COMPETITION-BASED ENVIRONMENTAL POLICY: AN ANALYSIS OF FARMLAND PRESERVATION IN MARYLAND[1]

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Abstract

Policymakers have turned to competition-based voluntary enrollment programs as a cost-effective way to achieve preferred land-uses. This paper studies bidder behavior in an innovative auction-based program in which farmers compete to sell and retire the right to develop their land. We derive a reduced form bidding model that includes private and common values. This model allows us to estimate the role of bidder competition, winner's curse correction, and the underlying distribution of private values. We estimate that the auction enrolled as much as 3,000 acres (12 percent) more than a take-it-or-leave-it offer would have enrolled for the same budgetary cost.

Keywords: farmland preservation, agricultural land preservation, development rights, easements, first-price auctions, interdependent values, winners curse

I. INTRODUCTION

A large proportion of environmental problems stem from private land use decisions that do not incorporate negative externalities. Such problems include biodiversity loss and threat of species extinction due to land conversion, carbon release due to deforestation and land cultivation practices, and nonpoint water pollution from agriculture, flood control, and loss of amenities such as scenery, local climate, and wildlife viewing. Indeed, it seems that a large portion of U.S. environmental problems would be solved if land use decisions could be optimized to include environmental externalities.

This prominent role for land use is important because the legal means used to regulate land use in the U.S. are very different from those used to regulate pollution. In the case of pollution, federal regulations directly limit what polluters can do. In contrast, land use in the U.S. outside of urban areas is much more loosely regulated. Instead, the primary policy tool has been to *pay* landowners to undertake the actions that we as a society would like them to undertake. The general principle is that for pollution, the environmental rights are held by the public, in the hands of the government, whereas for land use the rights are inherent in the property. This difference affects the policies and policy implementation issues that must be considered in addressing land use issues.

Due in part to the property rights movement and the shift away from regulations since the 1970's (Echevarria 2005), policymakers have sought voluntary-enrollment land use policies with low budgetary costs but that are nonetheless cost-effective. The most promising of these are *competition-based policies* in which landowners compete for shares of a fixed budget in return for implementing environmentally desirable land uses. A prominent example is the Conservation Reserve Program (CRP), a Federal program under which landowners submit bids to take environmentally sensitive agricultural land out of production for a 10 or 15 year period. Lowest bids (per environmental benefit) are enrolled first, with enrollment continuing until the budget is exhausted. Non-U.S. examples include Australia's Auction for Landscape Recovery, the U.K.'s Challenge Funds and initial auctions for greenhouse gas reductions, and Germany's Grassland Pilot. Competition-based policies are likely to be important components of future U.S. policies for two major environmental issues: nonpoint water pollution and carbon sequestration.

Although competition-based schemes have many desirable properties there is much that remains unknown about the bidders' behavior and its implications for policy design. Auctions modeled on environmental policies have been studied extensively in laboratory and field experiments. Schilizzi and Latacz-Lohmann (2007) conducted induced-value, private-value experiments to compare two bid acceptance rules for conservation auctions, and Cummings, Holt and Laury (2004) conducted induced-value, private-value experiments to study selection rules for the Georgia irrigation auctions. Induced value experiments, however, dictate the bidders' information structure rather than work with the complex real-world information structure that characterizes most auctions. Such information structures may distort bidding and may therefore cause competition-based programs to be potentially more costly than other voluntary-enrollment programs with more certain and straightforward payment structures. This paper attempts to shed light on this question using data from an actual competition-based policy.

Competition-based real-world land use programs such as the Conservation Reserve Program (CRP) have been the subject of some theoretical work (Smith 1995; Latacz-Lohmann and Van der Hamsvoort 1997) but only a small number of empirical articles have made use of the auction paradigm. Kirwan, Lubowski, and Roberts (2005) estimate a reduced form model of the CRP and infer reservation values from assumptions based on the portion of the reservation value that is observable. Vukina *et al*. (forthcoming) also use a reduced form model to examine how plot-specific environmental scores, which increase the probability of winning, ceteris paribus, affect bids. Our auction set-up and rich data allows us to estimate a broader set of relationships related to bidder behavior including the impact of competition, potential winner's curse as well as infer the underlying reservation values.

This paper studies bids in the Maryland Agricultural Land Preservation Foundation (MALPF) program, an innovative program in which Maryland farmers compete to sell their right to develop their land to the State while retaining ownership of their land. The State then retires these development rights, ensuring that the property remains in agricultural or related use.

The MALPF program, like other competition-based policies, relies on the principles that underlie auction theory which posits that participant behavior depends on the underlying information structure. Several unique features of this auction allow us to identify the informational components. Using data from 24 auction rounds over 19 years, we examine the effects of competition, information, and bidder entry and selection on bidding behavior in the MALPF auction. We find that on average bids are 5 to 15 percent above the underlying reservation value and show that increased competition (in the form of lower budgets or more bidders) reduces this mark-up. We also find evidence that bidders adjust for a possible winner's curse by increasing their bids by 8 to 14 percent.

This framework then allows us to back out the underlying distribution of reservation values. This distribution of values constitutes the supply curve for MALPF enrollment. We use the inferred reservation values to compare the performance of the MALPF auction to an alternative policy under which administrators make a take it or leave it offer to all potential enrollees. We find that the MALPF auction enrolled 5 to 12 percent more acres than this alternative for the given budget.

The remainder of the paper proceeds as follows. Section II describes the details of the MALPF auction. Section III describes the empirical model. Section IV describes the data. Section V discusses the results and Section VI uses the results in a comparison to an alternative farmland preservation policy. Concluding remarks are in Section VII.

II. MALPF AUCTION DESIGN

Maryland established the MALPF program in 1977. It was one of the nation's first statewide programs to restrict development on agricultural land by purchasing from landowners their rights to develop their property. Preservation is achieved through the attachment of a "conservation easement," a restriction on the deed that proscribes most forms of development, essentially in perpetuity. The enrolling owner of a parcel is free to sell the land but future owners continue to be bound by the development restriction. By 2003 the MALPF had preserved 228,854 acres, which is 4 percent of State land and 10 percent of its agricultural acres. Acquisition expenditures for these development rights for the fiscal year 2002 were $37.6 million, with a statewide average per-acre cost of $1,960.

We study bids from Carroll County, an urbanizing county just west of Baltimore. We chose this county because: (i) it experienced substantial development pressure during the period of study yet also had 178,000 acres of agricultural land at the start of our study period, (ii) it actively promoted the MALPF auctions, and (iii) there were no other competing preservation programs during the study period that paid compensation.[2]

In each round of bidding, eligible landowners submit offers to sell their parcels' development rights. After the offers are submitted, the program pays for two professional appraisals of the market value of the unconstrained property. The state selects the appraisal "which in their judgment reflects the most accurate value" (MALPF, 1984). A new appraisal is conducted each time a parcel is bid. Parcel values for parcels re-bidding a second or third time can change substantially from round to round.

The program then computes the agricultural value of the property (that is, its value if it were constrained to remain in agriculture) based on specified rules. The state calculates the "market easement value" as the difference between the property's unconstrained market value and its agricultural value. The landowner's submitted offer is then converted into a ratio by dividing it by the market easement value. These ratios are ranked and the program purchases development rights starting with the lowest ratio offer. The landowner is paid the amount of his offer, with exceptions described below; thus, this program is a type of first-price auction. The program works its way up this line-up of ratios until the annual budget is exhausted. In this way, the program buys development rights that are the least expensive relative to the assigned market easement value. Because of the auction-like approach we refer to the landowners' offers as bids.

The ratio approach represents an innovative design feature for farmland preservation. If the state were to purchase development rights from the lowest bidders, it would preserve those properties that were least likely to be developed, although it would be able to enroll the most acres. By comparing bids to the market's assessment, the state acquires easements that are cheapest relative to the market price; this adjustment is presumably no longer biased toward low development probability parcels. Our paper does not address the optimality of this feature nor MALPF's implicit objective function. The selection rule does not account for the effect of preservation of a given parcel on the development rates of other parcels, nor for other public goods provided by the parcels.

Like all government programs, the MALPF program has twists that complicate the analysis. For ratios greater than one, the program may offer to purchase the development rights at the market easement value, assuming the budget has not been exhausted by parcels with ratios less than one. For these parcels, this payment would be lower than the landowner's requested payment. Landowners can either accept this offer or decline it. The administrator selects these parcels for auxiliary offers based on unspecified criteria and not necessarily on the lowest-ratio-first rule.

Participants who are not accepted can re-bid in any future round. Multiple rebidding is allowed and indeed is common.

The program had an escape clause under which, if after 25 years a landowner can demonstrate there exists no profitable agricultural use and is willing to refund the MALPF the current value of the development rights, the landowner may petition to remove the restrictions. This clause has never been utilized and considerable opposition exists toward allowing any parcel to exit.

III. ESTIMATION MODEL AND EQUATIONS

This section provides a conceptual model that defines the informational structure of the auction, lays out our research questions, and forms the basis for our econometric model.

Land market

We start with a standard model of land conversion. Let $V(t)$ represent the discounted value of services on a given parcel were it to be developed at time t. This value is assumed to follow a random walk process. Development results in foregone profits from agriculture. Let x represent annual net returns from agriculture on this parcel; for simplicity these returns are assumed non-stochastic. Let ρ be the risk-free discount rate. Consequently, the market value of the land absent any opportunity for development is $X = x/\rho$.

The landowner's decision is the date τ at which to develop the parcel. When the parcel is converted the landowner gives up the remaining stream of x, valued at $Xe^{-\rho\tau}$. The parcel is converted when $V(t)$ exceeds X plus the option of waiting for a higher offer. Thus the value of an undeveloped parcel given current realization V is:

$$F^m(V) = \max_{\tau} E\left\{X\left(1 - e^{-\rho\tau}\right) + e^{-\rho\tau}V(\tau)\right\} \qquad [1]$$

The cost of land conversion is assumed to be zero in this model but such a cost would not change the underlying structure of the problem. Making agricultural returns stochastic would complicate the presentation but again would not change the result.

This is a standard investment under uncertainty problem, solvable by methods described in Dixit and Pindyck (1994) and regularly applied in the land conservation context (Plantinga, Lubowski, and Stavins 2002). The solution, described by Dixit and Pyndick (1994) is $F^m(V) = X + aV^{\beta}$ where $a = \beta^{-\beta}\left(X/(\beta - 1)\right)^{1-\beta}$ and $\beta > 1$ is a parameter that depends on ρ and the process governing $V(t)$. The market easement value, M, is the difference between the value of an undeveloped parcel, $F^m(V)$, and the value of the land restricted to remain undeveloped, X:

$$Market\ easement\ value = F^m(V) - X = aV^{\beta} = M(V) \qquad [2]$$

where M depends on the observation of V.

Since the MALPF program is based on both the landowner's and "the market's" valuation of a parcel's development right, it is necessary to consider how these values may differ. There are two possible sources.

First, landowners may derive utility from owning and operating the farm beyond the agricultural income it provides. This utility would make them less likely to convert the land at the "cash flow optimal" date to convert. We model this effect by multiplying agricultural income by an individual-specific parameter ψ_i in the landowner utility function. Thus landowner *i*'s value for his land is given by:

$$F^f(V) = \max_{\tau} E\left\{\psi_i X\left(1-e^{-\rho\tau}\right)+e^{-\rho\tau}V(\tau)\right\} \quad [3]$$

again with the expectation conditional on the current observation of V. We use superscript f to denote the farmer's valuations; the m subscript denotes the market's valuation. We expect ψ_i > 1, since this corresponds to landowners placing additional value on farming utility.[3] ψ_i may also be interpreted as representing the individual's private observation of agricultural income, with $\psi_i > 1$ indicating that agricultural income is higher than the market belief. A higher ψ represents a greater weight on farming utility as an income-generating occupation or a higher assessment of agricultural potential. In other contexts, ψ also forms the basis of the unobserved likelihood that the parcel will be developed. This likelihood is a common concern in the design of land use policies (e.g., Sánchez et al. 2006)

We assume ψ_i is known to the individual bidder but is unobserved by the administrator or by other bidders and is distributed independently of ψ_{-i} and of $V(t)$. It thus operates as an *independent private value* which forms the basis of the landowner bid, as in Milgrom and Weber (1982). For ease of notation, we drop the *i* subscript.

Equation (3) has solution $F^f(V) = \psi X + a_f V^{\beta}$ where $a_f = \beta^{-\beta}\left(\psi X/(\beta-1)\right)^{1-\beta}$. When the farmer observes the same V as the market his valuation of the parcel's development right is:

$$F^f(V) - \psi X = \psi^{1-\beta} a V^{\beta} \equiv \theta M \quad [4]$$

with $\theta \equiv \psi^{1-\beta}$. When $\psi > 1$ we have $\theta < 1$, which implies that for any observation of *M* the landowner requires less than the market easement value for his development rights.

Second, the market and the individual landowner may have different observations of $V(t)$ and thus of $aV(t)^{\beta}$. Such disagreement about land values is a natural element of any market although it is missing from the standard asset pricing model.

One way to incorporate this difference is to have both parties draw separate observations of $V(t)$, which then correspond to different assessments of $aV(t)^{\beta}$. Let the landowner's assessment be denoted $D = aV^{f}(t)^{\beta}$, where $V^{f}(t)$ is his belief about $V(t)$, analogous to the (un-superscripted) $V(t)$ in equation [2]. The landowner's reservation value for his development right, from equation [4], is then:

$$\textit{Landowner easement value} \equiv \theta D \qquad [5]$$

This formulation makes clear the two elements that constitute the landowner's reservation value: the extra utility he derives from owning and operating the farm, θ, and his observation of the price his unconstrained property would receive on the market, *D*.

Bidding

To participate in the MALPF auction an eligible landowner submits a bid, b_i, that represents the one-time payment he would accept in return for his parcel's development rights. After the bid, appraisals are conducted to determine *M*. For each bid the administrator constructs the ratio of the bid to the market easement value:

$$R_i = \frac{b_i}{M_i} \qquad [6]$$

This ratio R_i forms the basis for selecting the winning bids. Winning bidders are paid the amount of their bid, with the exceptions described in Section 2. Based on [6], the probability of acceptance at $R \leq 1$ is $\text{Prob}\left[b \leq \tilde{R}^* \cdot \tilde{M}\right]$ where R^* is the (random) cut-off ratio, M is the market appraisal (which is unknown when the bid is submitted) and a tilde denotes a random variable.

To construct the bid, a landowner should first construct the value of his development right conditional on bid acceptance and therefore conditional on the *ex post* report, M. There are many possible informational assumptions. Suppose the landowner adopts the market easement value as his ex post valuation. The landowner's expected value of his development right conditional on winning when submitting bid b would then be:

$$\tilde{v}(b) = E_M(\theta\tilde{M} \mid b < \tilde{R}^* \cdot \tilde{M}) \qquad [7]$$

Under this assumption, there is a *common value* between the landowner and the program administrator (e.g., Haile, Hong, and Shum, 2003). Our common value is different from standard models in which different bidders share a common value but its effect on bidding is comparable. Since b must be above θD, equation [7] implies that the expected value of the easement conditional on winning is above the unconditional expectation, $E(\theta M) = \theta D$. [4]

The informational assumption underlying [7] is not the only possible assumption. Rather than treat the market observation M as "correct" in forming his *ex post* valuation, the landowner may treat [5] as a true reservation value that need not be updated based on appraisers' assessments of M. In this case, there would be no common value element to the auction and no winner's curse. An intermediate case would be that landowners use M as informative but not definitive and therefore use Bayesian updating on D. In each case, [7] would be modified accordingly.

Because of these possibilities we allow for a winner's curse correction in our econometric model and estimate its magnitude. Note that we do not assume that the winner's curse exists; we merely accommodate the possibility in our estimation and interpretation.

Expression [7] is analogous to the winner's curse correction in standard common value auctions (Milgrom and Weber 1982; Athey and Haile 2002). Landowners whose bids are selected will be those who have most underestimated the market value, ceteris paribus, yielding a winner's curse (under the assumption that M is at least partially informative for the landowner's *ex post* valuation). They therefore have an incentive to correct for this risk by bidding as if they have values above θD. The more that the landowner relies on M in formulating his ex post valuation, and assuming that she incorporates this anticipated information in her bid, the greater is the bid above θD.

Entry and Selection

To illustrate bidder entry and selection we write out the bidder's objective function and use its notation to derive the final component of our model. We do not derive the optimal bidding strategy because of both the complex information environment and the dynamic nature of the auction. Expression [7] allows us to write the objective function for a risk neutral bidder facing a one-time auction as:

$$\pi(\theta, D) = \max_{b} E_{R,M}\left[(b-\tilde{v})\big(1-\Phi(b)\big)+\big((1-\theta)\cdot\tilde{M}\big)\Phi(b)Prob[offer]\right]-k \qquad [8]$$

The bidder selects his bid to maximize the expectation of profits from winning outright (the first term) or being made an offer less than his bid ex post (second term). Φ represents the cumulative distribution of the product $R^{*}\cdot M$, Prob[*offer*] is the probability that an ex post offer of $M < b$ is made, and k is a bid preparation cost. In a static framework this ex post offer would always be accepted, regardless of the bid.

In the MALPF program, bidders are faced with the additional decisions of when to enter the auction and when to rebid. Computational derivation of this result is complex and beyond the scope of this paper and thus we describe the results only heuristically.

Consider bidder entry. We assume that landowner surplus falls as θ increases ($\partial\pi/\partial\theta < 0$) which corresponds to the assumption that surplus falls with decreasing private utility from farming. Although this is a standard assumption it is difficult to establish definitively given the complexity of the winner's curse. Under this assumption we argue, again heuristically, that lower θ's lose more surplus, $\approx\rho\pi$, from waiting for the next round. This framework further yields $\partial b/\partial\theta_i < 0$, which implies that lower θ's are more likely to win a given auction.[5]

These conditions together suggest that the lowest reservation price bidders enter the auction earlier and win more frequently when they do enter. As these bidders leave the bidding pool, the remaining pool of potential and actual bidders contains a larger fraction of higher reservation price bidders. This relationship forms the basis for our identification of reservation values since the pattern of bids and ratios over time allows us to trace out the underlying distribution of θ's. This distribution in turn forms the supply curve for development rights.

Estimation Setup

We specify a reduced form bidding function based on the above model. Bids will be above the reservation value, θD, due to the information rent that bidders accrue from their private values, represented by γ, and to the winner's curse correction captured by [7], represented by ω. Our breakdown of bids into a winner's curse correction and a mark-up over the conditional reservation value due to competition is useful for intuition, although it is not strictly consistent with the theoretical model in [8], which does not yield a clear distinction between the two components.

We specify a functional form in which these mark-ups enter multiplicatively above the reservation value. The bidding function is thus:

$$b_{it} = \gamma_{(t)} \omega \theta_i D_i \qquad [9]$$

Equation [9] includes bidder and auction-round subscripts, i and t, to make clear how components vary across observations.

We cannot directly observe the elements of [9] but we do observe related variables that allow us to infer their values:

Private Values (θ). Although we do not observe individual θ_i's, we can infer the average θ among first-bidders in each bidding-round, a sequence we denote as $\{\bar{\theta}_{(t)}\}$ where t indexes the bidding round. Following the discussion above, we note that as cumulative acceptances increase, there are fewer bidders left in the pool and these are bidders with higher values of θ. Bidders with high θ's, relative to the remaining pool, should sit out auction rounds until they are competitive; that is, until their θ's are in the low range of remaining θ's. Therefore, the range of θ's in a given auction round should be relatively narrowly distributed around "local mean" $\bar{\theta}_{(t)}$, which will be an increasing function of the number of previously accepted parcels, denoted CA_t for cumulative acceptances. This component of our reservation price estimation strategy relies on the assumption that bidders are drawn from an otherwise invariant underlying distribution. We therefore restrict our main regressions to first-time bidders. We adopt the general specification:

$$\ln(\bar{\theta}_{(t)}) = \zeta - \exp(\phi_1 \cdot (CA_t + 10)) \qquad [10]$$

We expect bids to be increasing in cumulative acceptances, $\phi_1 < 0$.[6] The parameter ζ measures the lower bound of θ's since $\zeta = 1 + \ln(\bar{\theta}_{(0)})$.

Information Rent Mark-up (γ). Following the standard independent private values paradigm, we allow information rent mark-up, γ, to depend on the competitiveness of a given auction round. There are multiple possible measures of competition, such as the number of bidders or the (negative of the) available budget per bidder. We label these generically as $COMP_t$. Let $\ln(\gamma_{(t)}) = \gamma_0 + \gamma_1 COMP_t$. Greater competition implies that bids will be lower, yielding the prediction $\gamma_1 < 0$. We assume that $\gamma_{(t)}$ is the same for all bidders in a given round.

Winner's Curse Correction (ω). The winner's curse correction, ω, sets the bid above the unconditional estimate of the easement value to compensate for the fact that the winners will be those who have most under-estimated their market easement value. Theoretically consistent specifications of the winner's curse correction are difficult to derive. Gordy (1998) notes that closed-form equilibrium bidding functions are quite rare except for the simplest of common value assumptions. Paarsch (1992) describes the assumptions that yield a multiplicative or additive winner's curse correction but these derivations assume a different information structure from the MALPF setting.

We use a multiplicative specification in (9) and define $\ln(\omega) = \omega_0$.[7] In general, we expect ω to be (i) decreasing in θ, (ii) increasing in competition, and (iii) decreasing in bidder experience. We briefly consider each of these issues. The intuition for each of these claims can be gleaned directly from [7], although the full winner's curse correction comes from [8]. Interactions among competition, experience and θ greatly complicate formal statements about the winner's curse.

Relationship with θ. The winner's curse correction ω should be higher for bidders with a low θ_i because individuals with low θ_i's are more likely to have their bid accepted for a given signal F^f. Therefore, if their bid is accepted, they must have a lower *ex ante* estimate of the market easement value relative to its draw. They should shade their bids upward further to account for this greater winner's curse. This effect applies to bidders within a round, however, and not across rounds. The range of θ's within a round is much smaller than the range of θ's over the entire set of rounds. Therefore, this effect is likely to be small.

Relationship with competition. The winner's curse correction should be higher as competition increases because greater competition means that the cut-off R^* will tend to be lower and therefore winning bidders will have underestimated M to a greater degree. For example, we might write $\ln(\omega) = \omega_a + \omega_b COMP_t$, with $\omega_b > 0$. In this case, the estimated parameter γ_1 in [11] might be interpreted as measuring the *net* effect of the competition and winner's curse effects, as Hong and Shum (2002) discuss, and may be positive or negative.

Relationship with bidding experience. Second-bidders should be more informed about their parcel's market easement value than first-bidders due to the appraisals that were conducted following their first bid. As a result, second-bidders should have smaller winner's curse corrections. To examine this assumption we estimated a version of [9] with only second bidders.

Estimation Equations

These substitutions now allow us to specify the estimated regression, assuming that M is an unbiased estimate of the landowner's ex ante beliefs, yielding $E(D_i) = M_i$. Taking the log of equation [9] and adding an error term produces:

$$\ln(b_{it}) = \alpha_0 + \gamma_1 \cdot COMP_t + \ln(M_i) - \exp(\phi_1 \cdot (CA_t + 10)) + \varepsilon_i \qquad [11]$$

where $\alpha_0 = \gamma_0 + \omega_0 + \zeta$.

It is straightforward to interpret the slope coefficients in this model, γ_1 and ϕ_1. The challenge is to identify the constant terms, γ_0, ζ, and ω_0, from α_0. An extensive set of identification procedures is necessary because each of the relevant relationships has a constant term that cannot be distinguished without such structure.

When the auction is at its most competitive (represented by $COMP_{max}$) we should have $\gamma \approx 1$, which implies $\gamma_0+\gamma_1 COMP_{max} \approx 0$. Thus, we specify $\gamma_0 = -\gamma_1 COMP_{max}$. We discuss the specification of $COMP_{max}$ in Section IV.

In the calculations below we first assume $\omega_0 = 0$, which then yields $\zeta = \alpha_0 - \gamma_0$. The assumption of $\omega_0 = 0$ captures two possible scenarios. First, the assumption may be valid if there is no winner's curse. This would occur if the value the landowner places on his development right is unaffected by the state's declaration of the land's value; in other words, a pure independent private values setting. Using the notation of [7], let $\tilde{v} = E_M(\theta D \mid b < \tilde{R}^* \cdot \tilde{M})$. Because D is nonrandom at the time of bidding, the conditional expectation is exactly equal to the unconditional expectation, hence no winner's curse. Second, equation [7] could be correct but individuals fail to condition their expectation in forming their bids. In other words, they suffer the winner's curse. This is not an uncommon finding in the experimental literature (Kagel and Levin 2002), although empirical analysis of high-stakes auctions usually finds at least some correction for the winner's curse (Hendricks, Pinkse, and Porter 2003). (The implications of this second explanation are quite different from the first. Since we find at least some winner's curse correction, we leave further discussion of this issue to a separate paper.)

An alternative approach is to use bidder experience to estimate ω_0. We estimate the analog to [11] using second-bidders, who are more experienced than first-bidders. Note that this estimation must account for the selection effect, recognizing both that second bidders were rejected in the first round and have chosen to rebid and that the timing of the second bid is endogenous. Our heuristic model of entry provides a straightforward approach. Second-bidders should re-enter precisely when they are "competitive," namely at round t such that their θ_i is in the range of $\overline{\theta}_{(t)}$.[8] It is therefore sufficient to treat second-bidders as equivalent to first-bidders but with a different winner's curse correction. Let $\ln(\hat{\overline{\theta}}_{(t)}) = \hat{\zeta} - \exp(\hat{\phi}_1 \cdot (CA_t + 10))$ with $\ln(\hat{\overline{\theta}}_t)$ derived from a separate first-bidder regression. We then estimate:

$$\ln(b_{it}) = \alpha_1 + \gamma_1 COMP_t + \ln(M_{it}) - \ln(\hat{\overline{\theta}}_{(t)}) + \varepsilon_{it} \qquad [12]$$

Let $\alpha_1 = \omega_1 + \gamma_0 + \zeta$ where ω_1 is the winner's curse correction for second-bidders. Suppose that γ_1 reflects only information-rent effects and is unaffected by the winner's curse. Since our econometric results suggest this to be the case, we feel comfortable in imposing it here. Then we can identify γ_0 as described above. If we assume that second-bidders are perfectly informed then $\omega_1 = 0$ and we can identify ζ using the same procedure as for first-bidders. Using this ζ estimate we can then infer ω_0, the winner's curse correction for first-time bidders. These assumptions yield the prediction $\alpha_1 < \alpha_0$ which serves as an additional test to their validity.

Alternative specifications. The estimated θ distribution depends on the functional form. We estimated two alternative specifications to [11]. The first uses logged cumulative acceptances:

$$\ln(b_{it}) = \alpha_0 + \gamma_1 \cdot COMP_t + \ln(M_i) + \phi_2 \cdot \ln(CA_t + 10) + \varepsilon_i \qquad [13]$$

We then calculate $\overline{\theta}_{(t)} = (CA_t + 10)^{\beta_2} \exp(\zeta)$. We expect $\phi_2 > 0$.

We also estimated a specification in which we replaced θM with F-ψX, from [4]. This specification applies when the landowner, in forming the expected value of his development right conditional on winning, takes the market observation of $\tilde{F}^m$ as correct but does not update any market assessment of X. That is, the reservation value conditional on winning is $\tilde{v} = E(\tilde{F}^m - \psi X \mid b < \tilde{R}^*(\tilde{F}^m - X))$ with the expectation taken over $\tilde{F}^m$. This expression is identical to [7] whenever the landowner and the market share identical assessments of X.

Since $\psi \geq 1$ we use the functional form $\psi = 1+\exp(\phi_3 + \phi_4(CA_t+10))$. We converted the results to θ using $\theta = \psi^{1-\beta}$ where β comes from the underlying stochastic process, as in [2]. The estimated equation is:

$$\ln(b_{it}) = \alpha_0 + \gamma_1 COMP_t + \ln(F_i^m - (1+\exp(\phi_3 + \phi_4(CA_t + 10))) \cdot X_i) + \varepsilon_i \qquad [14]$$

We expect bids to be increasing in cumulative acceptances, which requires $\phi_4 < 0$. There is no prediction for ϕ_3.

IV. DATA

We collected a unique data set that includes parcels that satisfied the eligibility requirements and have enrolled in an agricultural district in Carroll County starting with the program's inception in 1977 to 1999. Because of the timeframe, we returned to the original parcel-level files via microfiche to track each parcel through each round of bidding. Changes of ownership presented the largest data integrity challenge. We constructed a panel dataset with an observation for each agent-parcel in each bidding round. The final data set is carefully constructed to ensure that we correctly followed each agent-parcel combination. By checking the MALPF's annual published reports, which publish the number of bidders and total acquisition expenditures, against the sum of accepted bids based on the parcel histories, we were able to ensure that we had as complete a record as possible of all bids. Final data include bids, parcel sizes, appraisals, agricultural values, and outcomes, as well as assorted parcel characteristics. We convert all dollars to $2002 using the Northeast Housing CPI.

Several events in the early 1990's affected the operation of the MALPF auction. Between 1990 and 1995, to ease the administrative pressure of one bidding round per year, the state decided to accept bids twice during each fiscal year. Thus, we have two round of bidding for some of these years. A state budget crisis led the state to rescind the MALPF budget after bids had been submitted in the first round of 1991 and thus no bids were accepted. No MALPF auctions were held for two years, although a few bids were submitted in the second round of 1991 and the first round of 1992. Funding was restored in 1993. In the first round of 1993, offers were made to 35 bidders on hold from the first round of 1991 bidding (those who would have been accepted had funding been available). And regular bidding began again in the second round of 1993.

In total, we analyze the bids in 22 auction rounds between 1980 and 1999. A second, competing preservation program became active in the County around 2000 which did not use an auction format. Therefore, we chose to use the data prior to this event. Data summaries are provided in Tables 1 and 2.

There are 306 unique agent-parcels with submitted first bids (a total of 574 bids are included in the dataset when multiple bids are counted). We lose first bid observations for three reasons. (1) The state did not conduct appraisals for all bids in all years, primarily because the bids were high relative to the budget, (3 first bids lost). (2) In rounds with no budget (1991 and 1992), no appraisals were conducted (21 first bids lost). (3) Some bids are clearly wild guesses or pure gambles. We drop bids with ratios greater than 3.31, the highest ratio ever accepted (5 first bids lost). The remaining usable first bids equaled 277.

The MALPF changed the formula by which agricultural values were calculated twice, once in 1990 and again in 1996. To adjust agricultural values to a common formula in this model, the post-1996 formula is assumed to be correct, since the changes were adopted by program administrators solely to make the values closer to the true value of agricultural production on the land. We estimated a model of average per-acre agricultural values on dummy variables for pre-1991 and for 1991-1996 and used the coefficients to calculate a consistent agricultural formula. The formula we use is $X = \{0.263X_t,\ t \le 1991;\ 0.638X_t,\ 1991 < t \le 1996;\ X_t,\ 1996 < t \le 1999\}$ where X_t is a given parcel's agricultural value per-acre as reported by the program. We subtract this adjusted measure of X to obtain $M = F - X$.

There are several reasons why we think this solution adequately corrects for measurement error in X. First, the regression coefficients to adjust X were essentially invariant to the sample we used to estimate them. In other words, these changes in X were "across the board" and not restricted to any class of bidders, such as those with large parcels or rebidders. Second, other adjustments to X (such as no adjustment or half-adjustment) yielded results that were nonsensical, such as bids being far below the estimated reservation values. This suggests that landowners' assessment of agricultural value were closest to those computed under the post-1996 formula. Third, our estimates of equations [11] and [14] yielded quite similar results. These expressions are identical if and only if the X's are measured correctly.

In the analysis of competition, we consider two possible budgets: (i) a statewide program budget for the given bidding round that was publically available as bids were being prepared. Since counties received more-or-less constant shares of this budget, this statewide figure is a good measure of budget availability in a given round; and (ii) acquisition expenditures at the county level for the previous bidding round, inflated for the previous year. Acquisition expenditures in 1985, for example, were inflated using the July 1985 CPI.

V. RESULTS

Competition Effects

Program administrators are often eager to know the role of competition in reducing bids. Some situations might naturally have few eligible bidders, so policy-makers would like to know how successful an auction might be in driving down procurement costs. In other situations, administrators may be able to increase the number of eligible bidders either by relaxing the eligibility criteria or publicizing the auction more widely. They would then like to know whether the costs of these actions would likely be covered by the savings generated from lower bids. Finally, administrators may want to use the effects of competition to argue to policymakers that a competition-based design is worth the increased complexity.

We examined several measures of competition: (i) the total number of bidders in each round, (ii) the State's announced budget for each round divided by the number of bidders, and (iii) the County's expenditure on parcels in the previous round divided by the number of bidders. Each competitiveness measure is also associated with a value for $COMP_{max}$, needed to identify γ_0. When competitiveness is measured by the budget or expenditure per bidder, we set $COMP_{max}$ = 0, since the most competitive auction has a zero budget; this then yields $\gamma_0 = 0$.[9] When competitiveness is measured by the number of bidders, we set $COMP_{max}$ = 60, which is above the highest number of bidders we observed, 53. This latter assumption is somewhat ad hoc and for this reason, among others, we rely mostly on the budget and expenditure measures.

Endogenous competition is a problem in many empirical auction analyses. The largest potential problem in our context arises when competition is measured by the number of bidders. A large budget may attract more bidders but leave the budget-per-bidder unchanged, therefore yielding no change in the likelihood of a given bid being accepted and thus no change in the auction's competitiveness. Endogeneity problems are probably less severe when competition is measured in terms of budget-per-bidder and therefore we focus our attention on these regressions. Year-to-year variation in the funds allocated to the MALPF reflects both variation in state revenues and in the conversion of agricultural land. Although these phenomena may be correlated with bidder valuations, this correlation should be captured by the market easement value. Therefore, these budget measures are likely to be exogenous regressors.

Still, to account for potentially endogenous numbers of bidders, we developed regressions to predict both number of bidders and budget-per-bidder. (See Haile, Hong, and Shum (2003) for a discussion of instruments used to address endogeneity.) Much of the variation in the number of bidders depends on the State and County's promotion of the MALPF program and on publicized problems or successes. Both elements have distinct time components which we capture through period dummies. Intuition also suggests that successful bidders will beget more bidders in subsequent rounds and therefore we include as an instrument the number of bidders accepted in the previous round. Results are shown in Table 4 for the full 24 bidding rounds.

We use the predicted values from Table 4 either directly, as a predicted number of bidders, or indirectly to construct the State budget per predicted bidder, predicted State-budget-per-bidder, County expenditure (at t-1) per predicted bidder, and predicted County expenditures at t-1 per bidder at t. We refer to these latter four measures generically as budget-per-bidder.

Results are shown in Tables 5 and 6. All of the predicted competition variables show that greater competition leads to lower bids. The possible permutations to instrument for competition are large; Table 5 represents a range of possible choices. Table 6 shows alternative specifications with two measures of competition: state budget per predicted bidder and predicted

County expenditures (at t-1) per bidder (at t). These results are therefore most directly comparable to regressions 2 and 4.

To judge the magnitude of the effects and demonstrate the range of estimates, we calculated for each regression the implied mark-up above the reservation value at the median level of competitiveness, denoted γ_{median}. We find γ, the bid multiplier, ranges from 1.05 to 1.39, depending on our measure of competition. For the more appropriate budget-per-bidder measures of competition, we find γ's ranging from 1.05 to 1.15. In other words, MALPF bids are roughly 5 to 15 percent above bidders' conditional reservation values.

We also calculated the predicted percentage change in the median bid due to one additional bidder, holding the budgets fixed. This number represents, roughly speaking, the value to the auctioneer of attracting one more bidder. We found that one additional bidder on top of the mean 23 bidders reduced bids by 0.1 percent to 1.4 percent, with a mode of 0.2 percent.[10] This calculation has the advantage that it does not depend on identification of γ_0. Its interpretation does, however, rely on the additional bidder being the same as existing bidders. In dollar terms, for example, in 1999, the average bid per acre of $2,839 would have been lower by $2.84 to $39.75 per acre.

Private Values Distribution

One of our main objectives is to estimate the distribution of θ, the bidder-specific parameter that captures the landowner's taste for owning and operating a farm and thus forms the basis for his reservation value. This private-value is the motivation for competition-based policies, which are designed to drive bids as close to the unobserved θ as possible. The distribution of θ is a key element of participation in land use policies generally, not only those that are competition-based, and thus affects enrollment in all voluntary enrollment land programs. This parameter is a crucial factor determining the probability of land conversion, which in turn is the main variable of interest in many environmental land use policies (Sánchez et al. 2006). Finally, θ can also indicate the compensation that should be awarded for eminent domain takings, since it can be used as a measure of how much a landowner values owning her property above the market price.

We estimate this parameter using [11], [13], and [14]. Results from these regressions are presented in Tables 5 and 6. In all cases, the coefficients are consistent with higher cumulative acceptances leading to higher bids: $\phi_1 < 0$ (regressions 1-5 using equation [11]), $\phi_2 > 0$ (regressions 6 and 7 using equation [13]), and $\phi_4 < 0$ (regressions 8 and 9 using equation [14]).

With these results we can infer the distribution of θ's, using the group-means implied by equation [10] and first making the assumption that the winner's curse correction is zero. Graphs of the implied distribution functions are shown in Figure 1 for regressions 1 through 5 and Figure 2 for regressions 4 and 6 through 9; regression 4 is included in both graphs for comparison. We use $\beta = 1.54$ to convert the estimated ψ's from regression 12 to θ's, using $\theta = \psi^{1-\beta}$, where $\beta/(\beta-1)$ is the trigger between investment value and investment cost from [1].[11]

Recall that $\theta < 1$ and that lower values of θ represent higher values for farm ownership and thus lower reservation easement values. Figures 1 and 2 show distributions of θ's that are far below one. Among regressions 2-7, which use the most appropriate measures of competition and do not require the additional parameter *β*, the highest θ's at the end of the period we analyze are below 0.80. These relatively low values are perhaps not too surprising since the program is never valuable in expectation to a risk-neutral bidder with $\theta = 1$; the program is designed to attract and enroll low θ farmers. Our findings are a bit surprising, however, since they suggest that all of the parcels could have been obtained with a take-it-or-leave-it offer of 0.80, even under a conservative assumption of no winner's curse correction. In contrast, the median ratio among accepted parcels over this period was 0.89.

Our estimates of the θ distribution are robust to functional form and competition measure. They are, however, sensitive to auxiliary assumptions about the level of competition that would drive bids to the reservation value and, in regressions 8 and 9, to the value of β, sometimes called the volatility parameter. For example, the highest value of $\hat{\bar{\theta}}_{(0)}$ comes from regression 8. If we instead take β=2 for this regression then $\theta_{(0)}$ = 0.37, which is quite similar to the regressions based on [9].

Winner's Curse

MALPF auction bidders would appear potentially vulnerable to a winner's curse since landowners bid without knowing the state's appraisal of the easement value. This market easement value should be informative to bidders and bids that are selected are those that are lowest relative to this value. Bidders who recognize the winner's curse should raise their bid above their unconditional reservation value.

More informed bidders should be less vulnerable to a winner's curse. An obvious instrument for bidder information is the comparison between first and second bidders. Therefore, to get a rough estimate of the winner's curse correction, we estimated [12] using only second-bidders, using results from regressions 2, 3, 4, and 5 for $\hat{\bar{\theta}}_{(t)}$, and compare the results to the same regressions for first-bidders There are 109 second-bidders with full data. Estimates are shown in Table 7.

We find substantially smaller intercepts for second-bidders in all four cases, as expected.

If we assume that second-bidders are perfectly informed and that the winner's curse correction for first-time bidders is invariant to all other factors, then the difference $\hat{\alpha}_0 - \hat{\alpha}_1$ is a measure of the winner's curse correction. Based on Tables 5 and 7 we find winner's curse corrections of 8-14 percent of the reservation value.

We have some evidence that the winner's curse correction is indeed invariant to other factors. Initially, we suspected that greater competition would increase the winner's curse correction and therefore lead to higher bids (e.g., Pinkse and Tan 2005). If these conditions held then γ_1 should be larger in magnitude for second-bidders than first-bidders. We find the opposite result, however, since the $\hat{\gamma}_1$s in Table 7 are uniformly below their counterparts in Table 5. This result leads us to conclude that the effect of competition on the winner's curse correction is non-existent and allows us to focus on models with a winner's curse correction that is invariant to all factors except bidder information.

A more sophisticated analysis of the role of information and experience would be valuable but lies beyond the scope of this paper. Joint estimation of first- and second-bidders would appear to be the most valuable approach but multiple sample selection issues would arise under this treatment, including whether offers were made to bidders at $b > M$ and whether they were accepted. We therefore leave this topic for future research.

VI. COMPARISON TO ALTERNATIVE POLICY

This section describes alternatives to competition-based environmental policy and presents our assessment of one prominent alternative to the MALPF auction, the take-it-or-leave-it offer, based on the results of Section V.

It is useful first to define categories of non-competition-based voluntary-enrollment programs. One such category is *formula-based* payments or point systems, in which the state offers a payment to enrollees that is based solely on observable parcel characteristics. Formula-based payments are used for the Conservation Reserve Enhancement Program, and have begun to achieve popularity in farmland preservation programs (Maryland Rural Legacy Program, Ohio's Agricultural Easement Purchase Program) and are also the main format of programs internationally (see Sánchez-Azofeifa *et al*. 2007). The take-it-or-leave-it offer is a form of formula-based payment. The third category is *negotiation-based*, which is the way most land ownership transactions are conducted. This is also the method by which non-governmental organizations such as The Nature Conservancy acquire property or development restrictions.

Our analysis of the MALPF auction leads naturally to the question of whether auctions might be expected on theoretical grounds to be generally superior to a formula-based or negotiation-based approach. The MALPF auction is similar to Bulow and Klemperer (1996) in which an English auction with N+1 bidders is compared to an auction with N bidders in which the auctioneer makes a take-it-or-leave-it offer to the winner after observing all submitted bids. They argue that regardless of the information structure, the pure auction always yields higher expected revenue than any take-it-or-leave-it offer with fewer bidders. This finding suggests that the MALPF set-up might be superior to any take-it-or-leave-it approach, although there remain many differences between their model and the real world MALPF auction.

A few empirical papers have addressed environmental policy questions similar to ours. Stoneham et al. (2003) analyzed auctions for conservation contracts in Australia and compared the existing auction with an alternative take it or leave it offer. They assumed that bids were equal to reservation values rather than inferring them. In this case, an auction always does better than a take-it-or-leave-it offer. Connor, Ward, and Bryan (2007) examined a second Australian program and compared an auction format to various uniform payment schemes and negotiated payments, but did not analyze bids econometrically and did not attempt to infer reservation values. Cummings, Holt, and Laury (2004) examined bids to sell irrigation rights in the Georgia Irrigation Auction and suggested that the rights could have been obtained more cheaply if landowners had been allowed to revise their bids after an initial bidding round. They did not analyze bids econometrically and their recommendation is based on their induced-value auctions. Messer and Allen (2008), examining a land preservation auction in Delaware that is similar to the MALPF auction, use existing bids and benefit measures to show the consequences of alternative parcel selection procedures. They also did not analyze bids econometrically and did not consider how bidding behavior might change if an alternative selection rule were used. Reichelderfer and Boggess (1988) addressed a similar question for the CRP.

We compare the MALPF program to a take-it-or-leave-it (TIOLI) offer under which the state would offer to purchase development rights from all interested landowners at a set percentage of their market easement value.[12] We selected this policy for comparison because it contains the same elements as the current MALPF program yet does not rely on competition among enrollees.[13] The TIOLI would be less expensive than the current set-up if the MALP auction's bids were greatly above landowners' reservation values (due either to high information rents or a large winners' curse correction) and if the distribution of reservation values were relatively flat. These conditions can be verified only through empirical analysis.

Let t be the announced ratio offer. A bidder is predicted to accept the offer if his θ is below t. He would be paid tM and his surplus from the program would be $(t-\theta)M$. To assess the TIOLI we then find the lowest t that would result in acceptances totaling approximately \$53.3 million, the amount spent by the state in Carroll County over the period of study. Using regression 4 as an example, we find that t = 0.602 would cost $53.3 million and would enroll 24,896 acres.

We next simulate MALPF auction bidding.[14] We multiply the reservation values θM by a uniform mark-up, γ. We use a uniform mark-up because otherwise we must simulate budgets and competition year-by-year. Accepted bidders are paid $\gamma\theta M$; we first assume no winner's curse correction. We rank bidders based on θ and sum the bids, starting with the lowest θ, until acceptances total $53.3 million. Again using regression 4 as an example and a mark-up of 1.06, we find that all bidders with θ below 0.67 would be accepted. The program would cost $52.6 million and would enroll 27,841 acres. (Because the θ's form a step function it is not possible to hit the budget-target dead on.)

In other words, the MALPF auction would enroll as much as 3,000 more acres for the given budget than the comparable TIOLI approach, or roughly 12 percent more acreage. Other regressions yield similar results, with the MALPF auction consistently enrolling more acres for the given budget. In addition, an added plus is that when using the MALPF auction approach, the administrator does not need to know the distribution of θ's. Under the TIOLI when the distribution of θ's is not known, the administrator must guess the right t to meet the budget.

The degree of superiority of the auction mechanism is sensitive to assumptions about the winner's curse. If we assume that bidders apply a winner's curse correction of, say, 12 percent then the true reservation values are lower than the values shown in Figure 2 by 12 points. Under this assumption about reservation values, the TIOLI would enroll 26,547 acres for $52.5 million. The MALPF auction calculations remain unchanged. Thus, even when bids contain a winner's curse correction, the MALPF program remains superior to the TIOLI. The MALPF auction would enroll 1,300 more acres for the given budget with a 12 percent winner's curse correction, or a little over 5 percent more acreage. In other words, even though the TIOLI's relative performance is improved when we assume auction participants correct for a winner's curse, the MALPF continues to outperform the TIOLI.

VII. CONCLUDING COMMENTS

The unique set-up of the MALPF program has allowed us to estimate several components of landowner bidding behavior. Our model includes an independent private value component and a possible common value component between each bidder and the administrator.

We find that bids are 5-15 percent above the conditional reservation value. Our finding is similar to a field experiment on which the Georgia Irrigation Reduction Auction is based which found that hypothetical water rights sold for 7-12 percent above reservation values (Cummings, Holt, and Laury 2004). We further find consistent evidence that greater competition leads bidders to reduce their bids. Policy makers have been motivated to adopt competition-based policies based on this theoretical feature which we uncover empirically to be true. We find that each additional bidder reduces bids by 0.1-1.4 percent, or $2.84 - $39.75 per acre. This suggests efforts to encourage more competition among bidders are worthwhile.

Because of the prominent role for the market easement value in the MALPF auction, we considered the possibility that bidders adjust for a possible winners' curse. Through a comparison of first-time bidders with more informed repeat bidders, and correcting for endogeneity in the timing of a second bid, we estimate that first-time bidders adjust for a possible winner's curse by increasing their bids between 8 and 14 percent. Our finding suggests that a modification to the MALPF program to conduct appraisals before bidding, as under Delaware's DALPF auction, might lead to lower bids by reducing a key source of uncertainty.

We derive and demonstrate a unique approach to inferring reservation values based on bidder entry and selection. These reservation values allow us to compare the MALPF auction with an alternative policy that does not involve bidding, called a take-it-or-leave-it offer. We find that the MALPF program would enroll 5 to 12 percent more acreage for a given budget than an “ideal” take-it-or-leave offer. In short, the competition-based design of the MALPF program appears to have paid off in this instance. The MALPF approach also has the advantage that the administrator does not need to know the underlying distribution of landowners’ valuations to reach the budget target.

Many empirical issues warrant further exploration. These include possible bidder collusion, asymmetric bidders, within-round distribution of θ, bidding by re-bidders, and the decision by bidders with ratios above one to accept a payment of R=1. Each of these topics would shed light on bidder behavior and thus potentially lead to better design of the MALPF auction and competition-based policies more generally. We leave these issues for future research.

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Table 1. Summary statistics For MALPF Program, Carroll County 1980-1999: Budgets and bidders					
Bidding year and round	**Statewide budget, thousands ($2002)**	**Carroll County expenditures, thousands ($2002)**	**Number of bidders**	**Number of first-time bidders**	**First-time bids used in estimation**
1980	$5,208	$3,528	11	11	11
1981	$10,221	$4,647	32	32	32
1982	$10,933	$2,977	35	22	21
1983	$12,174	$3,048	53	38	36
1984	$8,762	$1,953	42	24	24
1985	$11,666	$1,565	29	14	13
1986	$13,627	$1,911	17	7	7
1987	$13,539	$1,096	20	17	15
1988	$12,740	$1,931	12	3	3
1989	$17,064	$3,682	27	19	19
1990	$24,794	$6,006	25	24	23
1990-2*	$17,835	$1,821	6	2	2
1991	$0	$0	29	22	22
1991-2	$0	$0	1	1	0
1992	$0	$0	4	1	0
1993	$6,795	$558	0	0	0
1993-2	$8,008	$867	22	13	4
1994	$7,120	$812	25	4	4
1994-2	$6,605	$806	30	5	3
1995	$6,535	$1,342	30	4	2
1995-2	$6,720	$795	21	1	1
1996	$12,030	$3,074	26	7	7
1997	$18,872	$3,199	22	6	4
1998	$22,986	$5,734	34	25	21
1999	$25,466	$2,522	21	4	3
Mean	**$11,188**	**$2,155**	**23**	**12**	**11**
Total	**$279,701**	**$53,875**	**574**	**306**	**277**

*In 1991 the MALPF Program funding was cut to cover a statewide budget deficit; however, the 29 bidders from 1991 were ranked and the lowest bids were funded in 1993 Round 1. All bidders in 1991 Round 2 and 1992 were summarily rejected. No bids were accepted in 1993 Round 1. Normal bidding resumed in 1993 Round 2.

Table 2. Summary statistics for MALPF program, Carroll County, 1980-1999: Bids and ratios (N=545)

Bidding year and round	Mean ratio	Ave. bid per acre ($2002)	Highest accepted ratio	Accepted bids	Cumulative acceptances (CA)	Ave. payment per accepted acre ($2002)
1980	1.39	$3,407	2.10	10	10	$3,410
1981	1.15	$2,169	2.43	18	28	$1,963
1982	1.00	$1,613	0.95	16	44	$1,390
1983	1.26	$1,619	1.00	17	61	$1,332
1984	1.30	$1,528	1.00	11	72	$1,334
1985	1.20	$1,337	1.00	10	82	$1,175
1986	1.34	$1,305	3.31	12	94	$1,346
1987	1.52	$1,766	1.35	7	101	$1,591
1988	0.92	$1,662	1.20	7	108	$1,683
1989	1.29	$2,703	1.70	16	124	$2,520
1990	1.23	$3,827	1.79	20	144	$2,855
1990, 2nd round	1.16	$3,202	1.65	6	150	$3,202
1991	1.17	$3,139	1.31	6	156	$3,593
1991, 2nd round	.	$2,290	.	0	156	$0
1992	1.58	$2,676	0.00	0	156	$0
1993	.	.	.	0	156	$0
1993, 2nd round	0.86	$2,512	0.92	5	161	$2,053
1994	0.97	$2,428	0.59	1	162	$2,504
1994, 2nd round	0.83	$2,548	0.68	3	165	$1,906
1995	0.93	$2,679	0.74	3	168	$2,475
1995, 2nd round	0.92	$2,482	0.84	5	173	$1,481
1996	0.92	$2,287	0.87	10	183	$2,120
1997	0.92	$2,639	0.94	17	200	$2,197
1998	0.90	$2,980	0.87	16	216	$2,395
1999	0.87	$2,839	0.81	7	223	$2,567

Table 3. Summary Statistics for Variables Included in Regression Analysis

	Mean	Median	Std. Dev.	Min.	Max.	n
Tables 5, 6, & 7 (first bidders)						
Bid per acre	2282	2021	1120	563	11444	277
ln(Bid per acre)	7.64	7.61	0.41	6.33	9.34	277
Number of bidders	31.7	30	10.99	6	53	277
State budget/bidder	529	402	340	208	2972	277
County exp/bidder	91.6	73.6	84.3	25.3	1001	277
Market easement value	3556	3377	1123	1432	10153	277
Cumulative acceptances	90	82	63.08	0	222	277
ln(Cumulative acceptances+10)	4.33	4.52	0.83	2.3	5.45	277
Table 4 (rounds)						
Number of bidders	24	25	11.88	1	53	24
State budget/bidder	604	432	600	0	2972	24
County exp./bidder	117.0	73.1	196.4	0	1001	24
Accepted last round	9.25	9	5.35	0	18	24

Table 4. Estimated Coefficients for Predicting Three Measures of Competitiveness: Number of Round (n = 24)

	Dependent variable		
	Number of bidders in round *t* **#A**	**State budget at *t* per bidder at *t*** **#B**	**County expenditure at *t*-1 per bidder at *t*** **#C**
County expenditure at t-1	--	0.33 (5.07)	0.12 (8.01)
State budget announced for t	-7.82×10^{-5} (0.26)	--	--
# accepted parcels at t-1	1.11 (2.59)	-53.61 (2.61)	-19.46 (4.05)
1991-1992 = 1	-15.63 (3.02)	404 (1.77)	182 (3.41)
Post-1992 = 1	1.29 (0.31)	-206 (1.13)	-49.84 (1.17)
Constant	16.64 (3.08)	400 (1.77)	22.02 (0.42)
Prob. > F	0.0076	0.0008	0.000
R^2	0.50	0.62	0.80

Table 5. Estimated Coefficients for ln(Bid per acre), first-time bidders only (equation (11), n = 277)

	#1	**#2**	**#3**	**#4**	**#5**
α_0	0.57 (6.47)	0.091 (2.46)	-0.10 (1.03)	0.033 (0.55)	-0.027 (0.35)
γ_1: Predicted Bidders (#A)	-0.014 (5.85)	--	--	--	--
γ_1: State Budget at *t* per Predicted Bidder (#A)	--	0.00031 (6.69)	--	--	--
γ_1: Predicted State-Budget-per-Bidder (#B)		--	0.00023 (3.27)	--	--
γ_1: County Exp. at *t*-1 per Predicted Bidder (#A)	--	--	--	0.00082 (2.79)	--
γ_1: Predicted County-Exp.-per-Bidder (#C)	--	--	--	--	0.00065 (3.46)
ϕ_1	-0.0046 (6.10)	-0.0028 (4.90)	-0.0073 (4.37)	-0.0057 (5.71)	-0.0071 (4.58)
γ_{median} [b]	1.39	1.13	1.10	1.06	1.05
$\bar{\theta}_{(0)}$ [b]	0.31	0.42	0.35	0.40	0.38
R^2	0.56	0.58	0.53	0.52	0.53

[a]*t*-ratios in parentheses. [b]These estimates include Goldberger's correction (Goldberger, 1968).

Table 6. Estimated Coefficients for Alternative Specifications of ln(Bid per acre), first-time bidders only (equations (13) and (14), n= 277)

	#6 (Eqn. (13))	#7 (Eqn. (13))	#8 (Eqn. (14))	#9 (Eqn. (14))
α_0	-1.27 (13.89)	-1.55 (15.02)	-0.50 (8.53)	-0.31 (5.67)
γ_1: State Budget at *t* per Predicted Bidder (#A)	0.00035 (7.59)	--	0.00032 (7.21)	--
γ_1: County Exp. at *t*-1 per Predicted Bidder (#A)	--	0.00087 (2.83)	--	0.00087 (2.91)
ϕ_2	0.13 (5.70)	0.23 (10.34)	--	--
ϕ_3	--	--	0.65 (5.43)	0.97 (14.71)
ϕ_4	--	--	-0.011 (3.38)	-0.011 (4.75)
γ_{median} [b]	1.15	1.07	1.14	1.07
$\bar{\theta}_{(0)}$ [b]	0.38	0.36	0.59[c]	0.52[c]
R^2	0.55	0.47	0.57	0.50

[a] *t*-ratios in parentheses. [b] These estimates include Goldberger's correction (Goldberger, 1968).
[c] Assumes $\theta = \psi^{-0.54}$

Table 7. Estimated Coefficients for ln(Bid per acre), second-time bidders only (equation (12), n = 109)

	#10	#11	#12	#13
α_0	-0.03 (0.56)	-0.18 (3.26)	-0.09 (2.06)	-0.17 (4.44)
γ_1: Predicted Bidders (#A)	--	--	--	--
γ_1: State Budget at *t* per Predicted Bidder (#A)	0.00026 (3.18)	--	--	--
γ_1: Predicted State-Budget-per-Bidder (#B)	--	0.00004 (0.53)	--	--
γ_1: County Exp. at *t*-1 per Predicted Bidder (#A)	--	--	0.0001 (0.37)	--
γ_1: Predicted County-Exp.-per-Bidder (#C)	--	--	--	0.00017 (0.88)
$\ln(\hat{\hat{\theta}}_{(t)})$	from #2	from #3	from #4	from #5
$\hat{\alpha}_0 - \hat{\alpha}_1$	0.12	0.08	0.12	0.14
R^2	0.44	0.49	0.48	0.50

[a]*t*-ratios in parentheses.

Figure 1. Distribution of taste parameter, regressions 1-5

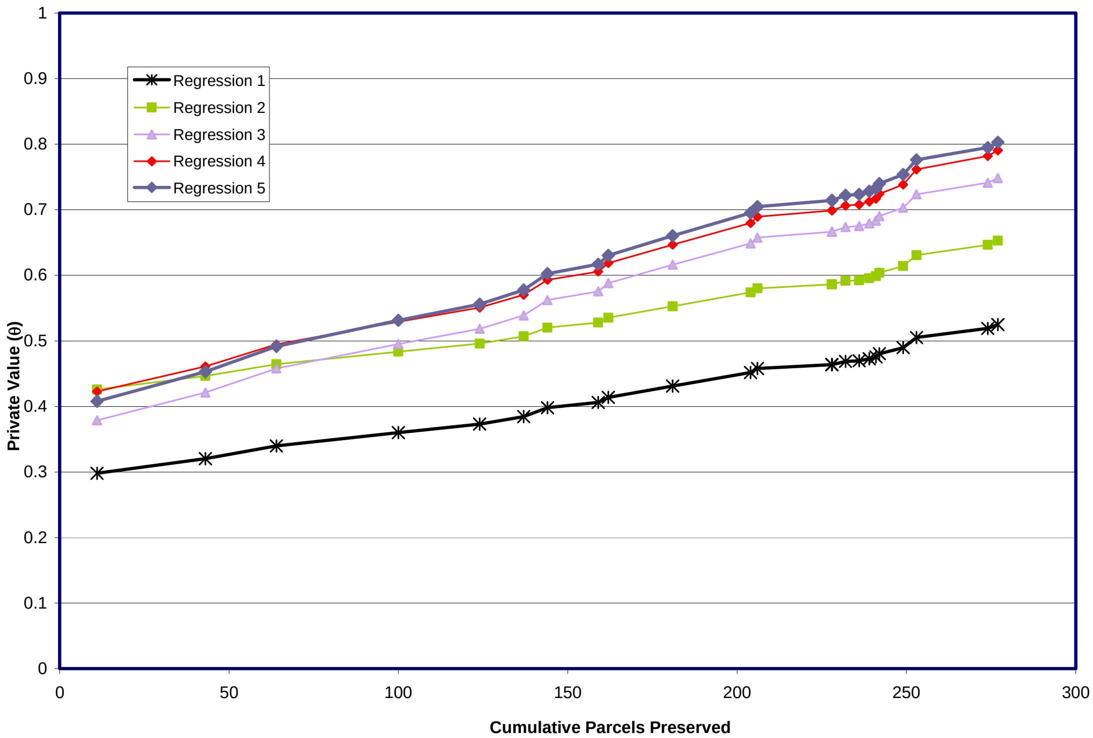
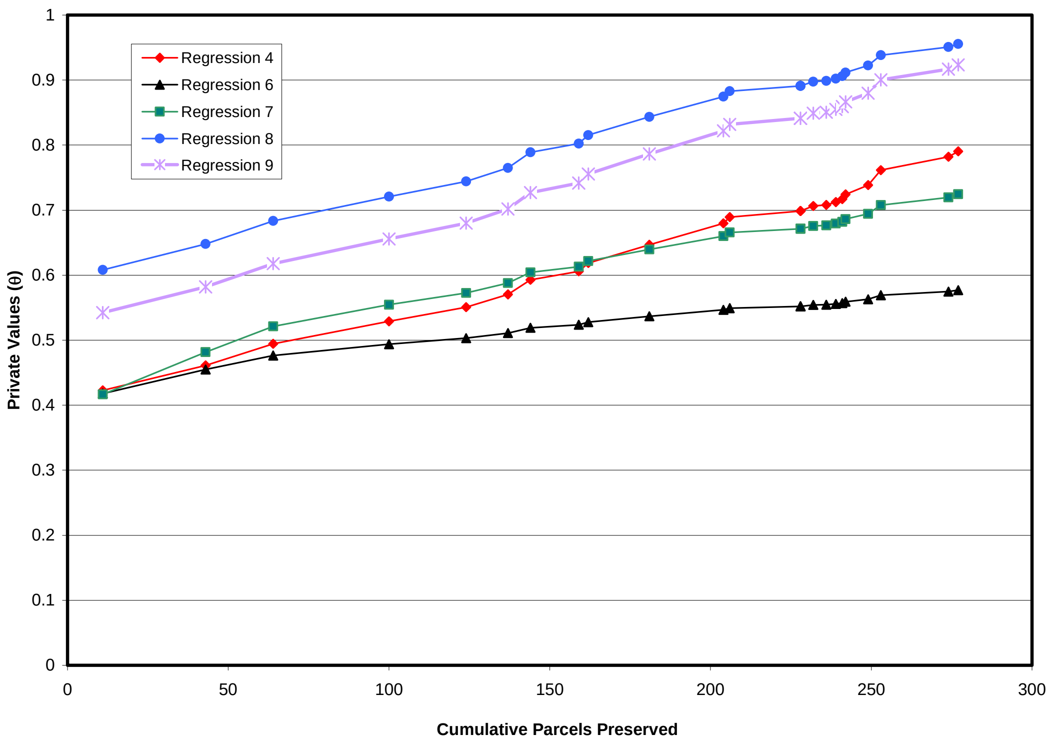


Figure 2. Distribution of taste parameter



Endnotes

[1]We thank Gary Biglaiser, Peter Cramton, Bill Neilson, Harry Paarsch, and Dan Vincent for helpful discussions.

[2]The Conservation Reserve Program operates in Carroll County but the maximum rental rates over this time period were not high and enrollment was quite low. Therefore, the CRP's impact on agricultural value calculations and enrollment decisions is likely to have been essentially non-existent. The Maryland Environmental Trust accepts donations of development rights. Landowners who donate their development rights could apply for tax deductions.

[3]Lynch and Lovell (2003) find both agricultural income indicators and non-consumptive values affect the likelihood of enrollment. These variables include farm size, cropland use, a child planning to take over the farm, and the share of family income from the farm.

[4]We do not consider the case where other bidders' information affects the ex post valuation other than indirectly through the realization of the cut-off ratio, R^*. An alternative assumption would be that M is less informative if all bidders have $D < M$ than if the D's are distributed around M. Likewise, we do not consider the case where D's are affiliated across bidders. These assumptions are obviously open to investigation.

[5]Formally, this condition relies on D being sufficiently independent of θ_i. When entry is costless, D will indeed be independent of θ_i even under more general assumptions about the winner's curse, because D contains all landowner information about M. Therefore, no landowner believes he has a "high" D relative to M. When entry is costly, D will be negatively correlated with θ_i.

[6]We were able to identify one Carroll county parcel whose development rights were donated before the MALPF program began. Other unidentified parcels may also have donated their rights. Thus, we add 10 parcels to cumulative acceptances to account for an estimated 0.5 percent of land that was preserved prior to the MALPF program.

[7]An alternative specification would use an additive mark-up $\gamma(\theta D+\omega)$. An additive mark-up has the valuable property that it is a greater percentage mark-up for low reservation values, which are the ones most susceptible to the winner's curse. Unfortunately, estimation did not converge with an additive mark-up.

[8]Our arguments further imply that second-bidders should have θ's in the upper range of the θ_t's at the time of first bid and that the greater the lag after which a second bidder enters, the higher his bidder was likely to have been in the set of θ's at the time of first bid. We do not model these effects in the current paper.

[9]These values for $COMP_{max}$ are out-of-sample. Kirwan, Lubowski, and Roberts (2005) note that predictions based on an out-of-sample regressor are typically undesirable. Such prediction is unavoidable here, however, since out-of-sample prediction is key to inferring true reservation values.

[10]It is difficult to know how these findings compare to other auctions since this calculation is rarely reported in the literature. Bajari and Hortacsu (2003) found that adding one more bidder resulted in bids that were 3.2 percent closer to the reservation value. This number may be higher than ours because the number of bidders in their auction was much smaller than in the MALPF.

[11]We apply Dixit and Pindyck's notation (1994, p. 142) with parameters from Quigg's study of land development: ρ=0.08, δ=0.03, and σ=0.20 (Quigg 1993).

[12]In the real world, policymakers would have to worry about running into the budget constraint if too many landowners were willing to accept the take-it-or-leave-it offer. The TIOLI policy would then have to include some sort of rationing rule, such as first-come-first-served. In our simulations we can choose the TIOLI offer that would exactly meet the budget, so this concern does not arise. We thank a referee for pointing out this important distinction.

[13]The Delaware Agricultural Land Preservation Foundation (DALPF) program is a competition-based program

under which appraisals occur before the bidding thus eliminating the largest potential opportunity for a winner's curse (DALPF 2007). Landowners submit ratio bids in a sealed-bid first-price auction. The DALPF purchases the easements with the lowest ratios until the budget is exhausted.

[14]For the comparison we simulate the bids rather than use actual bids and enrollments for multiple reasons: (1) Actual enrollments depend on yearly budgets and competition, which do not have direct counterparts in the TIOLI. (2) Actual enrollments include rebidders but the proper comparison is with first bidders. (3) The regressions are an unbiased representation of bidding behavior but not an unbiased representation of winning bids. This affects the simulation because actual bids include an error term; because accepted bids are more likely to have large negative errors they are not a representative sample for comparison with TIOLI. We can either simulate these errors in constructing a simulated TIOLI (for comparison with actual auction enrollment and costs) or can simulate the bids so that they are directly comparable to the TIOLI. We chose the latter approach. (4) Changes in the agricultural formula complicate comparison of raw bids across time.