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

Leah H. Palm-Forster, Scott M. Swinton, Frank Lupi, and Robert S. Shupp

In a world free of transaction costs, reverse auctions have the potential to 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 practices that reduce phosphorus runoff in Northwest Ohio experienced very thin bidding. According to a follow-up survey, auction participation was deterred by the perceived 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 can be less cost-effective than spatially targeted, uniform payment programs that attract higher participation.

Key words: Agri-environmental policy, conservation programs, cost-effective, endogenous participation, reverse auctions, transaction costs.

JEL codes: Q15, Q52, D82, Q58.

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

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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). It is also administratively challenging to use sophisticated biophysical models to predict benefits from BMPs in order to allocate funding via a reverse auction. Complex models can be used to guide funding decisions in a variety of programs, including uniform payment programs, but biophysical models are particularly important tools when reverse auctions are used to fund new BMPs on working lands because the wide array of management practices increases the heterogeneity of possible benefits from BMP adoption.

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, much of the theoretical and empirical literature assumes that submitting bids in reverse auctions is costless (Latacz-Lohmann and Schilizzi 2005), which likely overestimates participation rates that would occur in reality. Previous studies of agri-environmental programs in Europe have found that transaction costs can be high for participants in agri-environmental programs (Falconer 2000; Groth 2008; Mettepenningen, Verspecht, and Van Huylenbroeck 2009), and recent research suggests that transaction costs faced by farmers can greatly affect their willingness to participate in U.S. conservation programs (McCann and Claassen 2016; Peterson et al. 2014). Two recent experimental studies on conservation auctions keenly acknowledge the presence of transaction costs by incorporating them in the bidding process (Fooks, Messer, and Duke 2015; Fooks et al. 2016), but evaluating the impact of these transaction costs is not the goal of either study. To our knowledge, no research has explicitly examined the effect of transaction costs on participation in reverse auctions and the relative cost-effectiveness of alternative agri-environmental 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 (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 bid-benefit 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 reduce phosphorus runoff very little. A follow-up survey revealed barriers and deterrents to participation, including high transaction costs of bidding as perceived by landowners (Palm-Forster et al. forthcoming). A critical question that arises from this work is how the outcomes of a uniform payment program would have compared to the outcomes from the reverse auctions.

The objective of this article are (*a*) to develop an empirically grounded farmer behavioral model to simulate participation choice in conservation programs and (*b*) to assess the cost-effectiveness of simulated environmental outcomes from auctions as compared to targeted and untargeted 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 some 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: (*a*) cover crops, (*b*) filter strips, and (*c*) subsurface drainage control structures. Thirty-six bids for new BMPs were initially submitted by ten 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 twenty-nine parcels. After five additional bids were withdrawn from the program,[2] twenty-four 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 twenty-five dollars 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: (*a*) lack of knowledge about the BMP auction (30%), (*b*) perceived ineligibility to submit a bid (26%), and (*c*) lack of interest in submitting a bid (44%). Among individuals who knew about the auction and felt eligible, four key factors deterred participation: (*a*) the auction seemed complicated (38%); (*b*) they did not want to adopt any of the three eligible practices (26%), (*c*) land rental agreements complicated participation (28%); and (*d*) they perceived a low probability of bid acceptance (18%)[3] (Palm-Forster et al. forthcoming). These survey results inform our simulation model of farmer participation in conservation programs in the Tiffin Watershed.

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 (TCs) 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

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

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: $\psi\left(\boldsymbol{\rho_j}\right) = \psi_1\left(\boldsymbol{\rho_j}\right)+\psi_2\left(\boldsymbol{\rho_j}\right)$, where $\psi_1\left(\boldsymbol{\rho_j}\right)$ is disutility associated with applying for the program and $\psi_2\left(\boldsymbol{\rho_j}\right)$ is the disutility from complying with rules and regulations once accepted into the program. Assuming $v(a_0)=0$, status quo utility is $u_0 = m\ \pi(a_0)$. By specifying a constant marginal utility of income in equation (1), we assume risk neutrality throughout this analysis. We

[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 because this form of phosphorus drives algal production in Lake Erie (Baker 2010).

[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.

consider possible implications of this assumption in the discussion section.

Acceptance in a conservation program is not guaranteed, particularly when funding is allocated by a reverse auction. But regardless of whether an application is successful, the applicant incurs TC disutility $\psi_1\left(\boldsymbol{\rho_j}\right)$ 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 for a risk-neutral farmer can be written as

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

An individual will apply for funding from a conservation program if

$$(3)\quad E(u_j) - u_0 \geq 0.$$

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)

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

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 targeted environmental benefits. 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 bid-benefit ranking metric (β-score), $\beta = {}^{\theta}/_{e}$, where θ is the bid submitted and e is the predicted environmental benefit from the proposed project.

The land manager chooses a bid θ_j to maximize the difference between their expected utility and their status quo utility,

$$(5)\quad \max_{\theta_j} E\left(u_j\right) - u_0.$$

Conservation programs that use reverse auctions to rank and select contracts, like the USDA's Conservation Reserve Program (CRP), often employ a discriminatory price auction in which selected bidders are paid the amount of their bid (Hellerstein, Higgins, and Roberts 2015). In discriminatory price auctions, 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, Higgins, and Roberts 2015; Cason, Gangadharan, and Duke 2003; Jacobs, Thurman, and Marra 2014). In this article, we assume that bidders believe that they know (with certainty) the level of environmental benefits, e, that will be provided by a BMP on their land. However, we allow for the possibility that farmers' beliefs of e are not equal to their true e because the true level of environmental benefits may be different.

In choosing a bid, the manager considers the probability that the bid will be accepted. 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 the farmer's exogenous expectation of $\tilde{\beta}$, which is the highest β-score (i.e., bid per unit of benefit) that will be accepted. In our model, projects are scored on both the bid and predicted environmental benefit;

therefore, participants will form subjective expectations about the range of β-scores (bid-benefit ratios) that will be accepted. Let $\bar{\beta}$ and $\underline{\beta}$ be the expected upper and lower limits of the threshold β-score, respectively, and let $f(\beta)$ be the expected density function of $\tilde{\beta}$. For a given β, which depends on the bid and the environmental benefits, the expected probability that a bid is accepted is $\ddot{\sigma} = P\left(\beta \leq \tilde{\beta}\right) = 1 - F(\beta)$.

Individuals submit an application only if

$$(6) \quad E\left(u_{\mathrm{j}}|\theta_j^*\right) - u_0 \geq 0.$$

As shown in equation (2), $E\left(u_{\mathrm{j}}|v\theta_j\right)$ is affected by both monetary and nonmonetary factors, including profits using conservation actions a_{j}, the intrinsic value of stewardship actions, and TC. Since the TC of application $\psi_1\left(\boldsymbol{\rho_j}\right)$ is incurred regardless of bid acceptance, this cost does not influence the optimal bid amount; however, it does influence the participation decision. Particularly for programs that simulate environmental outcomes using biophysical models, detailed information may be required about baseline agricultural practices or past management. Such requirements increase $\psi_1\left(\rho_j\right)$, which will reduce participation.

Equation (6) shows that expected utility is conditional on the optimal bid θ_j^*. The full derivation of the optimal bid is presented in the supplementary appendix online. We show that, without specifying a functional form for the perceived probability of bid acceptance, the optimal bid (conditional on bidding) for a risk-neutral farmer can be written as

$$(7) \quad \theta_j^* = \pi(a_0) - \pi\left(a_j\right) + \frac{\psi_2\left(\rho_j\right) - v\left(a_j\right)}{m} - \frac{\ddot{\sigma}(\theta^*)}{\partial\ddot{\sigma}/\partial\theta^*}$$

where $\theta_j^* \geq 0$ since otherwise the farmer would have adopted the BMP voluntarily without the presence of an incentive program. The optimal bid presented in equation (7) also assumes that farmers believe that they know their true e. If farmers have uncertainty about their e values, the optimal bid would differ from equation (7). Assumptions about e are discussed in the supplementary appendix online.

The bid is influenced by (a) the change in expected profit reflected by the full cost of BMP adoption, (b) transaction costs of program compliance, (c) utility provided by environmental stewardship, and (d) 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_j^* looks similar to the individual's WTA for a uniform payment in equation (4), but there is now a negative monetary value $\left(\frac{\ddot{\sigma}(\theta^*)}{\partial\ddot{\sigma}/\partial\theta^*}\right)$, whose subtraction increases the optimal bid in equation (7) above the WTA derived in equation (4). As the probability of bid acceptance increases, the bid increases; therefore, if the individual thinks that their project is particularly competitive, they will increase their bid 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. We refer to this behavior as "strategic bidding" because the participant is trying to strategically inflate their bid to increase their payoff.

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 where the cost reflects the minimum payment that the farmer requires to adopt the BMP. 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

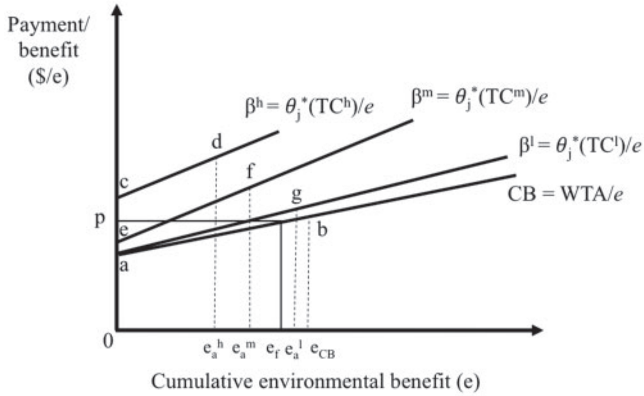

Figure 1. Contract curves for different conservation programs may differ depending on transaction costs of participation and strategic bidding, thus affecting the benefits that can be procured with a given budget

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.

A uniform payment program offering price p would generate environmental benefits e_f and make payments that total $p*e_f$. Holding the budget fixed ($Budget = p*e_f$), an incentive-compatible reverse auction, which allocates payments equal to the WTA of individual farmers, would result in an increase of benefits procured to e_{CB} and payments would equal the area $0,a,b,e_{CB}$. 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.

Ranking and selecting bids based on the true CB ratio is considered the first-best scenario. However, auction participants do not always have an incentive to bid their true WTA. For example, discriminatory price reverse auctions that pay winning bidders the amount of their bid are not incentive compatible. In a discriminatory reverse auction, farmers may inflate their bids (i.e., bid strategically) in an attempt to extract information rents. As shown by Cason, Gangadharan, and Duke (2003) and Glebe (2013), bidders have an incentive to bid above their minimum WTA in a discriminatory price auction. If farmers believe that the benefits of their project are large relative to other projects, they will strategically increase their bid in an attempt to receive more money from the auctioneer, causing the contract curve for the reverse auction to shift upward (more costly) relative to the contract curve generated in a first-best scenario.

Deviations between the first-best scenario (when farmers are paid their WTP) and the true contract curve can also be driven by differences in bids resulting from different TCs between the programs. Lack of knowledge about a program and other participation barriers can also affect the slope of the 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 (*a*) not knowledgeable, (*b*) not eligible, or (*c*) 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 1 shows how contract curves for reverse auctions (represented by β^l, β^m, and β^h) might differ from CB. The contract curve β^l shows a situation in which perceived TCs are low and the pool of participants is similar. In this case, TCs may not significantly deter participation; therefore, the level of total environmental benefits procured is e_a^l, which is still greater than e_f but less than e_{CB}.

Higher perceived transaction costs can shift the contract curves further upward, like those depicted by β^m and β^h. Less participation can limit the options for funding projects with low cost-benefit ratios. Curve β^h represents a situation in which TCs of bidding significantly reduce participation, particularly for projects with low β-scores. In this case, benefits procured are e_a^h using a budget equal to the area 0,c,d,e_a^h (the budget constraint is held constant for each scenario). Funding costly projects reduces the quantity of environmental benefits that can be procured with a limited conservation budget. 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 decline from e_{CB} to e_a^h.

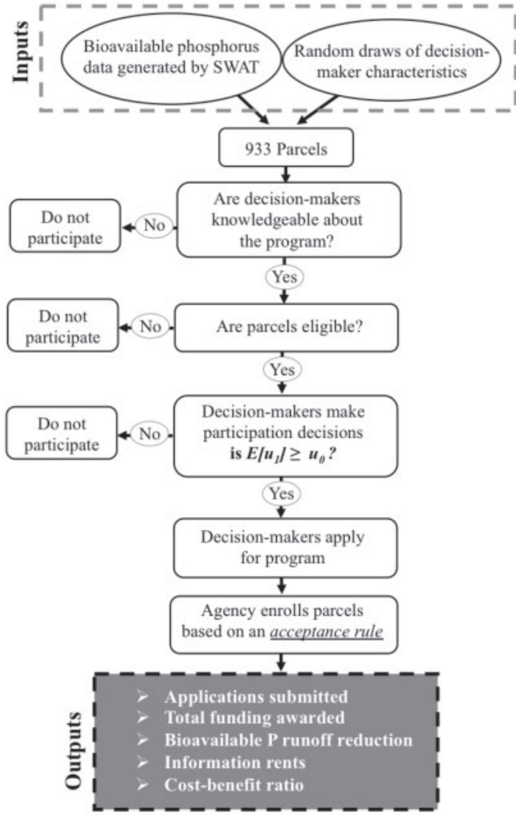

Figure 2. Policy simulation framework

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: (*a*) a reverse auction program, (*b*) an untargeted uniform payment program, and (*c*) 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 and selects projects with the lowest cost-benefit ratio until the budget is exhausted. Figure 2 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 phosphorus (P) loss. Cover crop decisions are simulated for 933 agricultural parcels in Defiance County, Ohio, within the Tiffin River Watershed (figure 3). The Soil and Water Assessment Tool (SWAT) is used to predict the amount of bioavailable P runoff generated, assuming that cover crops reduce per acre bioavailable P runoff by 6.9% for fields in the simulation (LimnoTech 2013). 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: (*a*) the cost of using cover crops, (*b*) TCs of applying to the program, (*c*) stewardship attitude, (*d*) land rental agreement, (*e*) knowledge of the auction, and (*f*) eligibility based on current BMP usage. In the auction simulation, additional characteristics are (*a*) a site-specific expectation about

[4] This assumption removes the need to rerun 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.

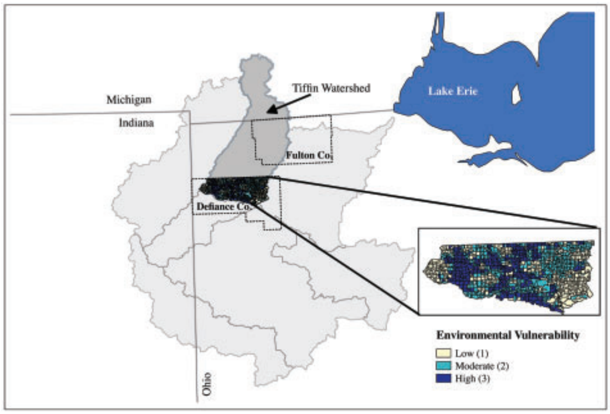

Figure 3. Map of the Tiffin Watershed and the three vulnerability scores for 933 parcels in Defiance County that were included in the simulation

bioavailable phosphorus reduction from adopting cover crops on the individual's land and (*b*) beliefs about the range of β-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 twenty dollars and sixty dollars 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 Natural Resource Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP) offered Ohio farmers a 100% cost-share of $44.24 per acre for winter-kill cover crops and $60.20 per acre for cover crops that overwinter and are killed chemically or mechanically in spring (USDA-NRCS 2015).

Previous research has quantified TCs as the time cost of applying for and participating in an agri-environmental program (Groth 2008; Peterson et al. 2014). In the simulation, TCs involved with applying for a conservation program are distributed uniformly on the interval [142, 1420], which represents a range of four to forty hours of application time (following Peterson et al. 2014), with time valued at $35.50 per hour.[5] The TCs 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 per acre. 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 per acre 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 TCs and rental agreements, we assume that TCs 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

[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/hour, assuming a forty-hour work week for fifty weeks per year.

Table 1 Parameters Used in the Conservation Policy Simulations

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
m	1	Marginal utility of income	utils	Author estimate
pr(know = 1)	0.70	Knowledge	%	Palm-Forster 2015
pr(eligible = 1)	0.90	Eligibility	%	Palm-Forster 2015
pr(rent = 1)	0.33	Involved in a rental agreement	%	Palm-Forster 2015
v	$\begin{cases} pr(\text{v} = 6.32) = 0.20 \\ pr(\text{v} = 0) = 0.80 \end{cases}$	Intrinsic utility from taking actions that align with environmental attitudes/values	\$	Palm-Forster 2015
$\tilde{\beta}$	U[567, 1343]	Uniform distribution for beliefs about the highest β-score that will be accepted in the auction	\$	Author estimate

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

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% to 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 who 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 equation (1), utility from conservation is comprised of three components: (a) income that includes the BMP payment, (b) disutility from transaction cost associated with applying for and participating in the program, and (c) 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 their expected utility of participating exceeds their status quo utility (see equation [6]). To compute the expected utility of bidding, two additional decision-maker characteristics are required for the auction simulation. First, managers have a site-specific belief about the reduction in bioavailable P runoff from planting a cover crop on their land $\ddot{e}_I$. This expectation depends on the environmental vulnerability of their land and the runoff reductions predicted by SWAT for the 933 parcels in the watershed. 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 3). Parcels with a score of I = 3 represent the most vulnerable parcels, with SWAT-predicted initial bioavailable P runoff between 0.73 and 3.27 pounds per acre per year. Parcels with a vulnerability score of I = 1 represent less vulnerable parcels, with SWAT-predicted initial runoff between 0.25 and 0.57 pounds per acre per year. The site-specific expectation, $\ddot{e}_I$, equals the median annual runoff reduction per acre generated by cover crops on land in each of the three vulnerability classes, such that $\ddot{e}_1 = 0.031$ pounds per acre per year, $\ddot{e}_2 = 0.045$ pounds per acre per year, and $\ddot{e}_3 = 0.059$ pounds per acre per year.

Second, each manager has a belief about the highest β-score (highest bid to benefit ratio, $\tilde{\beta}$) that will be accepted in the auction. This belief depends on the expected bids and benefits of proposals submitted by other farmers. We assume that β-scores are non-negative, which requires that cover crops do not increase runoff and that bids are non-negative. Individuals do not submit a bid if their expected β-score for their optimal bid exceeds their belief about the highest β-score that will be accepted in the auction. Beliefs about the threshold β-score may depend on the payment amounts offered in existing programs. Current uniform payment programs in the Tiffin offer land managers between twenty-five dollars and sixty dollars per acre; therefore, we assume that beliefs about the highest acceptable bid will fall in the range [25∗1.5, 60∗1.5]. The denominator of the threshold β-score (e.g., the runoff reduction associated with the largest bid) is set at 0.067 pounds per acre per year—the average level of runoff reduction for highly vulnerable fields. Therefore, beliefs of the threshold β-score are drawn from a uniform distribution on the support interval [567, 1,343]. We conduct sensitivity analyses to test the robustness of these assumptions.

Assuming that each manager knows their own costs to use cover crops, they formulate their bid using the optimal bidding strategy described in the supplementary appendix online. Conditional on bidding, the optimal bid is

$$(8) \quad \theta_j{}^* = \frac{m(e_I\ddot{}\bar{\beta} + \ c_j) + \psi_2(\boldsymbol{\rho_j}) - \ v(a_j)}{(2m)}.$$

Distributional assumptions and the full derivation of the optimal bid are presented in the supplementary appendix online. The optimal bid for each decision-maker is calculated using equation (8).[6] Next, the individual determines (*a*) if that bid would generate positive net utility $(E[u_j] - u_0 \geq 0)$ and (*b*) if they think their own β-score is below their belief for the maximum acceptable β-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 (i.e., the true β-scores). Then, bids are ranked from lowest β-score (most cost-effective) to highest β-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.[7]

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 who manage highly vulnerable parcels (I = 3), while the untargeted program covers all parcels, regardless of vulnerability status. 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 (twenty-five dollars, thirty dollars, thirty-five dollars, forty dollars, forty-five dollars, fifty dollars, fifty-five dollars, sixty dollars). Other uniform payment programs have offered payments in this range, including the Lake Erie Nutrient Reduction Program (LE-NRP), which offers twenty-five dollars per acre for cover crops,

[6] Alternatively, the optimal bid for each farmer can be solved using the constrained nonlinear maximization routine in MATLAB by maximizing the left-hand side of equation (A.6) (see the supplementary appendix online) with respect to the bid. We directly calculate the bid in equation (8) to reduce computation time.

[7] 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 twenty-five dollars 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 fifty dollars per acre for cover crops on 1,500 acres county-wide.

and NRCS EQIP, which pays sixty dollars per acre for cover crop species that are killed chemically or mechanically (e.g., cereal rye) (USDA-NRCS 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., 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 rents. 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. Five key conservation program outcomes are compared in each experiment: (*a*) number of applications submitted, (*b*) total funding awarded, (*c*) bioavailable P runoff reduction, (*d*) information rents extracted, and (*e*) cost-benefit ratio (cost per pound of bioavailable P runoff reduction). These five outcomes are compared among reverse auctions with three levels of TCs 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 β-score.

Perceived transaction costs of bidding in a reverse auction are varied on a spectrum of equal (1X) to double (2X) and triple (3X) the cost of applying for the uniform payment programs. We test multiple levels of TCs because data are not available to estimate the relative levels of TCs that farmers perceive to be associated with reverse auctions compared to uniform payment programs. TCs of bidding in auctions originate both from tasks associated with submitting a bid and the increased cognitive burden of formulating a bid. Participating in reverse auctions often requires tasks such as submitting information about current land management and producing field maps and information about land characteristics. Another challenge is determining how much to bid based on the costs of BMP adoption and learning how to be competitive in the auction. The cognitive burden of formulating a bid is exacerbated when farmers are unfamiliar with the auction process or the eligible BMPs. Research has found that farmers often seek assistance to formulate their bid via one-on-one consultations and by attending workshops and information sessions, which all require additional time and effort (Whitten et al. 2013).

Results

Results from the simulations illustrate how transaction costs reduce participation in reverse auctions and can 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 when the perceived probability of acceptance is low and promoting strategic bid inflation when the perceived probability of acceptance is high.

Since different levels of uniform payments may be offered, we compare auction outcomes to eight levels of uniform payments between twenty-five dollars per acre and sixty dollars per acre. Results from uniform payment programs offering the eight different payment levels are presented in table 2, but we focus our analysis on the programs offering forty dollars, fifty dollars, and sixty dollars per acre (see figure 4). These three payment levels are chosen for comparison because they are sufficient to attract enough participants to exhaust the conservation budget, and they are payment levels that have been offered by programs in the Lake Erie basin, like NRCS EQIP, which offers between forty-four dollars and sixty dollars per acre for cover crops depending on the plant species.

Equal Transaction Costs

In the first analysis, the TCs of submitting a bid are equal to the TCs 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

Table 2 Comparison of Funding Allocated, Reduction of Bioavailable P Export, and Cost-Benefit Ratios Among Targeted and Untargeted Uniform Payment Programs at Eight Payment Levels

Payment Per Acre	Untargeted Uniform Payment			Targeted Uniform Payment		
	Funding Allocated ($)	Bio P Reduction (lbs/yr)	Cost-Ben ($/lb BioP)	Funding Allocated ($)	Bio P Reduction (lbs/yr)	Cost-Ben ($/lb BioP)
25	25,953	51	505	8,952	25	357
30	93,626	154	609	34,424	80	432
35	100,000	135	743	81,997	163	503
40	100,000	118	848	99,990	168	593
45	100,000	105	954	100,000	137	731
50	100,000	93	1,070	100,000	123	815
55	100,000	84	1,184	100,000	112	893
60	100,000	77	1,286	100,000	103	966

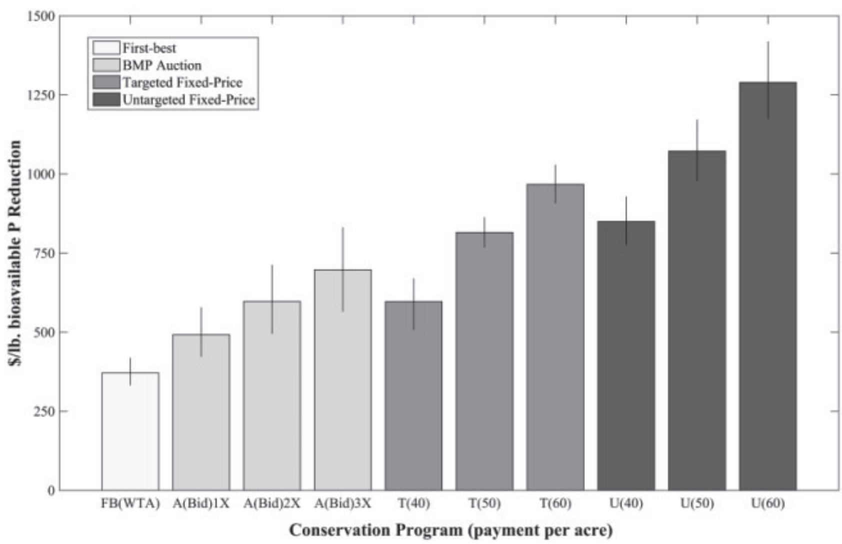

Figure 4. Simulated cost per pound of bioavailable phosphorus reduction for nine conservation programs and the first-best outcome. Bars represent the average cost from 933 parcels over 1,000 simulations; error bars show 95% confidence intervals. Per-acre payments are shown in parentheses. Three auction programs represent auctions with varying levels of transaction costs (TC). TCs in A(Bid)1X are equal to the TCs of applying for the uniform payment programs. TCs of application for auctions A(Bid)2X and A(Bid)3X are two and three times greater, respectively

pay more for each unit of bioavailable P reduction. Figure 4 presents a comparison of the average cost-effectiveness (measured in $ per pound bioavailable P reduction) across 1,000 simulations for ten programs (first-best outcome, BMP auction at three TC levels, and untargeted and targeted uniform payment programs at three of the eight payment levels). Recall that the first-best outcome is achieved by price discriminating with perfect information. In the first-best scenario, cost-effectiveness averages $372 per pound reduction in bioavailable P, while allocating funds with an auction results in a cost per pound of bioavailable P reduction of $492 per pound (figure 5, columns 1 and 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

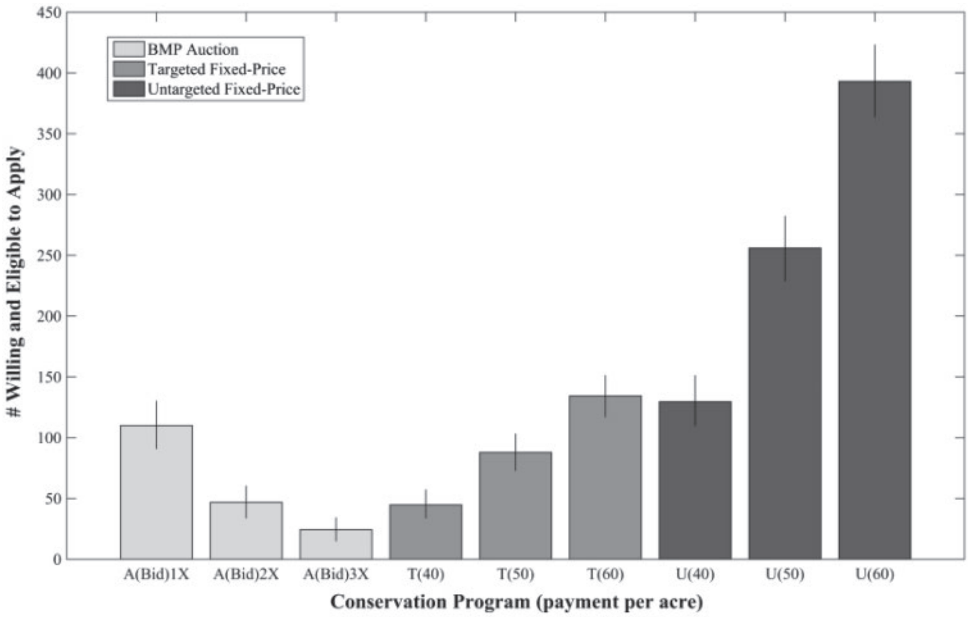

Figure 5. Simulated willingness to participate in nine conservation programs. Bars represent the average number of people willing and eligible to participate from 933 parcels over 1,000 simulations; error bars show 95% confidence intervals. Three auction programs represent auctions with varying levels of transaction costs (TC). TCs in A(Bid)1X are equal to the TCs of applying for the uniform payment programs. TCs of application for auctions A(Bid)2X and A(Bid)3X are two and three times greater, respectively

efficient than the targeted program at reducing P runoff at every payment level—untargeted programs are 38% more costly on average. Second, in both uniform payment programs, the cost per pound of P abated decreases with lower uniform payment levels because farmers are paid less information rent (see table 3). However, this benefit is partially offset by fewer applications being submitted when lower payments are offered. At the lowest payment levels, there are not enough applications to exhaust the available program funds (table 2); therefore, lower total benefits are procured (i.e., less runoff is reduced).[8]

Figure 5 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 ($p = 60$), 393 (42%) land managers are willing to enroll their parcels in the uniform payment program, relative to 110 (12%) who are willing to submit a bid in the auction when TCs are equal between the two programs. As the offered payment declines, fewer people are willing to enroll in a uniform payment program, with only ten and thirty-six people willing to enroll for twenty-five dollars per acre and thirty dollars per 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). Eligibility requirements for the targeted payment programs reduce participation further. At payment levels of twenty-five dollars per acre and thirty dollars per acre, the numbers of willing and eligible participants are four and twelve, respectively. As shown in figure 5, the number of applicants increases with higher payment levels, but greater participation does not necessarily result in improved program performance because the higher payments result in fewer people being enrolled for a given budget constraint, thus resulting in fewer benefits procured.

[8] As shown in table 2, the $100,000 budget is fully exhausted by accepting partial bids on the margin when funds are insufficient to pay for cover crops on all acres of the next highest-ranking parcel. Funding only portions of fields may not be realistic in practice because of the increased management effort required.

Table 3 Average Per-Acre Information Rents in Auction and Uniform Payment Programs

Auction		Uniform Payment		
TC Level	Information Rent ($/ac)	Payment Level	Information Rent ($/ac)	
			Untargeted	Targeted
1X	6.7	40	7.7	7.6
2X	6.2	50	12.1	11.7
3X	5.8	60	16.9	16.5

At higher fixed payments, 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. Information rents are also paid in the auction programs, but the ability to rank and select parcels can make auctions cost-effective when TCs of participation are low (figure 4). When TCs among auctions and uniform payment programs are equivalent, auctions are more cost-effective than both targeted and untargeted uniform payment programs paying forty dollars per acre and higher. (Compare the low-TC auction [1X] with targeted [T] and untargeted [U] uniform payment programs in figure 4.) However, as TCs increase, cost-effectiveness and participation both decline.

Transaction Costs Vary by Policy

In the previous section, we reported results when TCs of application are held constant across programs, but survey findings indicate that many farmer respondents perceived TCs 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 for our simulation that vary transaction costs of participation (measured in hours to submit a bid packet). Three levels of TCs are tested: TCs that are the same as (1X), two times (2X), and three times (3X) the participation cost of the uniform payment programs.

As the TCs of auction participation increase, the number of people willing to submit a bid declines from 110 when TCs are 1X greater to forty-seven when TCs are 2X greater and to twenty-four people when TCs are 3X greater (figure 5, columns 1, 2, and 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 $492 per pound to $597 per pound when TCs are double (2X) and to $697 per pound when TCs are triple (3X) the uniform payment reference level (figure 4). Importantly, when perceived TCs are three times higher than the reference level, there are not enough bidders to exhaust the conservation budget (figure 5). If the full budget was used, the per-unit cost for that auction would be greater than $697 per pound (figure 4, bar 4).

If the conservation program manager's goal is to maximize environmental benefits subject to a budget constraint, then cost-effective P reduction is a necessary condition, but the sufficient condition is to spend the entire budget. A helpful metric for program evaluation in this instance is the total environmental benefit procured with a given budget. Figure 6 shows the total reduction in bioavailable P across the simulated programs compared to the first-best case when program payments are based on perfect information. Asterisks in figure 6 indicate which programs did not use the full $100,000 budget—unallocated funds were associated with uniform programs offering low per-acre payments and auction programs with high TCs of bidding.

Two factors drive how much bioavailable P can be reduced under each program within the $100,000 budget constraint. First, reduced cost-effectiveness translates into reduced environmental benefits when the conservation budget is fully spent. Second, total bioavailable P reduction falls drastically when participation declines to the extent that the budget cannot be exhausted. This participation effect means that it can be misleading to focus exclusively on the cost to reduce a pound of P as a performance metric. This point is demonstrated by analyzing the reductions in bioavailable P for each program (figure 6) in relationship to program participation (figure 5) and the cost per pound of runoff reduction (figure 4). When TCs are at the highest

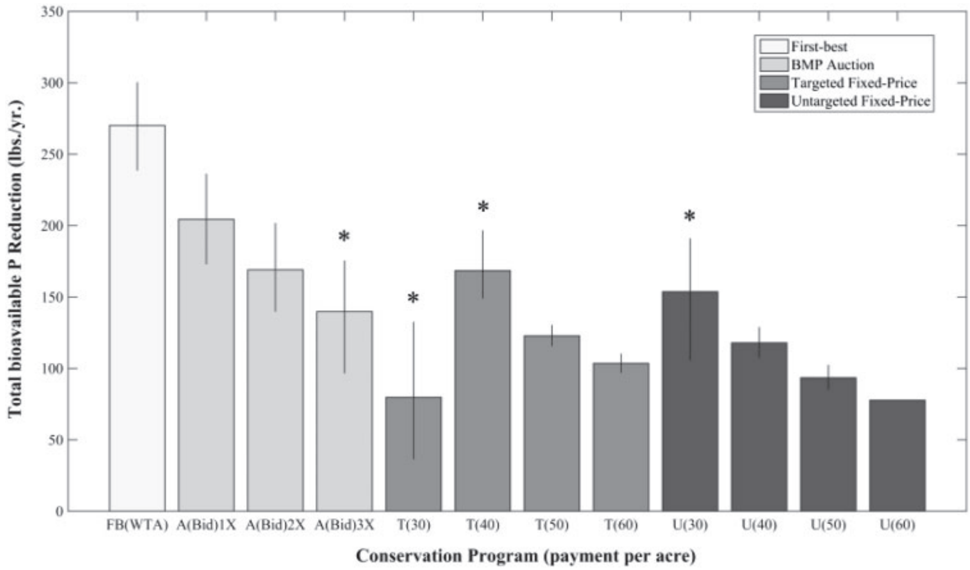

Figure 6. Simulated bioavailable phosphorus reductions in eleven conservation programs and the first-best outcome. Bars represent the average total bioavailable phosphorus reductions for conservation programs over 1,000 simulations; error bars show 95% confidence intervals. Three auction programs represent auctions with varying levels of transaction costs (TC). TCs in A(Bid)1X are equal to the TCs of applying for the uniform payment programs. TCs of application for auctions A(Bid)2X and A(Bid)3X are two and three times greater, respectively. Asterisks (*) indicate programs for which there are too few applicants to exhaust the $100,000 budget

level simulated (3X), the cost per pound of runoff increases (bar 4 in figure 4), but the unit cost appears moderate compared to targeted payment programs offering per-acre payments of fifty dollars per acre and higher and untargeted payment programs offering forty dollars per acre and higher. The full impact of higher TC is only revealed by comparing participation rates and total runoff reductions among the programs. When TCs of bidding are 3X, participation falls so far that the program budget is not fully utilized (figure 5). Figure 6 demonstrates that the total P reduction from the 3X TCs auction (bar 4) are lower than the other auctions and lower than the targeted and untargeted payment programs offering forty dollars per acre. High TCs also generate more variability in the results of the auction, as indicated by the 95% confidence intervals. This variation is also driven by instances where the participation level drops too low to exhaust the budget. Hence, when participation is low, the total P reduction from a conservation auction tends to be both lower and more variable than what could be achieved using uniform per-acre payments.

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 β-score deserve additional attention as they impact the perceived probability of bid acceptance that can result in censoring participation and strategic bidding in an effort to extract information rents. Beliefs about the maximum β-score pivot on the perceived ratio of the maximum acceptable bid amount to the associated level of environmental benefit. When farmers perceive the maximum β-score to be high, they are likely to strategically inflate their bids in an attempt to extract additional information rents. Sensitivity analyses were conducted by evaluating these parameters over a range of values.

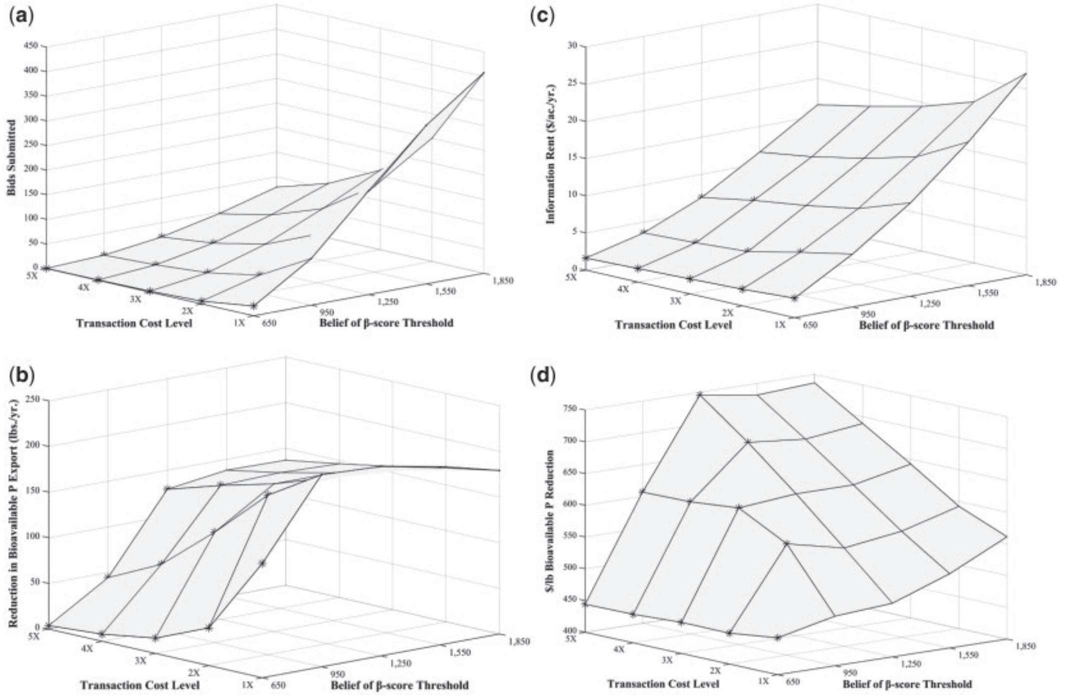

Figure 7. Sensitivity analysis to evaluate changes in the number of bids submitted (a), annual reduction in bioavailable P (b), average per-acre information rents paid (c), and average cost per pound of bioavailable P reduction (d) in reverse auctions with varying levels of transaction costs (TC) of application (five levels) and mean beliefs about the highest acceptable β-score, $\tilde{\beta}$ (five levels). Bidders seek additional information rents as $\tilde{\beta}$ increases. Outcomes are simulated 1,000 times for the 933 parcels in the watershed. Asterisks (*) indicate programs for which there are too few applicants to exhaust the $100,000 budget

(a) Bids submitted with varying levels of TCs and rent-seeking behavior
(b) Annual bioavailable P reduction with varying levels of TCs and rent-seeking behavior
(c) Information rents paid to participants with varying levels of TCs and rent-seeking behavior
(d) Cost per pound of reduced bioavailable P with varying levels of TCs and rent-seeking behavior

Figure 7 illustrates the sensitivity of several outcome variables to five TC levels (1X to 5X) and five levels of beliefs about the maximum acceptable (threshold) β-score (650, 950, 1,250, 1,550, 1,850). The outcome variables captured are (*a*) the bids submitted, (*b*) bioavailable P reduction, (*c*) information rents, and (*d*) the cost to reduce a pound of bioavailable P.

If bidders believe only low β-scores (e.g., low bids, high benefits) will be accepted, few bids are submitted, especially when TCs are high (figure 7[a]). When few bids are submitted, the total reduction of bioavailable P is minimal, especially when there are not enough bids (figure 7[b]) to exhaust the budget. Results of the sensitivity analysis presented in figure 7(d) appear to show a low cost per pound of P reduction across all levels of TCs when rent seeking is low, but this is only an artifact of not exhausting the full program budget. When people believe higher β-scores will be accepted, they are more willing to submit a bid because the likelihood of their bid being accepted is greater. As beliefs about the β-score threshold shift upward, the cost-effectiveness of the program declines because the agency pays additional information rents (figure 7[c]) when participants strategically inflate their bids.

Increasing TCs has the greatest effect on cost-effectiveness when the initial level of strategic rent seeking is moderate (figure 7d). This level of rent seeking occurs when participants believe that it is worth submitting a bid because their bid could be competitive, but they do not seek excessive information rents—i.e., participants believe that the β-score threshold is not high enough for projects with high bid-benefit scores to be competitive, so they do not inflate their bid in an attempt to gain larger payments. As TCs increase, fewer people participate because the payment that they would receive would not compensate them for the TCs involved with submitting the bid. As participation declines, the auctioneer has fewer bids to select among and will likely accept bids with higher cost per unit of benefit. If TCs increase and participation continues to decline, the agency will reach a point at which there are too few bids to exhaust the budget. The harmful effect of TCs on auction participation is exacerbated when the conservation budget increases because more bids are needed to expend all of the conservation funds.

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 desired 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 payment conservation programs when the transaction costs (TC) of bidding make participation in auctions costly. Results from this research suggest that high TCs of bid submission can affect both participation and cost-effectiveness of conservation auctions.

When TCs of bidding are perceived to be high, fewer people will choose to participate in a conservation auction. Lower participation reduces the cost-effectiveness of auctions in two ways. First, fewer bids result in fewer projects to evaluate for funding and thus a greater likelihood that projects with higher cost-benefit ratios may receive funding. Second, when participation falls far enough, there are no longer sufficient bids to exhaust the full conservation budget, so the total program benefits will decline. In cases in which the budget is not fully exhausted, the cost to reduce a unit of runoff can appear low, but caution should be exercised with comparing cost-benefit ratios among programs that do not allocate the full budget and ones that do. The participation problem becomes worse as conservation budgets rise because more participation is needed to utilize the full budget. When perceived TCs limit participation in auctions, the agency may have more success using a uniform payment program in which the payment level is carefully selected to encourage participation without paying excessive information rents.

Transaction costs may reduce participation even further if farmers are risk averse. By using a constant marginal utility of income, m, our model implicitly assumes that farmers are risk neutral. If we instead consider risk-averse farmers, both the optimal bid and auction participation would be affected. As previous research suggests, the optimal bid for risk-averse farmers would be smaller—i.e., closer to their true WTA—because farmers would not want to risk losing the contract in an effort to extract information rents (Glebe 2013). This result could make auctions look more favorable compared to uniform payment programs. However, if farmers are risk averse, TCs of bidding cause a greater reduction in participation rates for reverse auctions because downside risk is increased (i.e., if the bid is not accepted, TCs are still realized). The overall effect of risk aversion is not clear, a priori. Laboratory studies could be used to identify the effect of TCs on participation and auction performance when risk aversion varies.

Lowering perceived TCs and reducing inflated perceptions of high TCs 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 TCs 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 for auctions to succeed in such cases, managers must be educated about their ability to generate environmental benefits using BMPs, and they must believe that submitting a bid is worth their time. However, previous research suggests that as bidders become more familiar with reverse auctions, they learn to bid strategically and 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). These results suggest that a trade-off exists between boosting participation levels and minimizing rent seeking in discriminatory price reverse auctions. Future research could contribute to the literature by evaluating this trade-off under several assumptions about farmers' knowledge about the environmental benefits generated by BMPs.

In this article, we assume that farmers believe that they know how much environmental benefit (e) will be generated by BMPs on their land, but their belief is not necessarily equal to the true e. Additional research is needed to evaluate the impacts of TCs and strategic bidding behavior with various levels of uncertainty about environmental benefits. Transaction costs and knowledge about environmental benefits may change over time; therefore, research that analyzes TC, participation, and bidding behavior in a dynamic setting is needed.[9]

The research presented here shows how perceived TCs of bidding can reduce participation in reverse auctions and make them less cost-effective than some targeted uniform payment programs. 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 our simulation model suggest that well-designed targeted uniform payment programs may perform better when high TCs 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.

[9] Future research could use an experimental economics approach to analyze dynamic participation decisions in reverse auctions (see Fooks, Messer, and Duke 2015) when TCs and knowledge about environmental benefits change over time.

Supplementary material

Supplementary material is available online at http://oxfordjournals.org/our_journals/ajae/online.

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