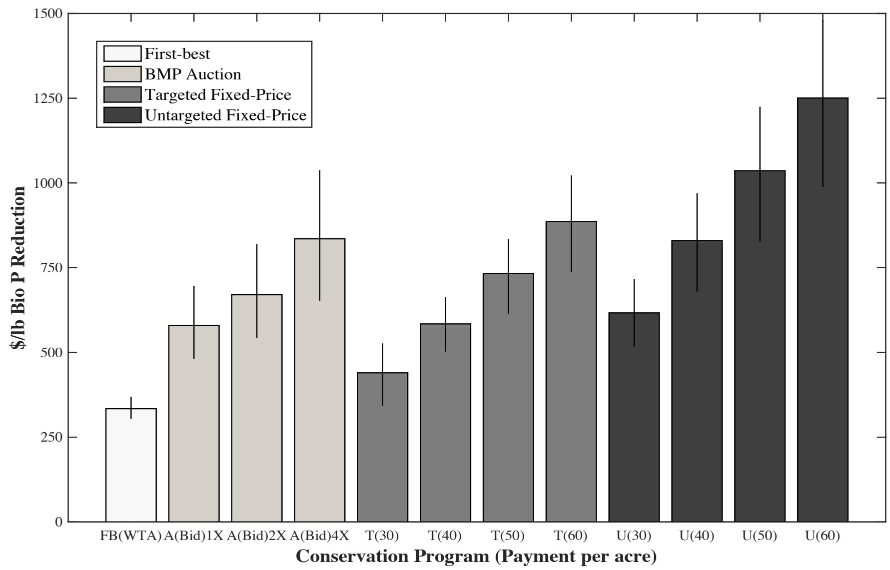


Figure 5. Simulated cost per pound of bioavailable phosphorus reduction for 11 conservation programs and the first-best outcome. Bars represent the average cost from 933 parcels over 1000 simulations; error bars show 95% confidence intervals.

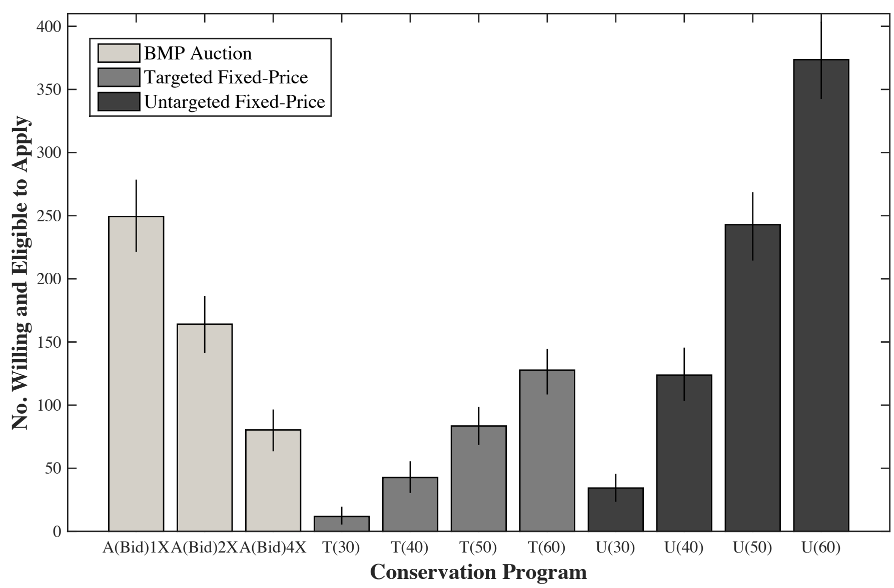
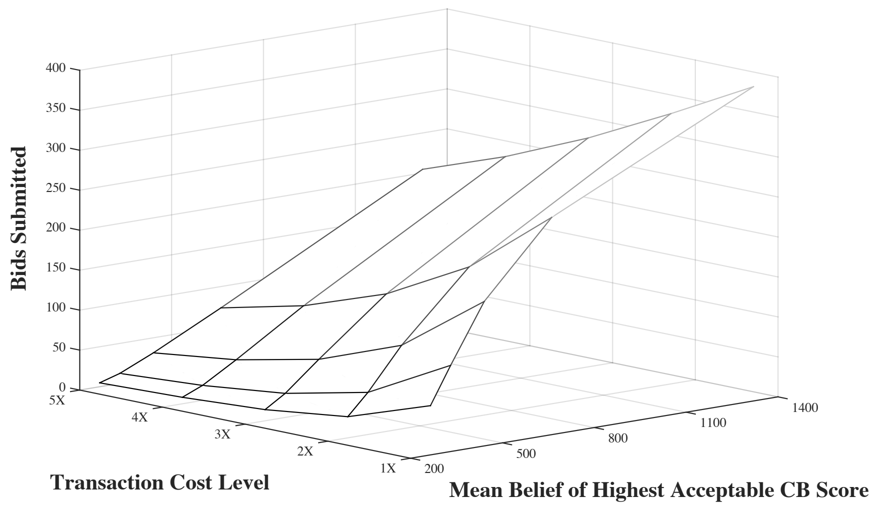
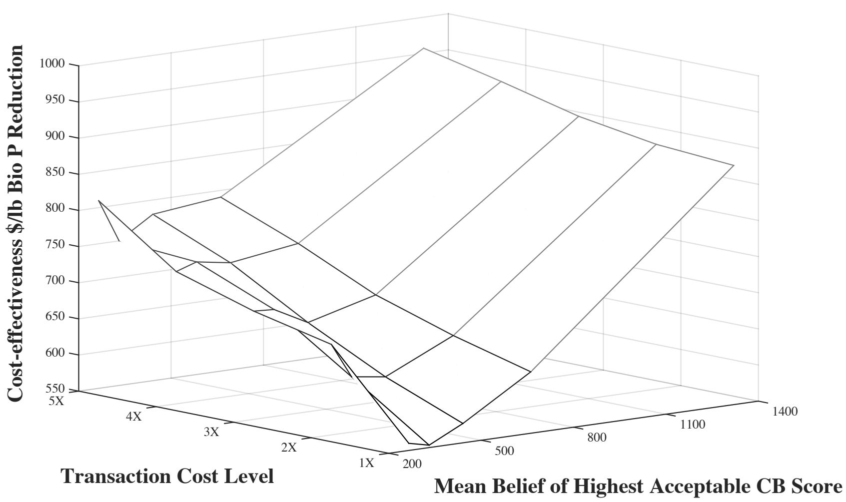


Figure 6. Simulated willingness to participate in 11 conservation programs. Bars represent the average number of people willing and eligible to participate from 933 parcels over 1000 simulations; error bars show 95% confidence intervals.



a. Bids submitted with varying levels of TC and beliefs about acceptable CB scores.



b. Cost per pound of reduced bioavailable P with varying levels of TC and beliefs about acceptable CB scores.

Figure 7. Sensitivity analysis to analyze changes in the number of bids submitted (a) and the average cost per pound of bioavailable P reduction (b) in reverse auctions with varying levels of transaction costs of application (5 levels) and beliefs about the highest acceptable CB score (5 levels). Outcomes are simulated 1000 times for the 933 parcels in the watershed.

Tables

Table 1. Parameters used in the conservation policy simulation

Variable	Form/Value in Numerical Example	Description	Units	Source
c_j	$U[20,60]$	Cover crop costs	$	Palm-Forster, 2015; NRCS, 2015
ρ_j [a]	$U[4, 40]$	Application time	hours	Peterson et al., 2014
τ [a]	35.5	Time cost	$/hr.	USDA-ERS, 2015
$pr(know = 1)$	0.30	Knowledge	prop.	Palm-Forster, 2015
$pr(eligible = 1)$	0.10	Eligibility	prop.	Palm-Forster, 2015
$pr(rent = 1)$	0.33	33% are involved in a rent agreement	prop.	Palm-Forster, 2015
v	$pr(v = 6.32) = 0.20$ $pr(v = 0) = 0.80$	Intrinsic utility from taking actions that align with environmental attitudes/values,	$	Palm-Forster, 2015
$\overline{\theta}$ [b]	$U[38,90]$, which is 1.5X the lowest ($25/ac.) and highest ($60/ac.) cost-share payments available from other programs.	Uniform distribution for beliefs about the highest bid that will be accepted in the auction.	$	Author estimate.
$\underline{e}$ [b]	50th percentile of beliefs about one's own runoff reduction.	Belief about the lowest amount of bioavailable P runoff reduction accepted in the auction.	lbs. bio P	Author estimate.

[a] The transaction cost of application equals the application time required times the cost of time.

[b] $\overline{\theta}/\underline{e}$ equals the expected CB cutoff score, $\tilde{\beta}$.

Table 2. Comparison of funding allocated, bioavailable P reduction and cost-benefit ratios among targeted and untargeted uniform payment programs at eight payment levels.

Payment per acre	Untargeted Uniform-Price			Targeted Uniform-Price		
	Funding Allocated ($)	Bio P Reduction (lbs./yr.)	Cost-Ben ($/lb. BioP)	Funding Allocated ($)	Bio P Reduction (lbs./yr.)	Cost-Ben ($/lb. BioP)
25	18,115	36	508	6,355	18	363
30	78,157	128	612	27,192	63	431
35	98,152	137	715	69,181	137	506
40	97,863	119	820	97,612	167	584
45	97,838	106	919	97,805	150	654
50	97,456	95	1027	97,549	134	727
55	97,303	86	1137	97,485	121	804
60	97,207	79	1238	97,208	111	874

Table 3. Average information rents per acre extracted in auction and uniform-price payment programs. Zero information rents are extracted in the First-best scenario in which managers are offered a payment equal to their minimum willingness to accept.

Auction		Uniform Price		
TC Level	Information Rent ($/ac)	Payment Level	Information Rent ($/ac) Untargeted	Information Rent ($/ac) Targeted
1X	11.4	30	3.8	3.8
2X	11.7	40	7.2	7.2
4X	12.2	50	11.1	11.2
--	--	60	15.5	15.5

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Appendix

Conditional on participating in an auction, land managers submit bids θ_k to maximize the difference between their expected utility of participating in conservation auction k and their status quo utility,

$$\max_{\theta_k} E(u_1) - u_0 \tag{A.1}$$

As shown in Eq. (2) in the article, expected utility can be written as,

$$E(u_1) = [m(\pi(a_k) + \theta_k) + v(a_k) - \psi_2(\boldsymbol{\rho_k})]\sigma + m\,\pi(a_0)[1-\sigma] - \psi_1(\boldsymbol{\rho_k}) \tag{A.2}$$

where, m is the marginal utility of income, k is a conservation auction program, and $\boldsymbol{\rho_k}$ a set of non-price attributes of the program. Let a represent agricultural management decisions that affect agricultural income π (including conservation payments θ) and stewardship utility v. We assume that certain management decisions are required to participate in a conservation program; therefore, instead of choosing a, land managers choose their bid, conditional on participating. Status quo utility is $u_0 = m\,\pi(a_0)$ and σ is the probability of contract acceptance. $\psi_1(\boldsymbol{\rho_k})$ is disutility associated with transaction costs (TC) of applying for the program (i.e., submitting a bid) and $\psi_2(\boldsymbol{\rho_k})$ is the disutility from TC associated with complying with rules and regulations once accepted into the program. Recall that $\psi_1(\boldsymbol{\rho_k})$ is experienced regardless of bid acceptance.

Accounting for the two-dimensional cost-benefit (CB) bid scoring system commonly used in conservation auctions, we expand upon and adapt the model proposed by Glebe (2013). The bid (θ) and predicted benefit level (e) are used to determine the scoring index, $\beta = \theta/e$, which is simply the bid per unit of environmental benefit.

The probability that bid n is accepted depends on how bid n ranks among the other submitted bids. When projects have heterogeneous environmental impacts, bids are ranked and selected based on an environmental score that takes into account both the payment requested (bid) and the predicted environmental benefits. Thus beliefs about bid acceptance depend on the land manager's bid and their beliefs about how their own environmental benefit (often unknown) will compare to their beliefs about the costs and benefits of competing project tenders.

Individuals do not know the true probability of bid acceptance (σ), but instead develop their perceived probability of bid acceptance ($\ddot{\sigma}$). The perceived probability depends on farmer beliefs about the distributions of bids $[\underline{\theta}, \overline{\theta}]$ and the predicted environmental benefits $[\underline{e}, \overline{e}]$ associated with bid submissions, which form the expected upper and lower limits of the scoring index, $[\underline{\beta}, \overline{\beta}]$. Subjective beliefs about these distributions generate a belief about $\tilde{\beta}$, which is the highest CB score (i.e., bid per unit of benefit) that will be accepted. Thus the perceived probability that a farmer's bid is accepted can be written as $\ddot{\sigma}(\ddot{\beta}_n, \ddot{\beta}_{-n})$, where $\ddot{\beta}_n$ is the subjective belief of one's own score and $\ddot{\beta}_{-n}$ is the subjective beliefs of others' scores.

Let $f(\beta)$[8] be the expected density function of $\tilde{\beta}$, which characterizes farmers' beliefs about the bid acceptance cutoff point. Given the predicted environmental benefits of the proposed conservation project, the expected probability that a bid is accepted is,

$$\ddot{\sigma} = P(\beta \leq \tilde{\beta}) = 1 - F(\beta) \tag{A.3}$$

Bidders submit a bid (θ) if the expected utility from participation is at least as great as the reservation utility when no conservation practices are adopted (i.e. *status quo* utility). The *individual rationality* (IR) condition, requires that participants prefer or are at least indifferent between participation and non-participation,

$$u_k[1 - F(\beta)] + \left(u_0 - \psi_1(\boldsymbol{\rho_k})\right)F(\beta) \geq u_0 \tag{A.4}$$

where, u_k is the utility received when one is enrolled in the conservation program.

Since $u_0 = m\pi(a_0)$, substituting Eq. (A.2) into Eq. (A.4) results in,

$$\left(m[\pi(a_k) + \theta_k] + v(a_k) - \psi(\boldsymbol{\rho_k})\right)[1 - F(\beta)] + \left(m * \pi(a_0) - \psi_1(\boldsymbol{\rho_k})\right)F(\beta) \geq m * \pi(a_0) \tag{A.5}$$

Rearranging Eq. (A.5), it can be shown that,

$$\left(m[\pi(a_k) - \pi(a_0) + \theta_k] + v(a_k) - \psi_2(\boldsymbol{\rho_k})\right)[1 - F(\beta)] - \psi_1(\boldsymbol{\rho_k}) \geq 0, \tag{A.6}$$

As shown in Eq. (A.1), farmers will choose a bid θ_k that maximizes expected net payoff in the program. This is analogous to maximizing the left-hand side of Eq. (A.6), which is the difference between expected utility of participating and the status quo utility. Note that farmers face a tradeoff when choosing their bid – a higher bid increases their potential payment, but it increases the agency's cost per unit of environmental benefit, thus decreasing the probability that the bid will be accepted.

Assuming separability and linearity of the arguments in the utility function, maximizing the left-hand side of Eq. (A.6) with respect to θ_k yields the farmer's optimal bid, ${\theta_k}^*$. For clarity, the derivation of the optimal bid is shown in four steps.

First, using the product rule to take the derivative of the left-hand side of Eq. (A.6) with respect to θ_k we can show,

$$m[1 - F(\beta)] + \left(m[-c_k + {\theta_k}^*] + v(a_k) - \psi_2(\boldsymbol{\rho_k})\right)\frac{\partial[1 - F(\beta)]}{\partial\, {\theta_k}^*} = 0 \tag{A.7}$$

For simplicity of notation, let c_k represent the full cost (direct and opportunity) of taking conservation action a_k, such that $c_k = \pi(a_0) - \pi(a_k)$.

Second, recall that $\beta = \frac{{\theta_k}^*}{e}$ so that we can use the chain rule to show that the derivative of $1 - F(\beta)$ with respect to θ_k is,

$$\frac{\partial[1 - F(\beta)]}{\partial\, \theta_k} = -\frac{\partial F(\beta)}{\partial \beta}\frac{\partial \beta}{\partial \theta_k} = -\frac{f(\beta)}{e} \tag{A.8}$$

Third, substitute Eq. (A.8) into Eq. (A.7),

$$m[1 - F(\beta)] = \big(m[-c_k + \theta_k] + v(a_k) - \psi_2(\boldsymbol{\rho_k})\big)\frac{f(\beta)}{e} \tag{A.9}$$

Fourth, rearrange Eq. (A.9) to show that,

$$\theta_k{}^* = c_k + \frac{\psi_2(\boldsymbol{\rho_k}) - v(a_k)}{m} + \frac{[1 - F(\beta)]e}{f(\beta)} \tag{A.10}$$

To solve numerically, a functional form must be assigned to $F(\beta)$. Following the literature, we assume a uniform distribution such that,

$$F(\beta) = (\beta - \underline{\beta})(\overline{\beta} - \underline{\beta})^{-1} \tag{A.11}$$

where, $\overline{\beta}$ and $\underline{\beta}$ are beliefs about the upper and lower limits of the scoring index, β.

Taking the derivative of $F(\beta)$ with respect to β yields,

$$f(\beta) = (\overline{\beta} - \underline{\beta})^{-1} \tag{A.12}$$

Therefore, we show that

$$\frac{1 - F(\beta)]e}{f(\beta)} = \frac{\left[1 - (\beta - \underline{\beta})(\overline{\beta} - \underline{\beta})^{-1}\right]e}{(\overline{\beta} - \underline{\beta})^{-1}} = (\overline{\beta} - \beta)e = \left(\overline{\beta} - \frac{\theta_k{}^*}{e}\right)e = \overline{\beta}e - \theta_k{}^* \tag{A.13}$$

Then, by substituting (A.13) into (A.10) it can be shown that,

$$\theta_k{}^* = c_k + \frac{\psi_2(\boldsymbol{\rho_k}) - v(a_k)}{m} + \overline{\beta}e - \theta_k{}^* \tag{A.14}$$

Finally, conditional on bidding, we can solve for the optimal bid,

$$\theta_k{}^* = \frac{E[e]\overline{\beta}m{*} + m\, c_k + \psi_2(\boldsymbol{\rho_k}) - v(a_k)}{(2m)}. \tag{A.15}$$

where, the individual considers their expected environmental benefit $E[e]$ since the true e is unknown to potential bidders.

[1] Bioavailable phosphorus = SRP + (OP + PIP) * 0.30, where SRP is soluble reactive phosphorus, OP is organic phosphorus, and PIP is particulate inorganic phosphorus (DePinto, Young and Martin 1981). Bioavailable phosphorus was the target pollutant

[2] One farmer withdrew his five bids due to concerns about cover crop management.

[3] Responses are not mutually exclusive because respondents were allowed to indicate multiple barriers.

[4] This assumption removes the need to re-run the SWAT model for each parcel in the watershed, while still reflecting the heterogeneity of cropland by proportionally reducing baseline runoff calculated for each hydrologic response unit (HRU) within the landscape.

[5] The cost of time is justified by assuming the 2014 median household income for farm operator households of $71,000 per year (USDA-ERS 2015), which equates to about $35.50/hr., assuming a 40 hour work week for 50 weeks per year.

[6] The $100,000 budget constraint reflects funding earmarked for cover crops in two incentive programs that were implemented in Defiance and Fulton Counties in 2014, 1) the Lake Erie Nutrient Reduction Program (LE-NRP) that offered $25 per acre for cover crops on 1,000 acres county-wide, and 2) the NRCS Tri-State Western Lake Erie Basin Phosphorus Reduction Program that offered $50 per acre for cover crops on 1,500 acres county-wide.

[7] As shown in Table 2, the \$100,000 budget is never fully exhausted because funds were insufficient, on the margin, to pay for cover crops on all acres of the next highest ranking parcel. In this simulation, partial funding was not awarded to projects on the margin, but doing so would reduce the level of unutilized conservation funds.

[8] The probability density of the expected bid cap can be rewritten as the marginal impact of increasing one's bid on the probability that the bid is rejected (i.e., $f(\beta) = \partial F(\beta)/\partial\theta$). If a bidder increases their bid, ceteris paribus, the probability of bid acceptance declines and it becomes more likely that the bid will be rejected, thus $f(\beta) = \partial F(\beta)/\partial\theta > 0$. Therefore, the entire term $\left(1 - F(\beta)\right)/f(\beta)$ is positive.