Auctioning Conservation Contracts: A Theoretical Analysis and an Application

Uwe Latacz-Lohmann and Carel Van der Hamsvoort

Auction theory is used to analyze the potential benefits of auctions in allocating contracts for the provision of nonmarket goods in the countryside. A model of optimal bidding for conservation contracts is developed and applied to a hypothetical conservation program. Competitive bidding, compared to fixed-rate payments, can increase the cost effectiveness of conservation contracting significantly. The cost revelation mechanism inherent in the bidding process makes auctions a powerful means by which to reduce the problems of information asymmetry. Strategic bidding behavior, which may adversely affect the performance of sequential auctions, is difficult to address by means of auction design.

Key words: auctions, bidding for contracts, conservation contracting, cost effectiveness, information asymmetry, nonmarket goods.

The award of contracts on the basis of competitive bidding is a method frequently used in procuring commodities for which there are no well-established markets (Holt). The buyer announces a contract for the procurement of a specified item and calls for bids from potential market participants. Auctions have a long-standing tradition in government procurement contracting. Their usefulness in allocating environmental goods in the countryside has only been discovered relatively recently. Since 1986, the U.S. Department of Agriculture has been awarding land retirement contracts for the Conservation Reserve Program (CRP) on the basis of a competitive bidding mechanism. The applicability of auctions to conservation contracting, however, is not limited to land retirement programs, but can be extended to intensive-margin incentive instruments as well. Farmers would indicate in their bids the amount of incentive payment (or the percentage cost-share) required to adopt the conservation practice in question.

Auctions are of particular interest for conservation contracting for at least two reasons. First, the item being traded, the provision of environmental benefits, is a public-type nonmarket good which has no standard value (Baneth). Second, there is a clear presence of information asymmetry in that the farmers know better than the program administrator how participation would affect their production plans and profits. Auctions in this respect enable the participants to deal with uncertainty about the value of the object being sold or purchased (McAfee and McMillan). Despite these theoretical advantages, the use of auctions in conservation contracting has, by and large, been limited so far to the CRP. Most practice-based environmental conservation and enhancement programs in farming, especially those in the European Union (EU), currently operate on the basis of predetermined fixed-rate payments.

In this paper we employ auction theory to analyze the potential efficiency gains from using auctions in conservation contracting, regardless of the type of conservation program under consideration. With this analysis we aim to demonstrate the broader set of possible applications in this field. Moreover, we intend to show that a bidding scheme with less than full information can achieve high levels of efficiency in the provision of environmental benefits.

The analysis begins with a brief essay on
Auction theory and its applicability to conservation contracting. In the third section, a model of optimal bidding behavior is presented and subsequently, in the fourth section, applied to a hypothetical conservation program. Program performance is simulated for different auction designs under various assumptions. An offer system of fixed-rate, posted-prices contracts serves as a reference. The analysis explicitly takes into account the presence of information asymmetry. With a focus throughout on the interaction of auction design and auction environment, issues like strategic bidding behavior in multiple-signup auctions, as well as the direct targeting of program objectives, are analyzed. Finally, conclusions are drawn as to the usefulness of auction theory in the practical design and implementation of green auctions.

Auction Theory and Conservation Contracting

"An auction is a market institution with an explicit set of rules determining resource allocation and prices on the basis of bids from market participants" (McAfee and McMillan, p. 701). Four basic auction types can be distinguished for a unique item being bought or sold: English, first-price sealed bid, second-price sealed bid, and Dutch, although many variations on the basic forms are used (McAfee and McMillan). In the English auction, which is often used for selling antiques and artwork, the price of the good to be sold is successively raised until only one bidder remains.1 The Dutch or descending-bid auction is the reverse of the English auction. The seller announces an initial bid that he or she successively lowers until one bidder accepts. The Dutch auction is used, for instance, for selling flowers in the Netherlands. In the first-price sealed bid auction, each potential buyer submits one bid and the highest bidder wins. The basic difference between this auction type and the English auction is that in the latter each participant can observe the rival bids and accordingly can revise his or her own bid. In the former auction type, on the contrary, each participant submits a bid in ignorance of the rival bids. The second-price sealed bid auction or Vickrey auction, exerts the same rules as the first-price sealed bid auction, except that the winning bidder who offers the highest price only pays the second highest bid. This auction type, developed and introduced by Vickrey, is seldom used in practice.

Which of the four auction types should be chosen for allocating conservation contracts? It can be shown that under the same set of basic assumptions each auction form, on average, yields the same revenue to the auctioneer. This is known as the Revenue Equivalence Theorem (Myerson, Riley and Samuelson, Vickrey). The assumptions are that (McAfee and McMillan)2 (a) the bidders are risk neutral, (b) the bidders have independent private values, (c) there is symmetry among bidders, (d) payment is a function of bids alone, and (e) there are zero costs to bid construction and implementation.

This model is referred to in the literature as the benchmark model. Relaxation of one or more of these assumptions violates the Revenue Equivalence Theorem and consequently leads to other conclusions about the optimal auction form. Most of the analytical literature on auctions deals with the benchmark model. Milgrom states that although this makes data collection, model construction, and solving the optimization problem easy, it may often "fail to portray the auction environment accurately" (Milgrom, p. 4). Rothkopf and Harstad support Milgrom by pointing out that most of literature analyzes "single isolated auctions" that sometimes lack realism. In this paper we intend to overcome these criticisms. Although the analysis starts with the benchmark model, in the remainder of this section some of the basic assumptions are relaxed, making the model more realistic for the specific case of conservation contracting with consequences for optimal auction design.

Although the benchmark model assumes risk neutrality among bidders, farmers are generally considered to be risk averse. Empirical studies assessing farmers’ conservation attitudes in this respect, however, do not arrive at a unanimous judgment. Lynne, Shonkwiler, and Rola, for instance, show that there is some degree of risk aversion involved in the conservation attitude. Works by Gasson and Potter and by Fraser, on the other hand, conclude that risk aversion with respect to conservation is a phenomenon that is only marginally present among farmers. Assuming risk aversion has implications for the choice of auction form. The theoretical literature shows that with risk-averse bidders, the first-price sealed bid auction produces larger

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1 Also called the oral, open, or ascending-bid auction.

2 In some game theory models of single auctions two additional assumptions are made: there is a single, isolated auction involving a fixed set of bidders; and the rules of the auction are commonly known, firm, and credible.
expected revenues to the auctioneer than the English or second-price sealed bid auction (Riley and Samuelson). In the case of conservation contracting, risk aversion translates into a higher level of cost effectiveness. The reason behind this is that the conservation payment, as a nonstochastic income component, decreases farmers’ income uncertainty, which induces them to marginally lower their bids (as compared to the risk-neutral bidder) to increase the probability of acceptance.

The assumption of independent private values is one of two extremes. The “independent private values model” assumes that each bidder knows precisely how much he or she values the item, or, in the case of bidding for conservation contracts, how the application of the contracts would affect profits. Moreover, the individual bidder does not know the value of the item by the competing bidders but perceives those valuations as being drawn from some probability function. Learning about the competitors’ valuations will not cause the bidder to change his or her own valuation, although he or she is likely, for strategic reasons, to change the bid. This model applies, for example, to an auction for an antique with no resale, but also for government contract bidding (McAfee and McMillan). The other extreme is the “common values model” in which the item being auctioned has an objective true value. The bidders’ perceptions of this value are independent draws from a probability distribution that is known to all participants in the auction. An example of the common value model is an auction for an antique with no resale in which the buyers make a guess about the value of the antique on the resale market. With the aforementioned in mind, it is reasonable to maintain the independent private values assumption for conservation contract auctions. Each farmer is assumed to know his or her opportunity cost of program participation, which, besides some other factors, determines his or her bid. Experiences with the CRP have shown that a common-value element can arise when the conservation contracts are sold in sequential auctions. Farmers then can analyze the results of the preceding rounds and update (often increase) their bids (Reichelderfer and Boggess).

The requirement of symmetry among bidders means that all bidders draw their valuations from the same distribution function. However, for conservation programs this should not necessarily be the case. Land quality may differ by location, resulting in systematic differences regarding forgone profits and the potential for environmental improvements. For the conservation program, this implies that even if bids are equal in monetary terms, the resulting provision of environmental services may differ. This is an asymmetric bidding situation, where each farmer draws his or her valuations from different probability functions. Theory suggests that in the case of asymmetric bidders the optimal auction system generally is the one in which the item being purchased is assigned to the lowest bidder (Myerson). In the case of conservation contracts, however, such auction design is unlikely to achieve its goals, because it favors the lower bidders with possibly a low ratio of environmental output per monetary unit of bid against higher bidders with a higher ratio. This problem arises because the environmental services considered are not well-defined items. Practical solutions to this problem are discrimination of bids, the establishment of eligibility criteria with respect to which farmers are allowed to participate (Reichelderfer and Boggess), or the a priori distinction of homogeneous classes of bidders based on natural circumstances (Baneth, Latacz-Lohmann).

The benchmark model further assumes that payments can only be a function of bids. Sometimes, however, it is in the seller’s or buyer’s interest to make payments conditional on some additional information about the winner’s valuation of the item. McAfee and McMillan exemplify this approach with an auction of oil rights to government-owned land. After assignment of rights, the government observes the actual amount of oil extracted, which provides additional information about the winning bidder’s true value of the oil right. The payment by the winning bidder now equals his or her bid plus a royalty payment based on the amount of oil extracted. A similar system may be applied to conservation contracting by linking the payment level to the environmental monitoring. The winning bidders receive part of their bids when the contracts are assigned and the remainder at the end of the contract period.

Although the benchmark model assumes the costs involved in bid construction and implementation to be zero, these costs may not be negligible. Especially in the case of practice-based conservation contracts, it may be costly for the farmers to acquire information about the relative profitability of the conservation technology. These costs imply a loss to the farmer if the bid is rejected and a reduction in the accruing economic rent if the bid is accepted.

3 A solution used in the CRP.
Therefore, bid preparation costs that are too high may diminish the number of bidders and thus violate the efficiency potential of the auction. Clarity and simplicity of the contracts and the bidding process are a virtue.

The theory described so far applies to a unique item. A specific feature of conservation contract auctions, however, is that, generally, multiple identical contracts are offered. To what extent does this change the conclusions drawn so far? For multiple contracts either a discriminatory first-price sealed bid or a uniform-price auction can be used. In the first case, the n lowest bidders are rewarded, receiving the payment stated in their bids. In the uniform-price auction the n successful bidders receive a payment at the amount of the lowest unsuccessful bid. The uniform-price auction consequently corresponds to the second-price sealed bid auction in the single unit case, and, in determining the optimal auction form, the conclusions set out for a single-item auction also apply for the multiple-unit auction considered here (McAfee and McMillan). According to the theory, in case of multiple contracts with no budget constraint, optimal auction design additionally requires the use of a reserve price—that is, a maximum acceptable bid—to induce farmers to reveal their bids honestly (Myerson, Riley and Samuelson). A reserve price, however, only proves to be effective when bidding competition is weak (McMillan).

A Model of Optimal Bidding Behavior

Suppose that farmers have private information about profits from farming, both under the conventional and the conservation technology, denoted by $\Pi_0$ and $\Pi_1$, respectively. Define profits from farming as per hectare net returns to land, not including the conservation payment. If conservation technology consists of land set-aside, $\Pi_1$ is zero (or even negative). For management practice-based technologies, $\Pi_1$ is normally positive but smaller than $\Pi_0$.4 If the farmer submits a bid $b$ that is accepted, his or her utility will be $U(\Pi_1 + b)$, where $U(\cdot)$ is a monotonically increasing, twice differentiable von Neumann-Morgenstern utility function. If the bid is rejected, the bidder’s utility is $U(\Pi_0)$, the reservation utility. Assume further that the farmer’s bidding strategy is guided by the notion of a maximum acceptable payment level $\beta$, above which no bids will be accepted. This bid cap can be considered a reserve price, unknown to farmers in the bidding process. The farmer now will tender a bid $b$ if the expected utility in case of participation exceeds the reservation utility, as follows:

$$U(\Pi_1 + b)P(b \leq \beta) + U(\Pi_0)[1 - P(b \leq \beta)] > U(\Pi_0)$$

where $P$ stands for probability. It is plausible to assume that each bidder forms expectations about $\beta$. These can be characterized by the density function $f(b)$ and distribution function $F(b)$. The probability that a bid is accepted, can then be expressed as

$$P(b \leq \beta) = \int_{b}^{\beta} f(b) \, db = 1 - F(b)$$

where $\beta$ denotes the upper limit of the bidder’s expectations about the bid cap, i.e., the maximum expected bid cap. Substituting equation (2) into equation (1) yields

$$U(\Pi_1 + b)[1 - F(b)] + U(\Pi_0)F(b) > U(\Pi_0).$$

A common characteristic of all bidding situations is the balance between net payoffs and the acceptance probability. A higher bid increases the net payoff but reduces the probability of winning, and vice versa. The farmer therefore faces the problem of determining the optimal bid, which is the one that maximizes the expected utility [on the left-hand side of expression (3)] over and above the reservation utility [on the right-hand side of expression (3)]. In the remainder of this section, the optimal-bid formulas will be derived for both risk-neutral and risk-averse bidders. For ease of analysis, both benchmark assumptions that there are no costs in bid preparation and implementation and that payment is only a function of the bid are maintained.

For a risk-neutral decision maker, who simply maximizes expected net payoff, expression (3) can be rewritten as

$$U(\Pi_1 + b - \Pi_0)[1 - F(b)] > 0.$$
The optimal bid $b^*_m$ is found by maximizing equation (4) through the choice of $b$ which yields

\begin{equation}
(5) \quad b^*_m = \Pi_0 - \Pi_1 + \frac{1 - F(b)}{f(b)}. 
\end{equation}

For quantitative analysis of $b^*_m$, an assumption must be made on the type of distribution considered. For ease of analysis, it is assumed that the bidders’ expectations about the bid cap are uniformly distributed in the range $[\beta, \bar{\beta}]$, where $\beta$ and $\bar{\beta}$ represent the minimum and maximum expected bid cap, respectively. This model specification is in fact a deviation from the mainstream auction model where the bidding strategy is determined endogenously by, among others, the number of participating bidders. In a conservation contract auction, however, the maximum acceptable payment level is determined not only by the number of bidders, but also by external factors such as the amount of money appropriated to the program or a projected enrollment goal. Therefore, it is realistic to treat the farmer’s expectations about $\beta$ as external to the bidding model. This allows us to simulate the impact of variations in the auction environment on bidding behavior.

The density and distribution functions of a rectangular distribution are given as follows:

\begin{equation}
(6) \quad f(b) = \begin{cases} 
0 & \text{if } b < \beta \\
\frac{1}{\bar{\beta} - \beta} & \text{if } \beta \leq b \leq \bar{\beta} \\
0 & \text{if } b > \bar{\beta}
\end{cases}
\end{equation}

\begin{equation}
F(b) = \begin{cases} 
0 & \text{if } b < \beta \\
\frac{b - \beta}{\bar{\beta} - \beta} & \text{if } \beta \leq b \leq \bar{\beta} \\
0 & \text{if } b > \bar{\beta}
\end{cases}
\end{equation}

In analyzing optimal bidding behavior, it is important to note that it does not make economic sense for the farmer to submit a bid lower than the minimum expected bid cap $\beta$. Furthermore, a bid will be submitted only if the (optimal) bid price at least covers the opportunity costs of implementing the conservation contract. Taking these arguments into account and substituting equation (6) into equation (5), the optimal-bid formula of a risk-neutral decision maker then can be written as

\begin{equation}
(7) \quad b^*_m = \max \left\{ \frac{\Pi_0 - \Pi_1 + \bar{\beta}}{2}, \beta \right\} \quad \text{s.t. } b^*_m > \Pi_0 - \Pi_1.
\end{equation}

Expression (7) shows that the optimal bidding strategy of a risk-neutral decision maker is a linearly increasing function of both the bidder’s opportunity costs of program participation and the expected bid cap. Notice further that a positive bid of $1/2 \bar{\beta}$ (or at least $\beta$) will be submitted by farmers who have already been applying the conservation technology on their farms and therefore incur no additional costs when implementing the conservation contracts. This may be regarded as a free-rider problem if the program administrator is unable to identify those farmers and reject their bids.

For a risk-averse bidder it is important that the conservation payment is a nonstochastic income component. Moreover, in the decision whether to participate or not he or she also will take into account possible changes in the variability of the profits from farming (excluding the conservation premium) which may result from adopting the conservation technology. These aspects affect the risk-averse farmer’s utility as introduced in equation (1). However, since utility as such is not tangible, it is replaced in the following mathematical exposition by the certainty equivalent (CE). Bearing in mind the definition of the certainty equivalent (expected income minus risk premium [RP]), equation (3) can be rewritten as

\begin{equation}
(8) \quad [\Pi_1 + b - RP_1(b)](1 - F(b)) + (\Pi_0 - RP_0)F(b) > \Pi_0 - RP_0
\end{equation}

where the risk premium $RP$ is a function of the expected value and the standard deviation of income (see Laffont). After rearranging terms, the equation is rewritten as

\begin{equation}
(9) \quad [(\Pi_1 + b - RP_1(b)) - (\Pi_0 - RP_0)](1 - F(b)) > 0.
\end{equation}

Expression (9) denotes, analogous to equation (4), the expected gain in certainty equivalent through participation in the conservation program. Maximizing equation (9) with respect to $b$ yields the optimal-bid formula of a risk-averse decision maker. Again, take into account that no bids will be submitted below the minimum expected bid cap and that the (optimal)
bid will be submitted only if it ensures a gain in certainty equivalent. Then,

$$b^*_{ma} = \max \left\{ \Pi_0 - \Pi_1 - [RP_0 - RP_1(b)] + \left(1 - \frac{\partial RP_1(b)}{\partial b}\right) \left(1 - F(b) \frac{F(b)}{f(b)} \beta \right) \right\}$$

s.t. $CE_i(b^*_{ma}) > CE_0$.

From equation (10) it is clear that the optimal bid comprises forgone profits minus the difference in risk premiums plus a premium multiplied by a factor less than one. The greater the risk aversion, the smaller the factor and, thus, the lower the optimal bid price. In other words, risk-averse bidders try, ceteris paribus, to increase the probability of acceptance by lowering their bids. The analogy to the bidding strategy of risk-neutral bidders is clear by setting $RP_0$ and $RP_1$ equal to zero. Then expression (10) is reduced to the optimal-bid formula of risk-neutral decision makers as given in equation (5). From equations (5) and (10), we see that risk-averse farmers normally will tender lower bids than risk-neutral farmers, unless the variability of profits under the conservation technology (affecting $RP_1$) is significantly higher than under the conventional technology. This may be the case, for example, when the conservation contracts require that farmers not apply pesticides.

Model Application to a Hypothetical Conservation Program

In order to gain some quantitative insights into the efficiency of auctions in conservation contracting, the above bidding model is applied to a hypothetical intensive-margin conservation program. The contracts being auctioned are assumed to impose only one restriction: an upper limit of 80 kilograms of nitrogen per hectare, aimed at reducing both nitrogen emissions and commodity surpluses. Assume further that the low-nitrogen practice. For ease of analysis, assume that farmers can enroll their land in the program only on an all-or-nothing basis.

Each of the farms is characterized by a production function of the type $y(n) = a + bn + cn^2$, describing the technical relationship between nitrogen input ($n$) and grain yield ($y$) on a per hectare basis. Farms differ in soil quality and other natural circumstances. These differences are reflected in different values of the technological parameters $a$, $b$, and $c$, resulting in different initial levels of nitrogen application and grain yield. Assuming a product price of $p$ and a nitrogen per unit price of $r$, for each of the model farms the optimal level of fertilization, $n^*$, the corresponding yield, $y(n^*)$, and profit, $\Pi_0 = p \cdot y(n^*) - rn^*$, are calculated. Subsequently, individual nitrogen balances ($NB$), indicating the environmental impacts of the agricultural production process, are calculated as the difference between the optimal input level and the nitrogen removal with the corresponding crop yields: $NB = n^* - \gamma \cdot y(n^*)$, where $\gamma$ denotes the amount of nitrogen removed per unit of crop yield. The economic, environmental, and supply control effects of adopting the conservation practice are now simulated by recalculating the model with the target nitrogen intensity $\bar{n}$. The table in the appendix illustrates this approach for a selection of model farms.

Assumptions and Scenarios

The above farm-level model is linked up with the bidding model through the profit differential. Recall from expressions (7) and (10) that profit forgone is one of the main determinants of the optimal bid. Application of the bidding model additionally requires assumptions on the farmers’ expectations about the maximum acceptable payment level. As explained earlier, the farmers’ expectations are treated as external to the model. To begin with, we assume the bidders’ expectations about $\beta$ to be uniformly distributed in the range of minus 40% to plus 40% of the presumed average opportunity cost of program participation. This

1 The technological parameters have been chosen in approximation to empirically estimated production functions, like those of Schindler and of Claupein.

6 In the calculations made, the average cost is ECU 67 per hectare. Consequently, the range of expectations is bordered by $\bar{\beta} = ECU 40.2$ and $\bar{\beta} = ECU 93.8$ per hectare.
strong assumption will be relaxed below. Moreover, it is assumed that each bidder faces the same density and distribution function, implying that all bidders have the same expectations about the bid cap. This conforms with the benchmark assumption of symmetry among bidders.

As theory is ambiguous about optimal auction design when benchmark assumptions are relaxed, program performance (in terms of number of participants, overall achievement of program goals, and cost effectiveness) is simulated for different auction types and other payment schemes. The variants chosen are as follows.

Reference: flat-rate offer system: A flat-rate payment \( \bar{p} \) fixed by the program administrator at the presumed average forgone profits of all farmers with positive opportunity costs, is offered as incentive to adopt the reduced-nitrogen practice. All farmers who sign up are accepted. Most conservation programs in the EU framework employ this payment scheme. From the farmer’s point of view, participation is worthwhile if \( \Pi_i + \bar{p} > \Pi_0 \) for risk-neutral decision makers, and if \( \Pi_i + \bar{p} - \text{RP}, \Pi_i > \Pi_0 - \text{RP} \) in the case of risk aversion. This payment scheme serves as reference against which the following schemes will be compared.

1. Simple auction (uniform bid cap): Farmers submit sealed bids to the government prompting the amount of payment needed for participation. The winning bidders receive the payment stated in their bids (discriminatory first-price, sealed-bid auction). Within this variant two scenarios are considered:

1a. Targeting enrollment: The government accepts bids, starting with the lowest bid, until the budget is exhausted. This implies that the government’s objective is to maximize enrollment with a limited amount of public money—a strategy that was pursued by USDA during the first nine signups of the CRP.

1b. Targeting program objectives: It is assumed that the program administrator has information sufficient to estimate the prospective environmental benefits of enrolling each farmers’ land. This allows him or her to rank all bids for acceptance based on the ratio of benefits to public cost of enrolling the land. This “cost-effectiveness targeting” was employed during CRP signups 10–12.7

In our model we simulate the outcome of this mechanism by ranking all bids for acceptance according to the ratio of nitrogen reduction \( (n_i^* - \bar{n}) \) to the individual farmers’ (optimal) bids.

In the following two variants, the benchmark assumption of symmetry among bidders is relaxed by distinguishing homogeneous classes of bidders based on natural circumstances. It is assumed that the government has information on foregone profits sufficient to cluster all farmers into three pools \( j \) of equal size: farms with low, average, and high opportunity costs of participation. Again it is assumed that the bidders’ expectations about the maximum acceptable bid level are uniformly distributed in the range of minus 40% to plus 40% of the presumed average foregone profits of the pool. All farmers within one pool face the same density and distribution function. By doing this, we relax the symmetry assumption only between the pools, but maintain this assumption within the pools. The different variants chosen are as follows.

2. Offer system with differentiated payment rates: Pool-specific, preannounced payments \( \bar{p}_j, j = 1, 2, 3, \) are offered as incentive for the farmers to adopt the conservation practice. Similar to the reference variant, the payment rate for pool \( j \) is fixed at the presumed average of foregone profits of all pool \( j \) farmers with positive opportunity costs.

3. Bidding pool auction system (differentiated bid caps): Similar to variant 1, farmers tender sealed bids to the government. Each bid received is assigned to a bid pool. As in variant 2, there are three pools of different opportunity costs. Every farmer knows to which bidding pool his farm is assigned. As above, the two bid selection mechanisms, (3a) targeting enrollment and (3b) targeting objectives, are analyzed.

4. Perfect-information offer system: This variant is intended to serve as “best-case” reference regarding program cost-effectiveness. It is assumed that the government has perfect information about each farmer’s opportunity costs and potential contribution to the program goals and therefore can offer each farmer a payment equal to or marginally above his or her opportunity cost. The farmers are accepted in the order of their benefit-cost ratios within the overall budget.8

To assure comparability among the various variants, the budget of each of the variants is assumed to be restricted to the amount of the flat-rate offer system (reference). With a flat-rate offer system and a perfect-information of-
fer system as reference points, we are now able to assess the efficiency potential of auctions within the range of these two extremes.

**Results**

The quantitative results of the model calculations are listed in table 1 for risk-neutral bidders. The columns indicate the various payment schemes and the rows indicate the variables that measure program performance. All measures are depicted in relation to the flat-rate offer system which is set to 100.

Implementation of the various bidding schemes enhances program performance significantly. Under all bidding scenarios considered, more of the program goals are achieved with the same amount of public money. The reasons for these efficiency gains are twofold. First, the windfalls (difference between payments and costs—row F) accruing to farmers who enroll land with lower-than-average opportunity costs are reduced. Their bid prices lie below the fixed-rate offer. Second, producers with opportunity costs above the level of the fixed-rate payment (who would not participate under the offer system) are encouraged to tender cost-covering bids. Given the same budget for all variants, those farmers can be accepted to the extent of the savings provided by the low-cost participants.

As expected, the cost-effectiveness indices are higher when program objectives are targeted directly (variants 1b and 3b compared to 1a and 3a), although fewer contracts are awarded. This is because, in the targeted variants, mainly farmers with higher-than-average contributions to the program goals are selected, while the reverse is true for the variants that target enrollment. Notice further from table 1 that a bidding pool auction with cost-effectiveness targeting (var. 3b) almost measures up to the "best-case" reference of a perfect-information offer system (var. 4).

**Auctions and Information Asymmetry**

The results presented in table 1 can be re-examined from another angle. Each of the variants and scenarios in the table implies a different level of information available to the program administrator. In the reference variant and in variant 1a information is limited to the average opportunity cost of program participation. In variants 2 and 3 it is assumed that the program administrator has information on opportunity costs sufficient to cluster all farms into three groups. Variants 1b and 3b assume the availability of farm-level information on the level of fertilization, and variant 4, finally, assumes perfect farm-level information on both forgone profits and fertilization levels. Therefore, the numbers in table 1, except those for variant 1a, represent the combined effects of two events: the implementation of an auction scheme and the utilization of different levels of information. It stands to reason that increasing information results in better program performance and lower windfalls for farmers. It is obvious that in the extreme case of perfect information, the implementation of a bidding scheme would not yield any benefits. Conversely, the benefits of auctions are higher when there is less information available to the program administrator, that is, the larger the gap between the farmers' and the government's information. The italic numbers in table 1 furnish evidence of this. The efficiency gains of replacing a three-pool offer system (variant 2—implying some information) by a bidding pool auction (var. 3a and 3b) are substantially lower than the benefits of switching from the flat-rate offer system (implying very limited information) toward a simple auction (var. 1a and 1b). The reason for this phenomenon is that the marginal value of the information provided with the bids is higher, translating into high gains of program performance when less information initially is available.

With the aforementioned in mind, the windfalls (row F in table 1) may be regarded as returns to private information on farm-level relationships earned above the payment needed to encourage participation. The more information the government acquires, the less farmers will be able to extract high information rents because the program administrator can identify and discriminate applicants with "unreasonably" high bids. However, acquiring information is a costly venture. In this respect, it is important to note that the implementation of an auction reduces information asymmetry inherently (and at almost zero cost), as the bidding process reveals, though imperfectly, the individual bidders' opportunity costs of program

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9 The results for risk-averse bidders do not differ significantly, although the level of the absolute performance is slightly higher in all variants.

10 Here the three-pool offer system is set equal to 100.
Table 1. Simulated Performance of the Conservation Program for Risk-Neutral Decision Makers Under Different Payment Schemes (Flat-Rate Offer System = 100)

<table>
<thead>
<tr>
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<th>1b</th>
<th>2</th>
<th>3a</th>
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<td>Perfect Information Offer System</td>
<td>83</td>
<td>57</td>
<td>32</td>
<td>38</td>
<td>25</td>
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a Total program outlays minus total profits foregone, i.e., overcompensation of profits foregone.

participation. Since the optimal bid is, among others, a linear function of the profit foregone, a high bid indicates high opportunity costs and vice versa. This cost-revelation mechanism makes auctions a valuable tool for governments to use in coping with information asymmetry and deficiencies in allocating contracts for the provision of nonmarket goods.

A Note on Bidding Competition in Sequential Auctions

Green auctions are normally designed as multiple-signup auctions. Bids for the same contracts are invited in a sequence of several years or, as in the case of the CRP, several times per year. CRP bidding behavior gives evidence of decreasing bidding competition in multiple-signup auctions through the presence of Bayesian learning. During the first four signups, the mean value of the bids increased (Osborn, Llacuna, and Linsenbigler), while the distribution of the bids declined (Reichelderfer and Boggess), implying that the farmers had learned the bid caps. By the ninth signup, the majority of the bids were almost exactly equal to the bid caps (Osborn, pers. comm.). In the language of the bidding model, learning the bid caps narrows the range \([B, \bar{B}]\) of expectations about the maximum acceptable bid level. According to the optimal-bid formulas (7) and (10), this encourages farmers wishing to enroll low-cost land to bid at least \(\bar{B}\), while high-cost farmers are discouraged from tendering bids, because \(\bar{B}\) would not cover their costs of implementing the conservation contracts. In the extreme, when the bidders know the bid cap with certainty (\(\bar{B}\) equals \(\tilde{B}\)), the bidding scheme degrades to a fixed-rate offer system. On the other hand, a very wide range \([\beta, \bar{B}]\), which may occur in the first signup due to lack of bidding experience, may encourage the farmers to tender "unreasonably" high bids. We have employed the above model to simulate the impact of the degree of uncertainty about the maximum acceptable bid level on the performance of the auction (figure 1). All performance measures in the figure are depicted in relation to the flat-rate offer system which is set to 100. The degree of uncertainty about the acceptable bid level is depicted on the horizontal axis as percent of deviation of \(\beta\) and \(\bar{B}\) around the average opportunity cost. It has so far been assumed that the bidders’ expectations about the bid cap were distributed in the range of minus 40\% (\(\beta\)) to plus 40\% (\(\bar{B}\)) of the average opportunity cost. This assumption is now varied between 0\% (certainty) and 100\% (high uncertainty).
Per cent deviation of $\hat{\beta}$ and $\bar{\beta}$ around the average cost (AC) of program participation

$\hat{\beta} = AC \cdot (1 - c/100), \quad \bar{\beta} = AC \cdot (1 + c/100)$

- Number of participants
- Total emission reduction
- Total program outlays
- Average bid

Figure 1. The effect of uncertainty on the performance of a green auction with a uniform bid cap (variant la)

The figure shows that the full efficiency potential of auctions is mobilized when the bidders expect the bid cap to be set in the range of plus/minus 30% of average cost. A higher degree of certainty (to the left of this point) causes the performance of the auction to decline due to strategic bidding behavior (learning the bid caps). Increased uncertainty (to the right of the 30% mark) also diminishes the efficiency of the auction because of increasing (optimal) bid prices in combination with a fixed budget. Performance measures may even fall below the level of the offer system. These relationships call for the auctioneer, on the one hand, to keep farmers in the dark about the maximum acceptable payment rates. One possibility to maintain a reasonable degree of uncertainty would be to conceal the functional form of the bid acceptance mechanism. On the other hand, in the first signup, inexperienced bidders should be given some guide as to the range of realistic payment levels.

Conclusions

In this paper we show that auctions are a valuable tool for governments in allocating conservation contracts among farmers. Auctions are generally superior to a posted-price offer system for providing low-cost solutions to the provision of environmental benefits, because they introduce an element of competition between farmers.

Bidding reveals information about the farmers' costs of program participation and enables the government to discriminate positively between the competing claims. Moreover, the government is able to control the allocation of funds by setting up rules under which the tenders offered by the farmers are selected. This mechanism, however, requires information on site-specific environmental impacts of farming which may not be consistently available. The high efficiency gains, which can be achieved by directly targeting the program objectives in the bid selec-
tion process, may in fact call for increased investment in agroenvironmental data collection.

These conclusions apply irrespective of the conservation policy tool employed (land set-aside or management prescriptions). Programs that could benefit from applying a bidding mechanism include the Environmental Quality Incentive Program in the United States as well as the large number of environmental incentive programs offered under EU regulation 2078/92.

The major contribution of this paper is that it makes auction theory applicable to the specific case of conservation contracting. Some of the benchmark assumptions have been relaxed to portray the auction environment as accurately as possible. Nevertheless, some simplifying assumptions remain, both with respect to the model and auction theory. For example, the farm-level model considers only one input and one output. A more elaborate model with multiple inputs and outputs, which allows for substitution, may produce a more moderate effect on program performance. Another simplification is the assumption of independent private values, which requires that farmers know precisely their opportunity costs of program participation. In practice, however, there is often an element of uncertainty among farmers as to the consequences of adopting conservation practices, resulting in affiliated values instead of independent private values. Also, farmers in the EU have proved to be reluctant to participate in conservation programs because they fear that the government will not allow them to remove the management changes after the contracts have expired. All this may have unforeseeable implications for bidding behavior, which, consequently, could affect the results presented here.

Bearing this in mind, how useful is auction theory in assisting practical auction design? Because of its shortcomings, the theory cannot provide us with a cut-and-dried solution in most real-world settings. In our opinion, it can, however, and should play an important role in considering auction design and bidding behavior so as to avoid drawbacks that might otherwise occur. In this respect, the analysis in this paper suggests that had auction theory been consulted in devising the CRP bidding process, it might have been able to predict some of the problems of that bidding process (e.g., declining bidding competition after multiple signups; problems resulting from pursuing an enrollment target) in advance.

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References


Rothkopf, M.H., and R.M. Harstad. “Modelling


### Appendix

**Characteristics of Selected Model Farms under the Conventional and the Conservation Technology**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>1</th>
<th>25</th>
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<td>-0.0001</td>
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</table>

Conventional technology

- $\Pi_0 = \Pi(n^*)$ (ECU/hectare)
- $\Pi_1 = \Pi(\tilde{n})$ (ECU/hectare)
- $NB(n^*)$ (kg/hectare)$^b$

Target technology

- $\Pi_0 = \Pi(\tilde{n})$ (ECU/hectare)
- $NB(\tilde{n})$ (kg/hectare)$^b$

Differences:

- Yield (mt/hectare)
- Nitrogen balance (kg/hectare)$^c$
- Profit (ECU/hectare)

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$^a$ At $p = \text{ECU 100 per mt grain}$ and $r = \text{ECU 0.4 per kg nitrogen}$.  
$^b$ At $\gamma = 18 \text{ kg nitrogen per metric ton (mt) yield}$ (Source: Hygro Agri Dülmén).  
$^c$ Only reductions of nitrogen emissions are considered environmental improvements. If under the low-input technology the nitrogen balance is negative, only the initial nitrogen balance surplus over and above zero, not the entire difference between $NB(n^*)$ and (negative $NB(\tilde{n})$), is taken into account.