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Options for Improving Conservation Programs: Insights From Auction Theory and Economic Experiments

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Abstract

The U.S. Department of Agriculture spends over $5 billion per year on conservation programs, mostly on voluntary programs that give financial assistance to farmers and landowners to provide environmental services (such as implementing nutrient management programs or planting native grasses). Since most programs cannot fund all interested parties, program managers must use some mechanism to select applicants. One option is to elicit offers through an auction. This report addresses the use of auctions in conservation programs. It considers how information in the hands of Government officials and rural landowners affects the auction's performance, and how auction design can reduce Government expenditures or encourage landowners to provide greater environmental services. Results of laboratory experiments are discussed, highlighting shortcomings of common features of conservation program auctions (such as limits on the rent landowners may request), as well as how alternative auction designs can improve performance.

Keywords: Conservation Reserve Program, CRP, auctions, enrollment mechanisms, bid caps, reference-price auction, quota auction

Acknowledgments

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What Is the Issue?

The U.S. Department of Agriculture spends over $5 billion per year on conservation programs, mostly on voluntary programs that give financial assistance to farmers and landowners to provide environmental services. Most programs cannot fund all interested parties and some use auctions to select from among competing applicants. Auctions are an appealing competitive enrollment mechanism for USDA's conservation programs—they can be cost effective and relatively easy to administer. While well-designed Government auctions can achieve program objectives while utilizing tax dollars efficiently, auctions can also have unintended consequences stemming from the manner in which they are implemented. Auction theory, lessons learned from existing Government auctions, and the results of economic laboratory experiments can all be used to better understand the impacts that auction design can have on outcomes.

What Did the Study Find?

Using the current design of USDA's Conservation Reserve Program (CRP) auction as an example, this report explores how alternative auction designs might provide a bigger "environmental bang for the buck."

Auctions are especially useful when:

(1) The buyer (e.g., USDA) can leverage available information about participants to keep costs down;

(2) No well-established market exists; and

(3) The Government needs a fair and transparent way of selecting participants when budgets are constrained. In reverse auctions, such as the CRP (where there is one buyer and many sellers), competition between participants can improve cost-effectiveness and set a market-clearing price for ecosystem services when private markets do not exist.

Auctions may be less useful when:

(1) The buyer has very good information on the sellers' costs and can make efficient purchase decisions by simply making take-it-or-leave-it offers to targeted parcels;

(2) Costs and benefits of environmental services vary little across potential participants, so a fixed price could be set and offered to anyone providing the environmental service;

(3) The market has too few buyers and sellers for effective competition within an auction environment (e.g., when only a handful of landowners meet program qualifications);

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(4) Cost-effectiveness is one of several potentially conflicting design criteria; considerations such as income support or broad geographic distribution of participants may be as important.

In these cases, auctions may be no better than administratively simpler approaches, such as offering a single price to anyone wishing to sell or negotiating a seller-specific price. Furthermore, if farmers would have adopted good stewardship practices without financial assistance, any payment mechanism that deters voluntary action can be counterproductive.

When designing a conservation auction, the details matter. Decisions on how to elicit offers, the choice of criteria used for ranking and selecting offers, and the amount of information that will be provided—all of these can affect the auction's performance. Such design elements can also affect who chooses to participate in the auction, how competitive their submitted bids will be, and whether their offers are accepted. All of these outcomes will also influence an auction's cost-effectiveness.

The auction mechanism used in the CRP's general signups, responsible for most of the land enrolled in the program, is a good example. The CRP uses a parcel-specific *Soil Rental Rate* (SRR)—an estimate of the parcel's agricultural rental value—to determine the parcel's maximum acceptable bid, or *bid cap*. While intended to prevent excessive landowner profits, bid caps can have negative consequences. The bid cap is essentially an estimate of the minimum price a seller would accept and still participate in an auction. If the bid cap is less than a seller's true cost of program participation, however, the seller will not make an offer. If dissuaded landowners have eligible parcels with low agricultural value and high environmental benefits, an under-estimated bid cap can lead to higher overall program costs. Bid caps can also discourage landowners from incorporating conservation practices that improve the quality of their offers—even though such improvements are valued highly by the conservation program.

Other types of auctions could do more to limit costs and improve performance. For example, both *quota auctions* and *reference-price auctions* could be implemented with the information currently used by the CRP (the SRR), but neither imposes a bid cap. Quota auctions group similar participants together, and a fraction of the least competitive offers from each group is rejected to induce competition among low-cost participants. This approach requires accepting some higher cost participants into the program, but may be worthwhile if it increases participation and competition among low-cost participants, improving the overall cost-effectiveness of the program. Reference-price auctions assign an estimate of value—a reference price—to each parcel of land. Bids are ranked relative to the reference price—in the CRP example, the reference price could be the SRR. Sellers are penalized if their bids exceed USDA's expectations, but they are not prevented from submitting any bid they wish. Since all bids are considered relative to their SRR, offers with exceptionally high environmental benefits could be accepted even if their bid exceeds their SRR. This could result in improved program cost-effectiveness by both increasing competition among low-cost sellers and increasing the program's overall environmental benefits. While improved performance is not guaranteed, laboratory experiments show that these alternatives can reduce costs up to 18 percent using a reference-price auction, and up to 14 percent using a quota auction.

How Was the Study Conducted?

A literature review highlights the basics of auction theory and design, the advantages and disadvantages of auctions, the different kinds of auction mechanisms that conservation programs could use, and factors to consider when designing an auction. The auction mechanism used by the CRP is examined in some detail, focusing on the impacts of the bid cap. Using actual offers in the CRP's general signup, the limitations and drawbacks of the imposition of bid caps are explored, focusing on how bid caps can dissuade potential participants or the installation of conservation practices that improve the environmental quality of offers. Alternative auction mechanisms are investigated via economic experiments performed in classroom laboratories. These experiments mimic the design of conservation programs to test the potential impacts of alternative auction mechanisms. Regression analyses of experimental results, as well as a numerical simulation model, demonstrate the size of potential gains.

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Introduction

Environmental conservation has been an integral part of U.S. Federal agricultural policy since the Soil Conservation and Allotment Act of 1936. Currently, the U.S. Department of Agriculture (USDA) spends over $5 billion per year on conservation programs.[1] The largest Federal conservation program is the USDA's Conservation Reserve Program (CRP), which pays farmers to voluntarily shift crop acreage from crop production to land covers that conserve soil, enhance wildlife, and reduce erosion.

USDA conservation programs continually change. For example, when the CRP was created in 1985, it focused on reducing soil erosion. Since the mid-1990s, however, the program has considered a broader set of environmental goals, including enhancement of water quality, air quality, and wildlife habitats. Working lands programs—programs that provide financial assistance to farmers to adjust their management practices rather than retire land from production—also continue to expand.[2]

There have also been changes in conservation program implementation, such as how USDA elicits conservation proposals from farmers, decides which proposals to accept, and decides how much to pay participating farmers. These details of implementation, often the result of a mix of legislation and administrative decisions, can be critical to the effectiveness of the program in meeting its goals (Hamilton, 2010). They can help determine which farmers and which lands are ultimately enrolled, which farmers and landowners gain financially from the program and how much they gain, and the level of Government expenditures and environmental benefits associated with the program.

This report addresses how the use of auctions in conservation programs can enhance program efficiency and performance. It considers auction mechanisms used in current and past conservation programs, as well as mechanisms that are more commonly found in other types of auctions. To illustrate tradeoffs involved with different ways of compensating farmers for providing conservation services, the study reports best practices in auction design that apply to the specific case of *reverse auctions*—auctions with many sellers and one buyer—for goods that vary in quality and value (see glossary).

The results of several economic experiments comparing competing auction designs are also presented. These design attributes are chosen in light of current practices at USDA and use the CRP

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[1] USDA fiscal year budgets can be found at http://www.usda.gov/wps/portal/usda/usdahome?navid=BUDGET.

[2] Trends in USDA conservation program expenditures can be found at www.ers.usda.gov/topics/natural-resources-environment/conservation-programs/background.aspx.

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Glossary

Discriminatory Auction: An auction where sellers receive the bid they request. In multi-unit auctions, different sellers will receive different amounts. In contrast, all accepted offers receive the same amount under a uniform price rule (a *uniform-price auction* [see below]).

Economic Rent: The amount of economic profit earned by an activity. In contrast to financial profit, economic profit is net of *opportunity costs* [see below].

Information Rent: The amount of economic rent earned by participating in an auction that is due specifically to the private information that a bidder has. If a bidder earns economic rent by leveraging information about the true cost of participating in a conservation program, then these are information rents. For example, a seller with a true *reservation value* [see below] of $10 who earns a conservation payment of $15 will earn an information rent of $5.

Opportunity Cost: The value of foregone opportunities. If, by participating in a conservation program, a farmer foregoes the opportunity to earn money through the normal operation of the farm, then the money that would have been made through the normal operation of the farm is part of the opportunity cost of participating in the conservation program. Any other foregone benefits (such as the personal benefits of actively farming) are also part of the opportunity cost of participating.

Reservation Value: In auctions, the reservation value of an item refers to the value of the item to the buyer or the seller—the exact maximum amount that a buyer is willing to pay for an item, or the exact minimum amount that a seller is willing to accept for an item. For example, a profit-maximizing seller will enter an auction knowing that he or she will never accept less than his or her reservation value.

Reserve Price: A reserve price refers to a price ceiling or a price floor—a limit on the price of an item to be sold at auction. In an auction with a single seller and many buyers (a forward auction), a reserve price specifies the minimum amount of money that the seller is willing to accept for the item. In an auction with a single buyer and many sellers (a *reverse auction* [see below]), a reserve price specifies the maximum amount of money that the buyer is willing to pay for the item. This is referred to as a bid cap in the Conservation Reserve Program.

Reverse Auction: In a reverse auction, there is one buyer and many sellers. For example, the Conservation Reserve Program currently uses a reverse auction, with the USDA acting as the buyer and eligible landowners acting as sellers. In contrast, the more familiar forward auctions (e.g., Treasury bond auctions) involve one seller and many buyers.

Uniform–Price Auction: An auction where all sellers receive a single payment which may be different than their actual bid. This payment may be equal to the highest rejected bid, the lowest accepted bid, or some other measure (such as a randomly generated value, with all bids below this accepted). Note that setting a fixed price in a market is not the same as a uniform-price auction; although all sellers receive the same price, setting a fixed price in a market is done without gathering bids in an auction (any eligible seller can chose to participate after the fixed price is announced).

as an example of an auction designed specifically to reduce the cost to the Government of running a conservation program. The experiments reveal the potential effects of alternative auction designs. Taken together, the review of the literature and the laboratory experiments represent preliminary steps in a process that could eventually lead to modifications in current policy.[3] This report does not make policy recommendations on auction mechanisms. Instead, it highlights the feasibility (and limitations) of practical tools that might be used to enroll landowners and farmers in voluntary conservation programs, given what is currently known about auction design.[4]

Auction Basics

Auctions facilitate competition and can lead to efficient price formation.[5] With clear rules regarding participation, the bidding process, and selection criteria, auctions can facilitate simple and transparent enrollment. Many branches of the Government use auctions for various kinds of activities. A few prominent examples (see box, "Examples of Auctions Used Within the Federal Government") include regular sales of Government bonds by the U.S. Treasury,[6] auctions held by the U.S. Federal Communications Commission (FCC) for the telecommunications spectrum, and regular sales of Government property by the General Services Administration. These high-value, high-stakes auctions are remarkable both because of the important roles that they play in allocating public resources and because the coordinating agencies have modified them significantly over the years using a process of experimentation to explore new auction designs.

The design of an auction—how offers are elicited, scored, ranked, and selected, and how prices are set, as well as other details (such as the nature of the information shared by the buyer with sellers)—affects who chooses to participate in the auction, how competitive submitted bids will be, and which offers are accepted. This study focuses on auctions likely to be used by conservation programs—auctions where there are many sellers (such as rural landowners) and one buyer (such as the USDA). This class of auctions is known as reverse auctions.

The design of a USDA conservation auction ultimately determines how well the program achieves its environmental objectives. When designing any auction, information matters—particularly what the buyer knows about the attributes of the sellers. Consider a hypothetical case where the managers of a land retirement program possess perfect information on all eligible landowners. That is, the managers know the exact amount of money it would take to entice each landowner to participate in the program—a figure often referred to as a landowner's *reservation value* or *opportunity cost* (see glossary)—and the exact value society places on the environmental benefits the landowner would provide for that reservation value. Based on this information, a ranking of all eligible parcels could

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[3] Future steps could use different parameterizations and types of participants, a limited field test of the best-performing alternative method or methods, and a full-scale trial of the most favored alternative.

[4] Although this report considers auction mechanisms, other approaches are possible. As summarized by Ferraro (2008), these include acquiring information on observable landowner characteristics and the use of screening contracts. There is evidence (Arnold et al., 2013) suggesting that, for many conservation settings, screening contracts may perform better than auctions.

[5] See Vickrey (1961 and 1962) for the original theory of efficient auctions. See Cramton (1998) for a discussion of the relative efficiency of alternative auction designs (in this case, sealed bid versus dynamic auctions). See Madhavan and Panchapagesan (2000) for a discussion of the use of auctions specifically for the purposes of price discovery (in the context of large financial markets).

[6] See Back and Zender (1993) for a review of the literature on Treasury auctions. Accounts of the pilot's announcement can be found in the *Wall Street Journal* (1992) and Fuerbringer (1992). Contemporary accounts can be found in Mester (1995) or Sill (1994).

Box: Examples of Auctions Used Within the Federal Government

Treasury Auctions

The U.S. Department of the Treasury (Treasury) uses weekly auctions to sell bills and quarterly auctions to sell bonds; the results of these auctions help determine the cost of Government borrowing. The Treasury uses a uniform-price format to sell debt of different maturities—debt instruments with 1 year or less to maturity are known as bills, debt instruments with between 2- and 10-year terms are notes, and long-term debt is issued as bonds.

Many academics and public policy researchers have studied Treasury auctions, and the Treasury has adjusted its procedures as a result of their findings. Before 1992, Treasury used a multiple-price auction—an auction in which winners paid their bid prices (also known as a discriminatory auction). Due to academic research suggesting that the uniform-price format might lead to higher participation and lower debt-financing costs, Treasury instituted an experiment in 1992 to find out which auction was more cost effective. In the experiment, 2-year and 5-year notes were sold using a uniform-price format, while remaining securities were sold under the old format. Due (in part) to the results of the experiment, the uniform-price auction was implemented for all securities in 1998.

Spectrum Auctions

The Government allocates spectrum for telecommunications in another well-studied auction. In the 1950s, Herzel (1951) and Coase (1959) argued that auctions should be used to allocate the right to broadcast in certain ranges of the spectrum. Until 1981, the U.S. Federal Communications Commission (FCC) assigned spectrum based on cases made to the FCC by applicants; from 1981 to 1993, spectrum was allocated by lottery. In 1993, Congress directed the FCC to auction spectrum and, in 1994, the FCC held its first auction for wireless spectrum, the Nationwide Narrowband Personal Communication Service (Narrowband PCS) auction.

The FCC did not have a history of successful sales to draw on in order to decide what auction format worked best. Laboratory experiments were conducted at the California Institute of Technology, and a smaller July 1994 auction (worth $617 million) informed a subsequent December auction (worth $17 billion).

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be constructed. Program managers could then choose which parcels to recruit into the program and offer each parcel its reservation value.

In reality, information on eligible parcels is far from perfect. While measures that are predictive of reservation value (such as soil quality and local agricultural rents) may be available, these are not perfect predictors of a given parcel's value to its owner. Furthermore, collection of detailed information is costly. Careful auction design can leverage available information to achieve cost-effective results.

The amount of information available influences landowners as well as the Government. If landowners know the goals and budget of a conservation program and are aware of the reservation values of other parcels, they could strategically adjust their bids (Cason and Gangadharan, 2004). These bid adjustments could take the form of individual actions (such as owners of low-valued parcels demanding a high price) or even collusive behavior that could undermine the goals of the auction. However, auction design choices can also mitigate these risks.

Lessons from Auction Theory and Practice

Economists and scholars from other disciplines have studied auctions by examining bidding patterns observed in actual auctions and the results of auction experiments,[7] which provide some broad lessons that may be useful in the design of conservation program enrollment schemes. There is also a growing body of literature that studies the practical design of markets, especially markets created by Government entities, which offers lessons that are applicable to the design of Government auction markets for environmental services.

The Advantages and Disadvantages of Auctions

Auctions can offer several advantages over negotiations or fixed-price offers:[8]

1. Auctions reduce costs to the buyer by using competition to drive down prices. This is especially true when the buyer can leverage information about participants to limit *information rents*. Information rents are profits a seller obtains due to proprietary knowledge (say, about the seller's cost of production) that the buyer cannot observe (see glossary).

2. Auctions are effective at setting a price when the Government is uncertain of what price to pay. This frequently occurs when the Government is purchasing goods that have a limited number of buyers and sellers. Uncertainty is resolved through the price revelation (e.g., the price at which a buyer is willing to buy and a seller is willing to sell) that happens naturally in auctions between sellers and the Government. In comparison, bilateral negotiations (e.g., bargaining with individual landowners) can be a time-consuming and expensive means of information discovery. Auctions can also be an effective means of discovering a market-clearing fixed price, which may be used in future acquisitions (Athey et al., 2002).

3. Auctions are a fair and transparent way to allocate goods when rationing is necessary. When budgets are constrained (e.g., when a program is oversubscribed) the Government must choose whom to buy from and at what price. An auction resolves this problem by specifying a general set of rules before the auction occurs and evaluating potential offers according to these rules.

However, auctions are not always a superior mechanism. There are several factors to consider when deciding if an auction is the right procurement mechanism for a particular program:

1. Homogeneity in costs or environmental quality may reduce the advantage of auctions over alternative procurement systems. When the pool of suppliers is homogeneous, a properly chosen fixed-price mechanism will have a similar outcome to an efficient auction.

2. Auctions become more administratively expensive when parcels have unique benefits. If candidate parcels are wholly unique (such that the parcels have no close substitutes), a more explicit targeting mechanism that identifies desired parcels might be more suitable. Auctions can be used for procurement in these situations, but selecting offers becomes a more complex

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[7] See Paarsch and Hong (2006) for a textbook review of auction econometrics; Milgrom (1989) for a primer on auctions, including early experimental literature and formative observational work; Milgrom (2004) for an example of the practical implementation of many high-value Government auctions; and Athey et al. (2011) for a review of the auction-based timber pricing mechanism of the USDA Forest Service.

[8] Direct targeting of individual parcels can best be handled through negotiations since individual attention must be paid to each contract. Fixed-price offers are like standard markets, where the buyer announces a price and sellers can choose to sell, or not sell, at that price.

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process that includes a mechanism to weigh quality.[9] This process requires potentially costly input from the Government (see box, "Scoring Auctions").

3. If adopting a payment mechanism substantially deters prior voluntary actions, any payment mechanism—whether based on a market, an auction, or a Government program—may be counterproductive.[10] Similarly, auctions may not be cost effective if they end up enrolling those who would have undertaken a desired course of action without any payment (Arnold et al., 2013).

Box: Scoring Auctions

In Government procurement, reverse auctions can be used to procure many goods, including both commodities (goods of uniform quality) and highly differentiated goods (such as construction contracts or contracts to provide environmental services). Scoring auctions take quality into account when selecting the winning offers. In a scoring auction, a numerical score is assigned to each offer, offers are sorted by the score, and the winning offers are those with the best scores. The Conservation Reserve Program is an example of a scoring auction—offers are sorted according to the Environmental Benefits Index, a composite score that takes both the cost and the environmental implications of each offer into account.

The formation of the scoring mechanism is an extremely important part of auction design in a market for goods of heterogeneous quality. The score is a numerical representation of the buyer's preferences, including the relative preference of the buyer for various measures of quality and price. A scoring mechanism that is poorly designed can lead to the selection of offers that fail to achieve program objectives and the rejection of offers that would have yielded preferable results.

Construction contracts are another prominent example of quality-differentiated goods that are awarded by scoring auctions. Lewis and Bajari (2011) studied construction contracts awarded by the California Department of Transportation (CDOT), some of which used a scoring function of $b + c*d$, where both price (b) and days-until-completion (d) are considered. A value c equal to 10,000 means that contractors can lower their score—make their score more competitive— equally well by reducing their requested payment by \$10,000 or by shortening their contract term by 1 day. By increasing c, CDOT implicitly increases the public's preferences for shorter contracts by equating a reduction in the term of the contract with a larger reduction in price. For more information on the use of scoring auctions, see the recent report by the U.S. Government Accountability Office (2013) and Asker and Cantillon (2008).

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[9] Auctions of this type are sometimes referred to as scoring auctions. See Asker and Cantillon (2008) for a discussion of these types of auctions. The Conservation Reserve Program (CRP) is, effectively, a scoring auction where parts of the Environmental Benefits Index represent the quality measure. Because the CRP is a large auction and many parcels can be scored using a single technology, the costs of scoring are spread over a large number of parcels, reducing the transaction costs often observed in traditional scoring auctions.

[10] This phenomenon is known as "crowding out" (Sommerville et al., 2009). For example, landowners motivated by a stewardship ethic may voluntarily adopt environmentally friendly management methods even though these reduce their profits (van Noordjwick et al., 2012). Introduction of a market that pays landowners to adopt this management method may discourage this voluntary activity.

4. When accurate price information is available, auctions are less informative than they would be in a low-information environment. If the purchaser can observe characteristics (including costs) with a high degree of accuracy, auctions may not be more cost effective than more direct mechanisms (such as the Government making direct offers to sellers).

5. If public demand for the procured goods is large relative to supply, competition in an auction will be low and pressure on participants to place bids close to their opportunity costs will be reduced, thereby limiting the ability of auctions to reduce information rents. The expense of negotiations may be justified if competition cannot be relied upon to control costs.

6. The goals of the program must be compatible with competition. If cost-effectiveness is not a primary goal (e.g., if income support is the primary goal of the program) auctions may be inappropriate.

7. Efficient allocation is not always achieved by an auction. In general, social welfare—the value of goods and services produced by a society without concern for their distribution—can be maximized by setting a price equal to the social value of the good being procured and accepting all interested offers at that price. For example, if the managers of a conservation program know the monetized value of the reduction in soil erosion due to retiring an acre of farmland, a uniform price equal to this amount could be announced and all offered acres accepted. Since landowners willing to sell at this price will have an opportunity cost less than this price, total social welfare will be maximized.[11] In contrast, cost-effective auctions might entail rejecting some low-cost sellers to motivate competitive bidding by all participants.

However, if budgets are constrained and the Government is not capable of purchasing from all willing sellers at the socially efficient price, reducing procurement costs will free up money to purchase more units. As detailed in the box, "Economic Efficiency Under Limited Budgets," the social welfare gain from purchasing extra units can then justify the use of a least-cost procurement mechanism, even in a world where efficient allocation is important.

Designing an Auction

There are several considerations when designing an auction, such as defining the objective of the auction, defining the good being auctioned and communicating the rules of the auction (see box, "Auction Design—Primary Steps").[12] Other basic decisions include *uniform-price* versus *discriminatory*[13] auctions (see glossary), sealed versus observable bids, and the use of bid caps (maximum allowable bids) (see box, "Kinds of Auctions"). While these steps apply to all auctions, the characteristics of auctions most likely to be relevant for the procurement of environmental goods and services have further distinctions.

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[11] This simple example assumes that the same amount of erosion occurs on any parcel regardless of its location. It also assumes that a monetized value—one that should capture all the environmental benefits of reduced soil erosion—is available and does not change with the location of the parcel or as more acres are retired. In practice, this is rarely the case.

[12] See Klemperer (2002) for a discussion of auction design and Depiper et al. (2013) for Government-auction design. Latacz-Lohmann and van der Hamsvoort (1997) and Latacz-Lohmann and Schilizzi (2005) provide a discussion of theoretical and practical implementations of conservation auctions.

[13] In a uniform-price auction, all accepted offers are paid the same price (often, the price of the highest accepted offer). In a discriminatory auction, each accepted offer is paid its asking price, regardless of what other accepted offers receive (see glossary).

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Box: Economic Efficiency Under Limited Budgets

An economically efficient level of provision of a good occurs when its marginal benefit is equal to its marginal cost—where the value of the last unit consumed equals the expense of supplying it. Applying this idea to agricultural conservation, the conservation benefits from the last acre of land accepted into a conservation program should equal the best alternative use of the land. This outcome can be achieved using a simple market—where a single price is announced and all sellers willing to accept this price are accepted.[1] However, the optimality of a simple market depends on several assumptions. In particular, the purchaser (for example, the Government) should have no budget constraint.

This is not often the case, however. For example, an agricultural conservation program may have a fixed budget that is not large enough to purchase the socially optimal quantity of retired cropland. In this case, an auction mechanism—by allowing the available budget to purchase a quantity closer to the social optimum—can yield social welfare outcomes that are superior to a simple market.

The following land retirement example illustrates this case. Assume that:

- There are 20 1-acre parcels that have opportunity costs (net profits from agricultural production) between $2 and $40.
- The marginal value (benefits of ecosystem services) of retiring parcels is decreasing: the first acre retired provides $62 in environmental benefits, while the 20th acre retired provides $24.
- The marginal benefit and cost curves are linear.

The table below shows costs and benefits. The socially optimal price is $32, with a total expenditure of $512 and a total benefit of $900 (the sum of conservation benefits from retired land plus the sum of net agricultural profits of nonretired land).

Suppose, however, that the Government is constrained to spending only $338. If a simple market mechanism is used, only 13 acres can be retired at a uniform price of $26. The imposition of this budget constraint drops the net social benefits from $900 to $888. In contrast, consider a discriminative auction (that pays selected offers their bid) with a bid cap always $9.15 greater than the opportunity cost, and assume that all farmers make an offer equal to their bid cap. $338 will allow 14 acres to be retired, yielding total benefits of $896. Alternatively, retaining net benefits at $896 (by retiring 13 acres) would cost $301 under the discriminative auction (89 percent of the $338 in expenditures under a simple market).

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[1] In more complex situations, such as when conservation benefits differ across parcels, setting a single price may not be economically efficient. In these situations, other enrollment mechanisms can be used to maximize social welfare. For example, Polasky et al. (2014) introduced a subsidy auction, which achieves social efficiency by separating bids from payments (which incentivizes submission of bids equal to actual opportunity costs). However, the subsidy auction achieves efficiency by awarding all the net benefits of conservation to the parcel owners, and it assumes an unlimited budget.

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Box: Economic Efficiency Under Limited Budgets—continued

The discriminative pricing obtained through the auction mechanism reduces payments to low-cost sellers. These savings are then used to retire more acres, allowing the Government to purchase a number of acres closer to the optimum quantity. While this example's budget constraint (of $338) and bid cap (that is always $9.15 greater than the opportunity cost) were chosen for numerical simplicity, it does illustrate how auctions can yield better social welfare outcomes than simple market mechanisms.

Table: Results from three budget and pricing scenarios

Procurement mechanism	Acres retired	Opportunity cost of retired land	Conservation benefits from retired land	Payments to retired land	Total benefits
Using a socially optimum, uniform price of $32	16	$272	$752	$512	$900
Using a uniform price of $26, given a budget constraint of $338	13	$182	$650	$338	$888
Using a discriminative auction and a budget constraint of $338 (max payment is $37)	14	$210	$686	$338	$896

Note: Total benefits is the sum of conservation benefits from retired acres and the value of production (the opportunity cost) from nonretired acres.
Source: USDA, Economic Research Service.

Box: Auction Design—Primary Steps

Although the details of an auction matter, a great deal of practical experience suggests that good auction design begins even before detailed decisions are made. The following primary steps are also important to successful auction design (Depiper et al., 2013):

- Define the objective of the auction from the perspective of the buyer.

- Clearly define the good being auctioned. Design the auction to be appealing to potential sellers (more sellers translates to more competition) and safe for sellers to participate in (participating should not put sellers at undue risk).

- Clearly communicate the rules of the auction to all potential sellers. Sellers should feel confident that they know how they can improve their offers, and they should understand basic tradeoffs.

Box: Kinds of Auctions

There are four main types of auctions used to buy or sell single items.[1] Since there is no important conceptual difference between reverse auctions (one buyer, many sellers) and forward auctions (one seller, many buyers), the following descriptions focus on reverse auctions.[2]

First-price (or "low-price") sealed-bid auctions	Each potential seller offers a private (unannounced) bid to the buyer. The buyer selects the seller with the lowest bid and pays the amount of that bid for the good.
Second-price sealed-bid auctions	Each potential seller offers a private bid to the buyer, and the buyer selects the seller with the lowest bid. Unlike first-price sealed-bid auctions, however, the winning bid does not determine price. The buyer pays the winning seller an amount equal to the second-lowest bid.
Descending auctions	A starting price is announced. This price is sufficiently high that all sellers are willing to sell. Price is lowered successively until only one seller remains. The winning seller is paid the final price (the price at which he or she was the only willing seller).
Ascending auctions	The buyer begins by announcing a very low price and gradually raising it. The first seller to announce that he or she will accept the announced price supplies the good at that price.

When multiple units are bought (or sold) in a single auction, analogs of the above auction types exist:

Discriminatory sealed-bid auctions, or pay-as-bid auctions	Each potential seller offers a private (unannounced) bid to the buyer. The buyer orders bids from lowest to highest and purchases the lowest bids until he or she has purchased the desired amount. The buyer pays each winning seller an amount equal to his or her bid.
Uniform-price sealed-bid auctions	Each potential seller offers a private bid to the buyer and the buyer selects the lowest bids. However, the winning sellers are not paid according to their own bids. The buyer pays each of the winning sellers the same price. The price is usually determined by one of two rules: the highest bid submitted by a winning seller or the lowest rejected bid.
Descending auctions	A starting price is announced. This price is sufficiently high that, in total, sellers are willing to supply more good than the buyer is willing to purchase. Price is lowered successively until, as sellers drop out, the amount of supply offered by willing sellers is equal to the demand of the buyer. The winning sellers are all paid the final price (the price at which supply equals demand).
Ascending auctions	The buyer begins by announcing a very low price and gradually raising it. Sellers join as the price increases until the amount of supply offered by willing sellers is equal to the demand of the buyer. The winning sellers are all paid the final price (the price at which supply equals demand).

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[1]See Menezes and Monteiro (2005) and Krishna (2010) for extensive discussion of basic auction varieties.

[2]The forward-auction analogs of these reverse-auction types are known as a first-price auction, a second-price auction, an English auction, and a Dutch auction, respectively.

Observable differences in costs among sellers

One benchmark assumption in auction theory is that all potential sellers have private opportunity costs drawn from the same distribution. This means that, while some potential sellers may have higher costs of providing the good than others, neither the buyer nor the other sellers can observe these differences before the auction takes place. Each seller appears identical (symmetric) from the perspective of the buyer and from the perspective of all other sellers. In contrast, auctions in which there are clear observable differences between sellers—auctions where meaningful opportunity-cost differences can be predicted using observable information—are called asymmetric.

In conservation and environmental services auctions, an assumption of symmetry is often false— instead, the assumption of asymmetry is an important determinant of good auction design. The costs of providing environmental services can vary widely depending on where land is located and the agricultural or other economic activity that would otherwise take place on the land. While some of the cost differences between sellers may remain unobservable, many of these differences are clearly evident to all sellers and to the buyer. For example, it is commonly known that the opportunity cost (the lost revenue per acre from not producing crops) to a farmer of establishing native grasses on an acre of wheat in Montana is less than on an acre of corn in Iowa.

Observable differences among sellers may deter sellers from participating in an auction. Low-cost sellers (such as the Montana farmer with a low opportunity cost) are generally willing to accept lower prices than high-cost sellers (such as the Iowa farmer with a high opportunity cost); low-cost sellers expect to be accepted into the program while high-cost sellers expect not to be accepted. If sellers have a good understanding of others' costs, then high-cost sellers have little incentive to bid in the first place, especially if the act of bidding is costly. Low-cost sellers may recognize that high-cost sellers will not submit bids, and increase their bids accordingly.

More broadly, the fact that sellers are observably different should be considered in the design of an auction. Treating all potential sellers as identical can appear even handed but may deliver high profits to sellers with observably lower opportunity costs. Using observable information may help the Government construct an auction that gives all auction participants a chance to make some profit, but which reduces the large profits that low-cost sellers would otherwise enjoy.

Recurring auctions and repeat participation

The vast majority of auctions have been modeled and analyzed as single auctions: the auction happens, a transaction occurs, and the process ends. There is no interaction between the market and the auction, and no opportunity to participate in the auction again. Many conservation and environmental services auctions, however, are conducted on a regular basis (Latacz-Lohmann and Schilizzi, 2007), which creates opportunities for two types of important seller behavior—choosing when to bid and learning how to bid well.

If potential sellers regard the opportunity to bid as a recurring opportunity, they may delay bidding until they feel that the process will be most valuable to them. The value of waiting could be caused by strictly external factors, such as the opportunity to use land for an alternative purpose (i.e., during a period of high crop prices), or external changes in the structure of the program that make participation more or less favorable (i.e., congressional action to increase or decrease funding to the program). The value of waiting to bid is also influenced by the ability to learn from the outcomes of

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earlier auctions. By observing the outcomes of an auction today, a seller can learn how to modify his or her behavior to maximize profits in an auction tomorrow.

The ability of sellers to participate in the auction of their choice, and learning how to bid well in that auction, eliminates some of the monopsony power of the buyer. Informed sellers will use all the information available to them to extract profits from the auction, which may serve to erode several of the traditional cost advantages of auctions (Latacz-Lohmann and Schilizzi, 2007).

Entry

Encouraging sellers to enter an auction is always a key consideration of auction design. Without broad participation, an auction will not be competitive and, at the very least, the lack of competition erodes one of the major motivations for using an auction mechanism in the first place. In extreme cases, a lack of participation can lead to under-enrollment and an auction that does not meet its primary policy goals (e.g., retiring a targeted amount of highly erodible cropland).

Because conservation auctions frequently rely on the participation of a large number of individuals, many of whom are not necessarily experienced sellers, it is especially important that information about the auction is widely available to all potential participants. In fact, promoting the opportunity to participate is a key factor in good conservation auction design. In some cases, disseminating detailed information about the auction could enhance competition by lowering barriers to entry for inexperienced sellers.

An extreme case of this type of information campaign can be seen in the FCC's spectrum auctions, as well as the planned auction of takeoff and landing slots at major airports by the U.S. Federal Aviation Administration (FAA). In both instances, the Federal agency in charge of the auctions gave potential sellers the opportunity to participate in mock auctions so that they could learn about the auction system.[14] Potential sellers gained experience with the relevant software, asked logistical questions of the buyer, and could test bidding strategies in a setting without consequences. Additionally, the auction for agricultural irrigation rights held by the State of Georgia also used practice auctions to spread information and allow potential sellers to gain experience—in this case, farmers who were likely inexperienced with the particular mechanism chosen by Georgia for its natural resource procurement (Cummings and Holt, 2004).

Ambiguity

If auction rules are unclear, potential sellers could have difficulty assessing their best offers. The more complex and ambiguous the rules, the more difficult it will be for sellers to decide how to structure their offer. Substantial literature in behavioral economics indicates that individuals facing such complex decisions will tend to forgo making them and stay with a status quo alternative. For example, many employees choose not to enroll in subsidized retirement savings plans, choosing a default option of saving nothing instead (Congdon et al., 2011). More recent literature documents how simplifying decision environments can aid decisionmaking (see Beshears et al. (2013) for an example where simplifying retirement savings decisions can drastically change choice).

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[14] The Federal Aviation Administration auctions did not take place as scheduled, and have not taken place as of July 2014. The mock auctions did, however, take place.

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In the case of reverse auctions for environmental services, too much complexity may discourage participation or limit the effectiveness of participants. For example, in a land-retirement program auction, if a seller does not add an extra conservation practice to a field (because he or she does not understand that this is the least costly way to improve the offer), both the seller and the buyer are affected by the result. Ultimately, while some degree of complication is inevitable in many auctions, it is important to reduce the decisionmaking problem facing potential sellers so that it is manageable (i.e., so that the auction format clearly incentivizes behavior that the Government wants to encourage).

Risk and regret

Sellers who feel they may expose themselves to risk by participating in an auction may be less likely to participate, so an auction design that reduces unnecessary risks to potential sellers will encourage participation. Though it is impossible to eliminate all the associated risks, auction outcomes can be improved when risks can be decreased without harming the goals of the auction. For example, a landowner offering to participate in a multiyear program to improve bird habitat might give up the opportunity to hay grassland (leaving grassland largely untouched is beneficial to the provision of environmental services). At the same time, however, participation in the program exposes the landowner to risks, such as drought that affects the farm's other haying land. Rules that permit infrequent haying or haying in exigent circumstances without harming the provision of environmental services can mitigate the risks of participating in the program.

Common values

The nature of the costs of providing environmental services, particularly how costs are related among potential sellers, should be a consideration in conservation auction design. A seller's cost may be private or common. When the determinants of the cost of providing environmental services for one landowner are completely unrelated to the determinants of cost for other landowners, costs are said to be private; when the determinants are shared, costs are said to be common. In reality, costs frequently have characteristics that are a mixture of private and common. For example, the cost of providing bird habitat by planting native grasses (an environmental service) rather than producing corn on a parcel of land are determined by both private and common factors. Each landowner faces the same market price of corn (a common determinant of the opportunity cost of not producing corn), but the amount of corn that can be produced depends on soil characteristics that are unique to a landowner's parcel (a private determinant of opportunity cost).

When a large proportion of the determinants of cost are common, winning sellers may be susceptible to the "winner's curse" (Thaler, 1988). That is, when costs are entirely common, winning sellers might actually *regret* having won the auction.[15] This happens if winning sellers (those who bid the lowest) undervalue the opportunities they are foregoing by agreeing to participate in the conservation program. Auction design can mitigate this effect by ensuring that all potential sellers have easy access to public information (such as price forecasts and knowledge of alternative program

[15]The value of an oil lease, for example, is largely common—regardless of who wins the auction (and thus wins the right to drill for oil in a particular spot), the amount of accessible oil is unchanged. Since the amount of this oil is unknown before the auction (the amount of oil cannot be known for sure until a well is drilled and the oil is extracted), oil companies must estimate the amount of oil under the lease. The buyer most likely to win the auction is the buyer who has assessed the value as being highest (i.e., the winning buyer is also the buyer most likely to have been overly optimistic about the value of the lease).

opportunities)—this can create expectations that are more closely aligned with auction outcomes, which can encourage participation and increase competition and auction effectiveness (Ozbay, 2007).

Collusion and threats

Important practical considerations when designing auctions include preventing collusion among sellers (e.g., a secret agreement among sellers to limit competition) and deterring outside punishments by rival sellers for competitive bidding within the auction. These concerns typically apply to auctions with few sellers. While it is important for auction design to reduce opportunities for collusion and threats, these are small concerns for large-scale conservation programs because there are typically a large number of geographically dispersed landowners interested in participating.

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Case Study: Auctions in the Conservation Reserve Program

Enrollment mechanisms for many conservation programs already work in a manner similar to reverse auctions: bids or proposals are elicited from many farmers and landowners, and the Government scores, ranks, and selects which proposals to accept. The enrollment mechanism used by CRP, the Nation's largest conservation program, is a prime example of how reverse auctions are used in conservation programs.[16]

Established in 1986, the CRP retires highly erodible and other environmentally sensitive cropland from production.[17] With the program using 10- to 15-year contracts, enrollment peaked in 2007 at 36.8 million acres. As of September 2014, about 25.6 million acres were enrolled at a cost of about $2.0 billion per year (fig. 1). Most of these acres were enrolled in 262,000 competitive general-signup contracts. However, about 20 percent (5.7 million acres) were enrolled in 410,000 contin-

Figure 1
Conservation Reserve Program enrollment, acreage per county, September 2014
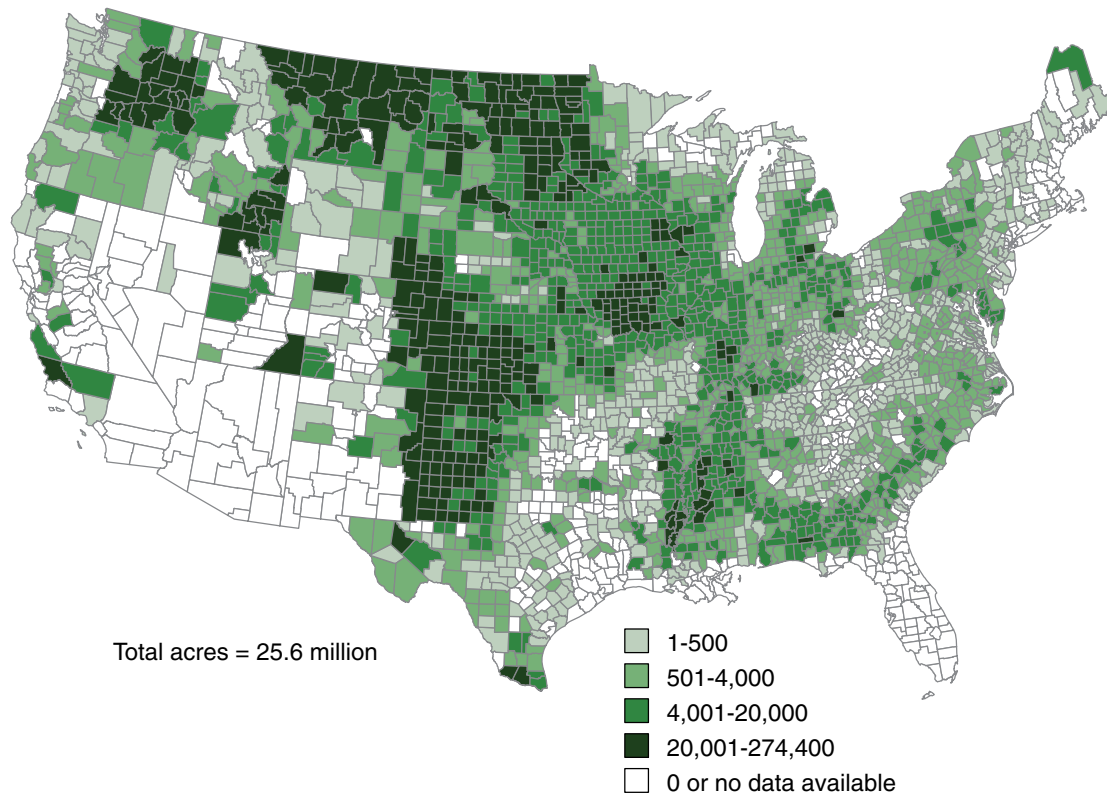
Total acres = 25.6 million

Legend:
- 1-500
- 501-4,000
- 4,001-20,000
- 20,001-274,400
- 0 or no data available

Source: USDA, Economic Research Service using confidential program data from USDA, Farm Service Agency, Conservation Reserve Program.

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[16]Other successful conservation auctions include Australia's EcoTender (Stoneham et al., 2003) and Auction for Landscape Recovery (Eigenraam, 2005), as well as Scotland's Challenge Fund Scheme (Messer et al., 2013).

[17]As of November 2014, the Conservation Reserve Program (CRP) covers about 24.2 million acres, at a cost of about $1.8 billion per year. Historical trends in the program are detailed in Hellerstein (2012) and current CRP statistics are available at the USDA Farm Service Agency's website: http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=rns.

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uous-signup contracts that target environmentally sensitive land (such as stream buffers) through a noncompetitive, "first-come, first-served" selection process.

Offers for enrollment in the CRP consist of a request by the landowner for an annual rental payment in exchange for installing a proposed cover practice (such as installing native grasses or longleaf pine) on a specific parcel of land. CRP participants must pay substantial penalties if they withdraw before the expiration of their contracts (which have a 10- to 15-year duration). Rental requests may not exceed a parcel-specific bid cap, which is set by the Government based on the geographic location of the parcel and the productivity of its underlying soils.[18]

Since 1996, CRP offers (at the national level for the general signup) have been ranked according to the Environmental Benefits Index (EBI),[19] which accounts for the environmental services expected to be produced by the retired parcel of land and the cost of the landowner's requested rent. Offers with the highest EBI scores are accepted into the program.

As with most conservation program auctions, landowners interested in participating in the CRP have a delicate decision to make when deciding how much compensation to request and what cover practice to install—the greater the compensation requested (and the less valuable the proposed cover practice), the lower the odds their offer will be accepted. Thus, a landowner wishing to maximize gains from offering land to the program will balance the desire for a higher payment (and less upfront expenditures on installing cover practices) against the lower odds of having the offer accepted.

The design elements of the CRP auction greatly influence which parcels are selected for the program, the amount landowners are paid, and, consequently, the success of the CRP in achieving its conservation objectives. Consider, for example, four key features of the CRP auction:

1. Contract length. The 10- to 15-year contract required in CRP has costs and benefits. A long-term contract can be beneficial from an environmental standpoint if it takes time to establish native covers, wildlife habitat, or buffer strips to accrue environmental benefits. On these grounds, contracts longer than 10-15 years may be justifiable.[20] On the other hand, landowners may require greater rental payments if they are locked into the program for a longer period of time (i.e., if they value flexibility).

2. The Environmental Benefits Index. The EBI is a formula that scores each parcel offered for enrollment into CRP. This scoring mechanism, perhaps the most crucial design element of the CRP, weighs environmental and cost-related priorities. Scoring implicitly values each of the program's environmental goals individually.

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[18]The Conservation Reserve Program bid cap is based on the Soil Rental Rate (SRR) of the parcels comprising an offer. The SRR is an estimate of the agricultural value of a parcel and is based on the county average rental rate for an acre of unirrigated cropland, adjusted to reflect the parcel's relative soil productivity. Given the limited accuracy of these component measures, the SRR can be thought of as a relatively inexpensive, but imprecise, appraisal of the opportunity cost of retiring a parcel of land from agricultural production.

[19] The Environmental Benefits Index (EBI) considers several environmental criteria, including soil erodibility, impacts on water quality, impacts on wildlife habitat, and impacts on air quality. The Conservation Reserve Program's use of an EBI reflects a balance between minimizing cost and increasing a variety of environmental services (such as reducing erosion and improving wildlife habitat).

[20]When a Conservation Reserve Program (CRP) contract expires, the landowner may re-offer the land (say, in the next general signup). Thus, land can be in the CRP for longer than 10-15 years.

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3. One-time sealed bids. The CRP uses general signups to enroll new acreage.[21] Each general signup uses a discriminatory sealed-bid auction where landowners have a single opportunity to privately submit their bids (bids are not announced publicly) which cannot be revised. This feature of the enrollment process also involves tradeoffs. If landowners could revise their offers after observing a first round of bids, those not accepted in an initial round may be willing to adjust their cover practices or rent requests. However, if landowners knew additional rounds of bidding would occur, they would have less incentive to bid competitively in the initial round.

4. Bid caps. Bid caps are based on an estimate of a parcel's agricultural rental value (its Soil Rental Rate (SRR)), and can have several powerful effects on the CRP. The CRP's bid cap is meant to prevent excessive rental payments. However, bid caps are not perfect measures of opportunity cost, and their use can have several undesirable side effects:

    i. Landowners with parcels that are likely to be accepted (such as highly erodible land) are likely to place a bid equal to the bid cap—they have little incentive to ask for less.

    ii Furthermore, landowners whose offers are likely to be accepted have little incentive to install EBI-improving practices (such as wildlife-friendly cover).

    iii. Landowners, regardless of their EBI scores, are highly unlikely to offer their land if the bid cap is less than their opportunity costs (i.e., what they could earn from their usual farming activities). As a result, even if their land would be more valuable (say, on a bene-fits-per-dollar basis) to the program than other land that is accepted into the program, the bid cap means these parcels will not be available to program managers for evaluation or selection.

For more information on these potential problems, see the box, "Drawbacks of the Bid Cap." Possible solutions to these bid cap issues and their effects on program participation, cost, and environmental quality are in the "Experiments on Auction Performance Using Alternative Designs" chapter of this report.

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[21] General signups happen nearly every year. Parcels offered but not accepted in one year can be resubmitted in other years, with the same or different bids. Thus, the impact of the single general signup is ameliorated by the possibility of trying again in another year. Continuous signups, which are noncompetitive and target particularly valuable practices or resource concerns on relatively small parcels, are also used to enroll about 20 percent of Conservation Reserve Program acreage.

Box: Drawbacks of the Bid Cap

Bid caps can prevent excessive overpayment, but they have several drawbacks. We consider three side effects, as mentioned in the report.

Point (i) notes that landowners whose probability of acceptance is high will ask for their bid cap, even if it is well above their opportunity costs. Thus, for parcels that are likely to be accepted—perhaps because they are highly erodible and have low soil productivity—the cap may limit excess profit, but may not eliminate it.[1] This tendency can be illustrated by examining the *automatic* EBI points of actual CRP contracts.[2] These are points a parcel will receive regardless of what the landowner chooses to ask for—they are points that are not affected by the landowner's asking price or the conservation practice the landowner commits to installing. Since parcels with a high number of automatic points are more likely to be accepted, they can be offered with a higher bid than other parcels (all else being equal).

Figure: Underbidding and automatic points

Underbid %, and % with no underbid

Automatic points (normalized)
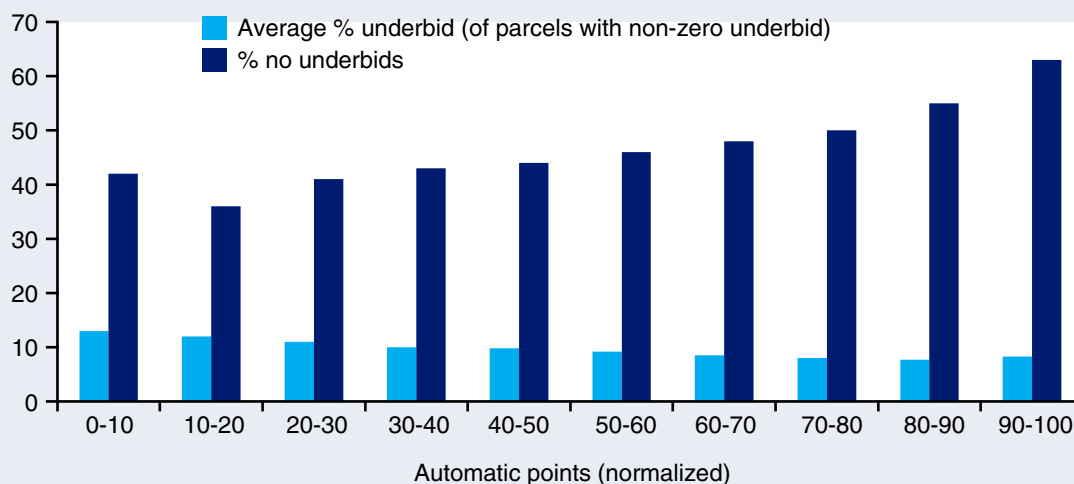
Notes: Each bar represents 10 percent of the offers, where offers are grouped by the normalized automatic points. Automatic points range between 0.1 and 0.89; with a 5-percent to 95-percent range of 0.25 to 0.57. The average percent underbid is for parcels with nonzero underbids.
Source: USDA, Economic Research Service using confidential program data from USDA, Farm Service Agency, Conservation Reserve Program, 1995-2013.

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[1] Prior research (Kirwan et al., 2005) estimated that between 10 percent and 40 percent of Conservation Reserve Program expenditures were due to information rent (bids higher than the landowner's reservation price).

[2] Automatic Environmental Benefits Index (EBI) points are awarded based on a parcel's characteristics, including the erodibility of the land, whether it is located in a wildlife priority or a water quality area, and it's Soil Rental Rate (SRR). All other things being equal, parcels with low SRRs will have more automatic EBI points—since they cannot ask for a high bid, the EBI cost factor (that awards more points the lower the bid) will always be large.

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Box: Drawbacks of the Bid Cap—continued

An examination of CRP contracts confirms this tendency. A 1-percent increase in automatic points will, on average, reduce a parcel's underbid (the difference between the bid and the bid cap) by about 0.12 percent (appendix 2). The figure illustrates that, as automatic points increase, the fraction of participants underbidding decreases, as does the average size of underbids.

Point (ii) notes that landowners with a high probability of acceptance have little motivation to improve their EBI scores by installing higher scoring (but more expensive) conservation practices.[3] If the extra environmental benefits provided by better practices are worth the installation costs, both the landowner and the Government would be better off if the practice was installed.[4] The automatic points of actual CRP contracts can be used to investigate how offer quality is affected by the probability of acceptance. A 1-percent increase in automatic points will, on average, lead to a roughly 0.3-percent reduction in EBI points due to less environmentally beneficial conservation practices being offered (appendix 2).

Last, and most importantly, point (iii) notes how bid caps can negatively affect participation rates. If seller-specific bid caps are set too low, many suppliers of conservation services may not offer their land for enrollment at all. For example, if the bid cap is set equal to the median opportunity cost of potential bidders, half of potential participants will not place offers, even though their parcels may have high environmental values (as reflected in their EBI scores).[5] This will reduce competition among remaining sellers and force the buyer to accept potentially higher bids to meet his goals. As a result, it is quite possible that accurate, but not perfect, bid caps will increase expenditures. For example, Hellerstein and Higgins (2010) present a numerical example illustrating how very accurate, but not perfect, bid caps can have perverse results. They compare expenditures required to achieve an acreage target to expenditures when a less accurate bid cap, that is always noticeably greater than opportunity costs, is used. They find that costs are 48 percent higher in the first (very accurate bid cap) case.

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[3] For example, rather than using an inexpensive grass cover to prevent erosion, a more costly cover could prevent erosion and also provide high-quality wildlife habitat. Given the USDA's traditionally non-adversarial relationship with farmers, enrollment mechanisms that induce landowners to improve the environmental quality of land enrolled in conservation programs, even without an overall reduction in Government expenditures, may be of great interest.

[4] The money that would be spent on better practices does not disappear—it could go to enroll additional acreages. However, a parcel with a superior practice may be worth more than the additional parcel(s) that could have been obtained. Thus, the drawback of bid caps discouraging installation of better practices matters the most when the environmental value of foregone practices exceeds the marginal environmental benefit of obtaining additional parcels (on a per dollar basis).

[5] If landowners are risk-neutral profit maximizers, and each parcel's Soil Rental Rate is an accurate measure of the median opportunity cost of observationally equivalent parcels, then half of the parcels will have a bid cap that is below their actual opportunity cost. Since landowners of these "higher than bid cap" valued parcels would be financially worse off if their parcels were enrolled, they will not offer them to the Conservation Reserve Program.

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Auction Design Alternatives

If cost differences are unobservable to the buyer, the buyer cannot effectively differentiate between sellers; consequently, sellers with very low costs gain much more than other sellers do, especially in a repeated auction where low-cost sellers can better estimate the highest price they can ask for and still have their offer accepted. However, if the buyer has some indication of which sellers have low costs and which have high costs, the buyer can adjust the auction scheme so that low-cost sellers bid less than they otherwise would.

One way to pay different prices to different sellers is to impose seller-specific bid caps that vary according to observed indicators of the seller's cost—such as the SRR used by the CRP. However, as discussed above, tight bid caps have a number of drawbacks. Relieving some of these drawbacks (say, by using an across-the-board increase in bid caps to increase participation) can increase other problems (such an increase in bid caps could end up paying landowners more to do the same thing).

There are other strategies to obtain lower bids from low-cost sellers. A ranking system could narrow the advantage of low-cost sellers when offers are scored and ranked. Low-cost sellers would then face stiffer competition from higher cost sellers who would otherwise be uncompetitive. For example, sellers from areas with higher rental rates might be assigned additional EBI points, or their asking prices could be discounted.[22]

Alternatively, a reference-price auction could assign a nonbinding estimate of value (a reference price) to each parcel of land, with bids ranked relative to the reference price.[23] For example, holding environmental quality constant, a bid of $20 submitted to enroll land with an estimated value of $20/acre would receive a score of 1, while a bid of $20 submitted to enroll land with an estimated value of $30/acre would receive a higher (more competitive) score of 1.5 (i.e., 30/20). Landowners placing bids from lower cost areas (e.g., areas with lower reference prices) would then have an incentive to boost their scores by lowering their bids.[24]

Both ranking systems and reference prices increase the probability that some low-cost sellers will not be accepted and that a high-cost seller might win instead. This feature is meant to induce low-cost sellers to make offers closer to their opportunity cost. In other words, these mechanisms threaten to accept high-cost sellers—sellers that an open auction would not be likely to accept. When successful, such a threat will cause low-cost bidders to submit lower bids, compensating for the increased acceptance of higher cost bidders and thus reducing total costs.

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[22] In bid-preference auctions, accepted offers are paid their bid. However, when determining who to accept, certain *qualified* sellers are preferred. For example, a qualified seller (such as sellers from a designated locale) might be chosen if his or her bid is within 5 percent of the lowest unqualified bid (Krasnokutskaya and Seim, 2011; Marion, 2009). Thus, all things being equal, offers from a qualified seller are more likely to be accepted.

[23] A reference-price auction was selected by the U.S. Treasury to purchase toxic assets under the Troubled Asset Relief Program (TARP) legislation during the 2008 financial crisis. Reference-price auctions have been the subject of substantial theoretical and experimental work; see Ausubel et al. (2014) or Armantier et al. (2010). Armantier (2013) also presents a succinct summary of reference-price auctions.

[24] The Maryland Agricultural Land Preservation Foundation uses what amounts to a reference price in its procurement system. An independent audit is conducted for each parcel under consideration, a valuation estimate is produced, and all bids are normalized by their valuation estimate (Horowitz et al., 2009).

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Quota auctions offer another strategy by limiting the number of offers accepted from any group having similar observed characteristics.[25] In an agricultural conservation context, groups could consist of contiguous counties with similar agricultural productivity—in other words, all eligible land within a group will have similar opportunity costs.[26] For example, in a program like the CRP, administrators might limit acceptances to 90 or 95 percent of all offers from any given county (or a USDA crop-reporting district), or place a limit on the absolute number of contracts or acres that can come from this group. Without the limit, landowners in a low-cost group (e.g., a crop-reporting district where agricultural productivity is less than the national average) can submit offers that far exceed their opportunity cost and still be confident of acceptance. A limit on the number, or share, of offers accepted would force landowners to compete with other landowners in their low-cost group, rather than with those (in other groups) with higher costs.[27] This kind of auction can only be used in a multiple-unit setting when there are clear observable differences between sellers, and an ability to readily assign sellers to a group (as is typically the case when buying conservation services across a broad landscape).

Depending on the particular situation, these alternative auction designs might significantly reduce the buyer's costs of procurement.[28] Alternatively, auction design can affect conservation policy goals beyond cost minimization. An auction mechanism that increases costs may be more costly on a per acre basis, but it may lead to a greater provision of environmental services—i.e., a sole focus on cost savings may fail to take advantage of opportunities to substantially increase ecosystem services (from better practices on the same total acreage). For example, even a well-designed bid cap for CRP offers may fail to incentivize low-cost sellers to improve their offers (say, by installing a wildlife-friendly cover practice).

However, any auction mechanism entails tradeoffs. For example, although the CRP's use of parcel-specific bid caps can dissuade participation by low-cost sellers who happen to have bid caps below their opportunity costs, bid caps do limit the amount of extra profit any one seller can obtain. Any plausible quota auction or reference-price auction necessitates accepting some high-cost sellers, which may more than offset savings from lower bids by low-cost sellers. Moreover, these auctions can also influence the distribution of benefits across sellers. In comparison to a standard open auction that treats all bids at face value, low-cost sellers would often gain less, and high-cost sellers would occasionally gain more (even though overall costs to the Government may decrease) in these alternative auctions.

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[25] What we refer to as a quota is similar to what some in the auction literature call set-asides. Often used in Government procurement (Ayres and Cramton, 1996) for both purchasing and selling multiple units, set-asides reserve some quantity to be won by qualified sellers. Qualified sellers are selected based on observable characteristics, often race or business size. While set-asides are often meant to promote social goals by encouraging participation by a minority class of sellers, they may also increase competition in an auction and enhance the outcome from the buyer's perspective (Milgrom, 2004).

[26] Well-constructed groups will minimize within-group variation of opportunity costs.

[27] In particular, when there is no quota, landowners in a low-cost group are likely to set their bid close to their estimate of the highest accepted bid. This means that they choose bids that are competitive with landowners in higher cost groups.

[28] In the case of the Conservation Reserve Program, this would mean reducing the total cost of retiring a given number of acres without reducing environmental benefits.

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Experiments on Auction Performance Using Alternative Designs

Given the complexity of conservation programs—with their variety of potential participants that have partially observable reservation prices—theoretical models that can predict the performance of different enrollment mechanisms are often unavailable. Even when theory exists, its predictions may depend on the specific characteristics of the pool of potential participants. Thus, economic experiments are often used to investigate the performance of alternative auction mechanisms.

A number of economic experiments on conservation auctions have investigated the effectiveness of auction design. One line of inquiry focuses on selection under asymmetric information with parcel and landowner heterogeneity. Theoretical (Wu and Babcock, 1996; Smith, 1995) and experimental work (Arnold et al., 2013) indicate that heterogeneity generates a systematic tendency for landowners of lower quality parcels to make offers that yield substantial information rents (extra profits due to information on the attributes of their land known only by the landowner).

A second area of experimental investigation compares the performance of discriminatory auctions with fixed-price procurement. Generally, discriminatory auctions outperform uniform-price auctions (Cason and Gangadharan, 2004; Schilizzi and Latacz-Lohmann, 2007). There is concern, however, that this advantage dissipates over time as participants gain experience (Hailu and Schilizzi, 2004).

A third area of inquiry is the role of public and private information in conservation auctions. The depth of information about the goals and budget of the buyer, and the costs and preferences of possible participants in an auction, can affect auction outcomes in a variety of ways. The impacts of information on auction outcomes have been explored in a number of experimental studies. For example, Cason et al. (2003) find that sellers' rents increase as they gain experience and garner more information about demand and seller heterogeneity. They also find that sellers tend to inflate their requested payments more for projects with a high value to the buyer. Consequently, less information about buyer value may increase auction efficiency. Messer et al. (2013) find that, for a discriminatory reverse auction, a limited-information setting leads to greater market efficiency than either no-information or full-information settings (i.e., providing just the right amount of information can encourage market competition while limiting market manipulation).

While the existing literature on experimental studies is informative, it is far from complete. In particular, it does not address the effectiveness of enrollment mechanisms that use available information with asymmetric sellers. To examine these kinds of questions, we review findings from experimental studies conducted by ERS and academic researchers on the effectiveness of bid caps, quota auctions, and reference-price auctions in improving auction performance. The box, "Basic Factors of Experimental Design," highlights design decisions that experiments should consider.

Bid Cap Experiment

Hellerstein and Higgins (2010) considered the impact of bid caps, such as the CRP's SRR. To simulate a population with asymmetric potential program enrollees, participants in the experiment were

Box: Basic Factors of Experimental Design

Economic experiments for policy and behavioral research have become popular over the last few decades. Economic experiments can provide replicability, laboratory controls, and the ability to incorporate incentives. Experiments can provide insights into policy options, as well as test and further develop theories of human economic behavior.[1]

The specific details of an experiment's design can be important. For example, in many lab experiments, individual subjects are provided with real-money payments that are dependent upon outcomes in the experiment.[2] How high should compensation be to induce realistic behavior (that is, behavior that is representative of behavior outside the lab)? How should the experiment be presented—i.e., what is the proper mix of text, visual tools, and verbal instruction? Does the setting matter—i.e., does behavior depend on where the experiment takes place, such as remotely in one's home, in a university's specialized laboratory, or in a community meeting hall?

A well-designed experiment considers these and other factors; the goal of proper experimental design is to create a cost-effective experiment that allows the experimenter to learn by evaluating hypotheses. For example, laboratory experiments tend to be inexpensive and relatively easy to design. In contrast, large-scale field experiments—experiments that take place in the context of a Government program or policy—can be very expensive. The quality of the information obtained by the two methods is not uniform, of course. While a lab experiment is capable of providing the researcher with feedback on how subjects respond immediately to small-stakes financial risk, lab experiments cannot determine the long-term effects of CRP participation on an individual's well-being.

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[1] Shogren (2004, p. 1218) described the process as being "like a wind tunnel to test airplane design, lab experiments provide a test bed for what is called *economic design*—the process of constructing institutions and mechanisms to examine resource allocation."

[2] See Smith (1976) and Smith (1982) for details of using induced-value theory to conduct lab experiments.

endowed with tickets of different types.[29] Each ticket type differed in its range of costs.[30] During each round, participants could offer their tickets for sale by choosing an asking price and selecting a level of quality improvements. If accepted, the participant receives the difference between the asking price and the costs (including the costs of providing the selected level of quality).

In line with the theoretical results, these experiments found that stringent bid caps (where 20 percent of tickets have costs greater than their bid cap) significantly reduced performance as many low-cost

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[29] This was a context-free experiment using induced values rather than one where endogenous (or home-grown) values occur. Context free means that neutral language was used, with no mention of agriculture or environmental quality. An equivalent experiment using landowners could introduce context by asking participants to consider "offering cropland parcels, with these characteristics, to a land-retirement program" rather than consider "offering your tickets, with this cost, to a computer."

[30] For example, the ticket cost of a participant with a type A ticket would be between $10 and $30, while the cost of someone with a type B ticket would be between $25 and $50.

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sellers with bid caps below actual cost chose not to make offers. Performance was best when 90 percent of tickets had bid-cap costs greater than their costs (so 10 percent could not be profitably offered). When quality improvements are valued as much as cost minimization, a bid cap equal to the maximum cost of a ticket of that type could yield the most effective results; higher bid caps encourage more participants to ask for more money and increase their quality commensurately. In fact, very high bid caps (twice the ticket-type maximum) yielded performance similar to the stringent bid cap scenario.

These results suggest that using average rental rates (e.g., the CRP's SRR) as a bid cap—which implies that 50 percent of parcels will have agricultural returns that are above the bid cap—may be counterproductive. Instead, a bid cap that is set high—say, equal to an estimate of the maximum cost across all potential participants—could be better. However, alternative design mechanisms (such as quota or reference-price auctions) may function even better than a well-constructed bid cap.

Quota Auction Experiment

Quota auctions group together sellers based on their observable features, and a fraction of each group—those with the highest bids—are rejected. Higgins et al. (2014) compared discriminative auctions to a quota auction. They began by applying a theoretical model to simulate auction performance under different conditions (such as the distribution of underlying costs).[31] As expected, their results suggest that low-cost sellers extract information rents because of the observable heterogeneity of high-cost sellers. They found that, in a quota auction (with the highest bid of each type automatically rejected), low-cost sellers significantly lower their bids while high-cost sellers slightly inflate their bids.[32] This illustrates a general finding (McAfee and McMillan, 1987) that the returns to enforcing a small bit of competition, by creating artificial scarcity, are highest when the amount of competition starts out low, as it does among the low-cost sellers in auctions without a quota.[33]

Experiments confirm these results. As described in appendix 1, laboratory experiments were conducted that looked at open auctions and quota auctions. In each session, five participants were given a low-cost ticket, and five were given a high-cost ticket. Each ticket type is characterized by a cost range and each ticket's cost pulled from this range. Participants knew the cost ranges of each type, but did not know the costs of other participants' tickets. Around 50 percent of offers were accepted, with accepted offers paid their bid (e.g., the auction was discriminative).

Figs. 2 and 3 graph the relationship between bids and ticket costs across a number of experimental sessions. If sellers bid to provide environmental services at just their actual cost, then the points should fall on the 45-degree (Cost=Bid) line. Bids that are above costs (that yield information rents) lie above the 45-degree line. Under a hypothetical, perfectly cost-effective auction design, offers would be equal to cost, so all points would be clustered along a 45-degree line from the origin. The vertical distance between the 45-degree line and the actual bid is a measure of information rents

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[31] Higgins et al. (2014) used the Constrained Strategic Equilibrium method to closely approximate equilibrium bidding behavior. In general, theory-based predictions of auction outcomes become intractable as auction complexity increases (which occurs when participants have asymmetric costs). Hence, numerical solutions are of interest.

[32] To be credible, a quota auction should accept some high-cost sellers even if their bids are greater than a rejected low-cost seller's bid. Since this increases the odds of acceptance of high-cost sellers, high-cost sellers may submit somewhat higher bids as a side effect.

[33] Technically, the returns-to-competition function is often concave—e.g., adding an additional seller is more valuable when there are 3 sellers than when there are 300.

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Figure 2
Auction bids versus seller costs: Results of open auctions
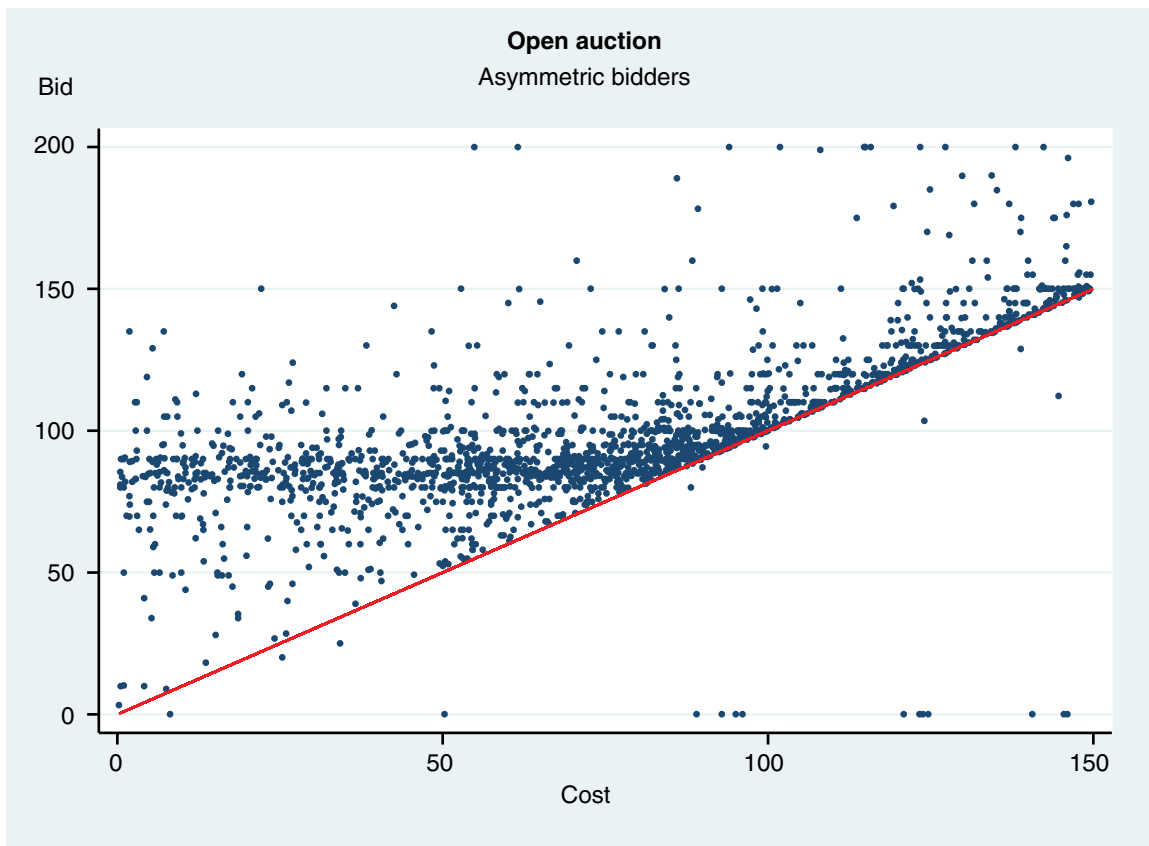
Note: 45-degree line is cost=bid.
Source: USDA. Economic Research Service.

accruing to ticket owners. In particular, given that only a fraction of offers are accepted, the sum value of this distance in the lowest bids is a measure of cost-effectiveness.

The results of the standard open (discriminative) auction (fig. 2) illustrate the behavior of low-cost sellers. Because low-cost sellers have a high probability of acceptance, they bid proportionally higher above their costs—the lower a seller's cost, the higher the economic profits. Due to this, the bids of low-cost sellers tend to be clustered around a horizontal line equal to the approximate maximum accepted bid.[34] However, due to the extra competition introduced by the quota (fig. 3), low-cost bids tend to be clustered closer to the 45-degree line. Low-cost sellers still bid on a horizontal line but this line has shifted down substantially in comparison to the open auction.

Fig. 4 plots estimated bidding functions using the data displayed in figs. 2 and 3, differentiated by ticket type (type A tickets have lower average cost, type B tickets have higher average cost). Significantly, type A ticket holders (low-cost sellers) submit lower bids during quota auctions than during open auctions.

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[34] This clustering is likely due to the multiple-round nature of the experiment. Participants could use the publically reported cutoff (highest accepted) bid in prior rounds to predict the likely cutoff bid in the current round, and set their bids accordingly (i.e., near this prediction).

Figure 3
Auction bids versus seller costs: Results of quota auctions

Quota auction
Asymmetric bidders
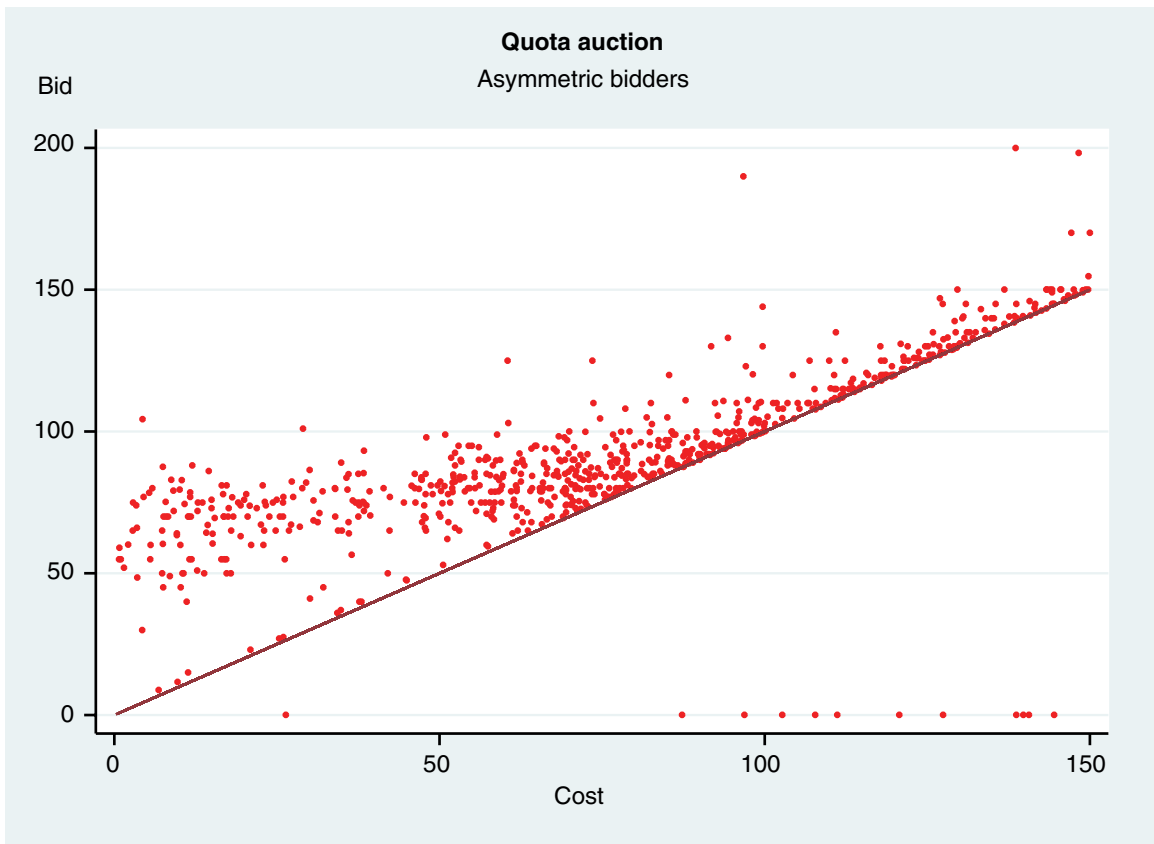
Note: 45-degree line is cost=bid.
Source: USDA, Economic Research Service.

These findings suggest that quota auctions are more cost effective than open auctions—low-cost sellers are incentivized by competitive forces to bid closer to their costs, while high-cost sellers don't change their bids by much, resulting in aggregate program savings. When estimated across all the experimental sessions, the procurement cost of quota auctions was 8.7 percent less than in the open auctions (which is greater than the 4.1-percent reduction the theoretical model predicted in appendix 1). These results suggest that, if between-group heterogeneity is sufficiently high, substantial savings can be achieved by imposing quotas. Further, if between-group heterogeneity is relatively low, total procurement cost is unlikely to increase by a substantial amount through a quota.

Reference-Price Auction Experiment

In reference-price auctions, a nonbinding estimate of value (a reference price) is assigned to all potential offers, with offers ranked based on the difference between the asking price and the reference price. The potential benefits and costs of reference-price auctions were also examined in a set of experiments (appendix 1). Compared to the quota experiments discussed above, a greater variety of types of sellers were used (low cost, high cost, and a high- and low-variance medium cost). Furthermore, participants were able to improve the quality of their offers as well as choose an asking price. This feature attempts to mimic programs like the CRP, where mere enrollment in a program is not the whole story—the benefits from conserving a given parcel can be enhanced.

Figure 4
Bidding functions based on figs. 2 and 3

Predicted bid
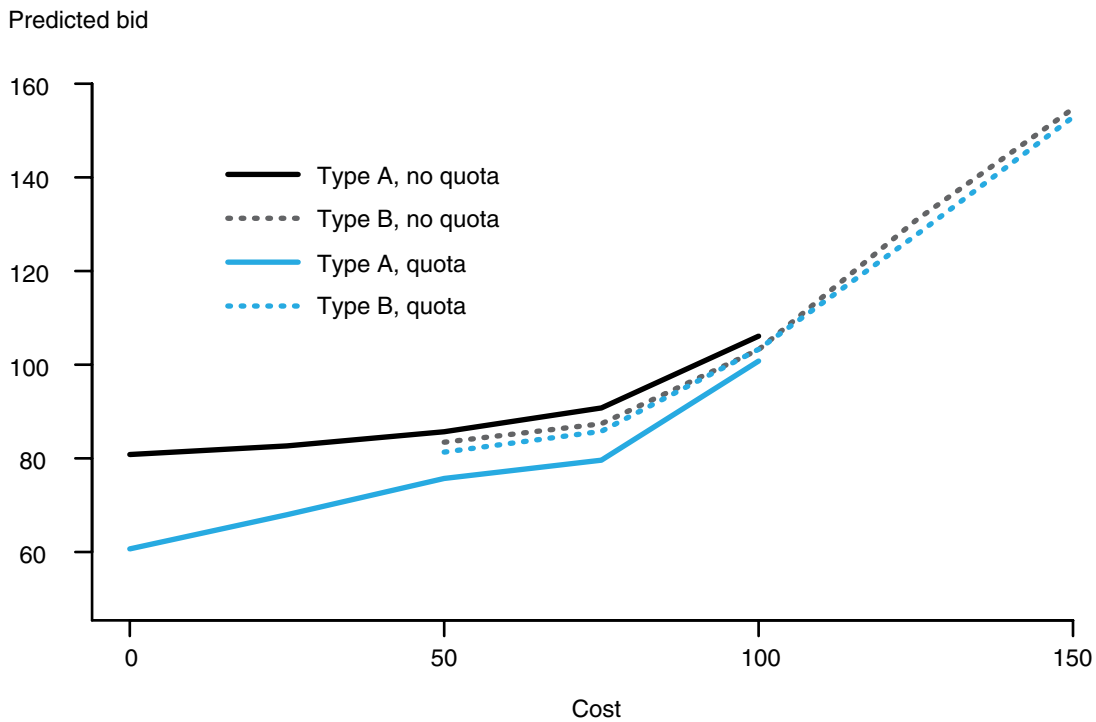
Source: USDA, Economic Research Service.

The distribution of average costs and average profits within each experimental round are in fig. 5. The line graphs suggest that the reference price and quota auctions are more cost effective than the open (discriminative) auction—the average profit rates tend to be lower (lower values of the profit rate imply more cost-effective results).

A more rigorous test is provided by regression analyses that compare performance across different treatments. Several types of regressions were performed using both average profit for accepted offers and expenditure efficiency, which compares actual expenditures to a full-information theoretical minimum (that is, to a world where the purchaser could obtain all desired parcels at cost).[35]

The regressions found that cost savings from the reference price and quota auctions were statistically significant. The simplest model (a linear regression using treatment dummies) predicts that the reference-price auction has 18 percent lower (hence better) *expenditure efficiency* than an open auction, while the quota auction is 14 percent better (table A1.4). Similarly, when considering average profit per offer (which abstracts from quality improvements), the reference price is predicted to have $10.50 less in average profit per offer than the open auction, while the quota auctions yield an average profit that is $7.70 lower. Other models, such as panel models and difference-in-differ-

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[35] Expenditure efficiency is the ratio of actual expenditures over full-information expenditures. Full-information expenditures are what would be paid if the purchaser offered an amount exactly equal to the seller's cost, and all participants were willing to make offers at this amount. Thus, values close to 1.0 signal a more cost-effective auction. Average profit is the average profit made on each accepted offer, so lower values imply better cost-effectiveness. Note that expenditure efficiency incorporates the ability of participants to change the quality of their offers.

Figure 5
Average profit and cost in open, quota, and reference-price auctions

Round by round results: Average cost and profits for three auction mechanisms

Legend: ■ Average cost ■ Average profit

Dollars

Standard auctions   Reference-price auctions   Quota auctions

Round by round results: Profit rate for three auction mechanisms

Profit rate

Standard auctions
(average profit rate = 61)

Reference-price auctions
(average profit rate = 43)

Quota auctions
(average profit rate = 47)

Notes: The upper three plots show the per-round average cost of accepted offers (in red) and the average profit for each accepted offer (in purple) for three kinds of auction: open (discriminative), reference price, and quota auctions. The lower three plots show the average profit rate—defined as average profit divided by the average cost.
Source: USDA, Economic Research Service.

ence models (that compare differences between rounds to control for the unobservable attributes of participants—see appendix 1) yielded similar, though slightly smaller, results.

By way of comparison, consider the overall results if these mechanisms had been used to enroll the CRP's 19.7 million general signup acres (as of September 2014) and the per-acre cost reductions suggested by these experiments were realized. With annual rental payments of $1.007 billion (circa September 2014), a reference-price mechanism that reduced costs by 18 percent would yield a $181-million reduction in program expenditures, while a quota auction that reduced costs by 14 percent would yield a $141-million reduction.

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Conclusion

Auctions offer an appealing means of choosing whom to enroll in conservation programs and determine what price to pay for services provided. Auctions can lower procurement costs, increase the quality of purchased goods and services, and facilitate the design and implementation of markets for ecosystem services. Results of economic experiments, which offer a useful means of testing alternative auction design, suggest that auctions (especially discriminative auctions) can be more effective in terms of reducing costs and maximizing environmental benefits than the simpler alternatives (such as using a single fixed price). However, much of what is currently considered good design in conservation program auctions may be sub-optimal.

In particular, the CRP's use of bid caps can be improved. Bid caps can prevent large profits (they can reduce information rents) to CRP participants with low-valued agricultural land that is highly erodible (e.g., land that will have a high EBI). However, an improperly set bid cap can reduce program participation, dissuading submission of offers for parcels targeted by the program (such as highly erodible parcels that have a greater agricultural value than the bid cap's assessment). Use of this auction mechanism can lead to higher costs and discourage improvements of land from parcels that are likely to be accepted at the bid cap, since costly improvements in quality cannot be compensated for by increasing the asking price.

Auction mechanisms that leverage observable information to discriminate among participants may improve the cost-effectiveness of conservation programs. Examples of these include quota auctions, which group similar participants together, and reference-price auctions, which relax the bid cap. In quota auctions, a fraction of each group is rejected in the first stage—this can induce competition between low-cost participants but requires accepting more high-cost participants. Reference-price auctions allow asking prices to be greater than the buyer's estimate of the seller's opportunity cost.[36] As a result, low-cost sellers are never fully excluded and they have an incentive to improve quality. The net effect, however, may be an increase in program costs if the increased competition is insufficient to deter all auction participants from increasing their bids.

Any auction mechanism involves tradeoffs. Economic experiments offer a means of testing the efficacy of alternative designs. A series of lab experiments, using university students, demonstrate that stringent bid caps could reduce auction performance as many low-cost sellers chose not to make offers. They also show that quota and reference-price mechanisms could improve program cost-effectiveness in scenarios where participants can choose both an asking price and make quality improvements to their offers. In particular, experiments using quota and reference prices yield improvements in quality-adjusted cost-effectiveness that range between 14 and 18 percent.

These experiments also indicate that, when considering auction design for an actual program, the degree of heterogeneity in costs and environmental benefits, the ability to accurately measure opportunity costs, and the extent to which the competitive behavior of the target population is not well represented by student participants in a laboratory all matter. Further experiments could yield different results, such as experiments that use a more representative sample (i.e., with rural landowners), that use an instrument that more closely resembles how decisions would be made, and that involve cost and benefit measures more reflective of agricultural profitability. Even after thorough

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[36] In a sense, reference prices are weak bid caps—the seller can ask for more but will be penalized.

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laboratory testing, field tests where actual decisions are made about the resource (e.g., land retirement) in question may be a suitable (albeit more expensive) next step.

The literature review and experimental results presented in this study illustrate and highlight the potential effects of alternative auction designs rather than offer firm policy guidance. Policy guidance would require a much broader set of experiments that consider a number of variations in both design and underlying population characteristics.

References

Armantier, O. January 2013. "A "Reference Price Auction" to Buy or Sell Different Assets Simultaneously," *Liberty Street Economics*, Federal Reserve Bank of New York. http://libertys-treeteconomics.newyorkfed.org/2013/01/a-reference-price-auction-to-buy-or-sell-different-assets-simultaneously.html#.U5G3CXJdVy5 (accessed July 2014).

Armantier, O., C. A. Holt, C. R. Plott. 2010. *A Reverse Auction for Toxic Assets*, Social Science Working Paper 1330, California Institute of Technology. http://authors.library.caltech.edu/20207/1/sswp1330.pdf (accessed July 2013).

Arnold, M., J. M. Duke, and K. D. Messer. 2013. "Adverse Selection in Reverse Auctions for Ecosystem Services," *Land Economics* 89(3):387-412.

Ashenfelter, O. 1989. "How Auctions Work for Wine and Art," *The Journal of Economic Perspectives* 3(3):23-36.

Asker, J., and E. Cantillon. 2008. "Properties of Scoring Auctions," *The RAND Journal of Economics* 39(1):69-85.

Athey, S., J. Levin, and E. Seira. 2011. "Comparing Open and Sealed Bid Auctions: Evidence from Timber Auctions," *Quarterly Journal of Economics* 126(1):207-57.

Athey, S., P. Cramton, and A. Ingraham. 2002. *Auction-Based Timber Pricing and Complementary Market Reforms in British Columbia,* MDI Report for British Columbia Ministry of Forests. http://works.bepress.com/cramton/119 (accessed July 2014).

Ausubel, L., P. Cramton, E.-F. Ozbay, N. Higgins, E. Ozbay, and A. Stocking. 2014 (Scheduled). "Common-Value Auctions with Liquidity Needs: An Experimental Test of a Troubled Assets Reverse Auction," in *Handbook of Market Design*, Z. Neeman, A. Roth, and N. Vulkan, eds. Oxford: Oxford University Press.

Ayres, I., and P. Cramton. 1996. "Deficit Reduction Through Diversity: How Affirmative Action at the FCC Increased Auction Competition," *Stanford Law Review* 48(1996):761-815. http://works.bepress.com/cramton/75 (accessed July 2014).

Back, K., and J. F. Zender. 1993. "Auctions of Divisible Goods: On the Rationale for the Treasury Experiment," *The Review of Financial Studies* 6(4):733-64.

Bajari, P., and A. Hortacsu. 2003. *Economic Insights from Internet Auctions: A Survey*, NBER Working Paper Series 10076, National Bureau of Economic Research, Cambridge, MA.

Bajari, P., and A. Hortacsu. 2003. "The Winner's Curse, Reserve Prices, and Endogenous Entry: Empirical Insights from eBay Auctions," *The RAND Journal of Economics* 34(2):329-55.

Beshears, J., J. Choi, D. Laibson, and B. Madrian. 2013. "Simplification and Saving," *Journal of Economic Behavior and Organization* 95:130-45.

Campbell, C., and D. Levin. 2006. "When and Why Not to Auction," *Economic Theory* 27(3):583-96.

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Options for Improving Conservation Programs: Insights From Auction Theory and Economic Experiments, ERR-181
Economic Research Service/USDA

Cason, T.N., and L. Gangadharan. 2004. "Auction Design for Voluntary Conservation Programs," *American Journal of Agricultural Economics* 86(5):1211–17.

Cason, T., L. Gangadharan, and C. Duke. 2003. "A Laboratory Study of Auctions For Reducing Non-Point Source Pollution," *Journal of Environmental Economics and Management* 46(3):446–71.

Coase, R. H. 1959. "The Federal Communications Commission," *The Journal of Law & Economics* 2:1-40. http://old.ccer.edu.cn/download/7874-1.pdf (accessed July 2014).

Congdon, W., J. Kling, and S. Mullainathan. 2011. *Policy and Choice: Public Finance Through the Lens of Behavioral Economics*, Brookings Institution, Washington, D.C. http://www.brookings.edu/~/media/Press/Books/2011/policyandchoice/policyandchoice_book.pdf (accessed July 2014).

Corrigan, J., A. C. Drichoutis, J. L. Lusk, R. M. Nayga, Jr., and M. C. Rousu. 2011. "Repeated Rounds with Price Feedback in Experimental Auction Valuation: An Adversarial Collaboration," *American Journal of Agricultural Economics* 94(1):97-115.

Cramton, P. 1998. "Ascending Auctions," *European Economic Review* 42(3–5):745-56.

Cummings, R., and C. Holt. 2004. "Using Laboratory Experiments for Policymaking: An Example From The Georgia Irrigation Reduction Auction," *Journal of Policy Analysis and Management* 23(2):341-63.

Depiper, G. S., N. Higgins, D. W. Lipton, and A. Stocking. 2013. "Auction Design, Incentives, and Buying Back Maryland and Virginia Crab Licenses," *Canadian Journal of Agricultural Economics/Revue Canadienne d'Agroeconomie* 61(2):353-70.

Douglas D. D., and C. A. Holt. 1992. *Experimental Economics.* Princeton: Princeton University Press.

Eigenraam, M. 2005. *EcoTender: Paying for Ecosystem Services, not Lemons,* The Ecosystem Marketplace: A Forest Trends Initiative. http://www.ecosystemmarketplace.com/pages/dynamic/article.page.php?page_id=3947&section=home&eod=1 (accessed July 2014).

Eigenraam, M., C. Beverly, G. Stoneham, and J. Todd. 2005. *Auctions For Multiple Environmental Outcomes, From Desk to Field in Victoria, Australia*, Energy and Earth Resources, Department of State Development, Business and Innovation, Victoria, Australia. http://www.energyandresources.vic.gov.au/about-us/publications/economics-and-policy-research/2005-publications/auctions-for-multiple-environmental-outcomes,-from-desk-to-field-in-victoria,-australia (accessed July 2014).

Ferraro, P. J. 2008. "Asymmetric Information and Contract Design for Payments for Environmental Services," *Ecological Economics* 64(4):810-21.

Filippos, E., A. M. Espin, and P. Brañas-Garza. 2013. "Experimental Subjects are Not Different," *Scientific Reports* 3(1213). http://www.nature.com/srep/2013/130214/srep01213/full/srep01213.html (accessed July 2014).

Fuerbringer, J. 1992. "Credit Markets; New Process For Auctions To Be Tested," *The New York Times*. http://www.nytimes.com/1992/09/04/business/credit-markets-new-process-for-auctions-to-be-tested.html?module=Search&mabReward=relbias%3Ar (accessed July 2014).

Hailu, A., and S. Schilizzi. 2004. "Are Auctions More Efficient Than Fixed Price Schemes When Offerers Learn?" *Australian Journal of Management* 29(2):147-68.

Hamilton, J. 2010. *Conserving Data in the Conservation Reserve: How A Regulatory Program Runs on Imperfect Information*, Resources for the Future, Washington, DC.

Hellerstein, D. 2012. "Conservation Reserve Program: Status and Trends," in *Agricultural Resources and Environmental Indicators, 2012,* EIB-98, U.S. Department of Agriculture, Economic Research Service. http://www.ers.usda.gov/media/874175/eib98.pdf (accessed July 2014).

Hellerstein, D., and N. Higgins. 2010. "The Effective Use of Limited Information: Do Offer Maximums Reduce Procurement Costs in Asymmetric Auctions?" *Agricultural and Resource Economics Review* 39(2):288-304.

Herriges, J., and C. Kling. 1999. *Valuing Recreation and the Environment*. Northhampton, MA: Edward Elgar Publishing.

Herzel, L. 1951. "Public Interest and the Market in Color Television Regulation," *University of Chicago Law Review* 18(1951):802-16.

Higgins, N., M. Roberts, and D. Hellerstein. 2014. *Using Quotas to Enhance Competition in Asymmetric Auctions: A Comparison of Theoretical and Experimental Outcomes*, Working Paper No 14.9, Department of Economics, University of Hawai`i at Manoa. http://www.economics.hawaii.edu/research/workingpapers/WP_14-9.pdf (accessed July 2014).

Horowitz, J., L. Lynch, and A. Stocking. 2009. "Competition-Based Environmental Policy: An Analysis of Farmland Preservation in Maryland," *Land Economics* 85(4):555-75.

Kagel J., and D. Levin. 1993. "Independent Private Value Auctions: Seller Behavior in First-, Second- and Third-Price Auctions with Varying Numbers of Sellers," *The Economic Journal* 103(419):868-79.

Kagel, J., and J. Richard. 2001. "Super-Experienced Bidders in First-Price Common-Value Auctions: Rules of Thumb, Nash Equilibrium Bidding, and the Winner's Curse," *The Review of Economics and Statistics* 83(3): 408-19.

Kirwan, B., R. Lubowski, and M. J. Roberts. 2005. "How Cost Effective are Land Retirement Auctions? Estimating the Difference between Payments and Willingness to Accept in the Conservation Reserve Program," *American Journal of Agricultural Economics* 87(5):1239-47.

Klemperer, P. 2002. "What Really Matters in Auction Design," *Journal of Economic Perspectives* 16(1):169-89.

Krasnokutskaya, E., and K. Seim. 2011. "Bid Preference Programs and Participation in Highway Procurement Auctions," *American Economic Review* 10(6):2653-86.

Krishna, V. 2010. *Auction Theory: Second Edition*. London: Academic Press.

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Options for Improving Conservation Programs: Insights From Auction Theory and Economic Experiments, ERR-181
Economic Research Service/USDA

Latacz-Lohmann, U., and C. van der Hamsvoort. 1997. "Auctioning Conservation Contracts: A Theoretical Analysis and an Application," *American Journal of Agricultural Economics* 79(2):407–18.

Latacz-Lohmann, U., and S. Schilizzi. 2005. *Auctions for Conservation Contracts: A Review of the Theoretical and Empirical Literature*, Report to the Scottish Executive Environment and Rural Affairs Department.

Latacz-Lohmann, U., and S. Schilizzi. 2007. "Quantifying the Benefits of Conservation Auctions," *EuroChoices* 6(3):32-9.

Lewis, G., and P. Bajari. 2011. "Procurement Contracting with Time Incentives: Theory and Evidence," *The Quarterly Journal of Economics* 126(3):1173-1211.

Madhavan, A., and V. Panchapagesan. 2000. "Price Discovery in Auction Markets: A Look Inside the Black Box," *Review of Financial Studies* 13(3):627-58.

Marion, J. 2009. "How Costly Is Affirmative Action? Government Contracting and California's Proposition 209," *Review of Economics and Statistics* 91(3):503–22.

McAfee, P. R., and J. McMillan. 1987. "Auctions and Bidding," *Journal of Economic Literature* 25(June 1987):699-738.

Menezes, F. M., and P. Monteiro. 2005. *An Introduction to Auction Theory.* Oxford: Oxford University Press.

Messer, K., J. Duke, and L. Lynch. 2013. "Applying Experiments to Land Economics: Public Information and Auction Efficiency in Ecosystem Service Markets," in *Oxford Handbook of Land Economics*, J. Dune and J Wu, eds. Oxford: Oxford University Press.

Mester, L. J. 1995. "There's More than One Way to Sell a Security: The Treasury's Auction Experiment," *Federal Reserve Bank of Philadelphia Business Review*, July/August:3-17.

Milgrom, P. 1989. "Auctions and Bidding: A Primer," *The Journal of Economic Perspectives* 3(3):3-22.

Milgrom, P. 2004. *Putting Auction Theory to Work*. Cambridge: Cambridge University Press.

Normann, H.-T., T. Requate, and I. Waichman. 2013. *Do Short-Term Laboratory Experiments Provide Valid Descriptions of Long-Term Economic Interactions? A Study of Cournot Markets*, Social Science Research Network. http://dx.doi.org/10.2139/ssrn.2057675 (accessed July 2014).

Ozbay, E. Y. 2007. "Auctions with Anticipated Regret: Theory and Experiment," *American Economic Review* 97(4):1407-18.

Paarsch, H. J., and H. Hong. 2006. *An Introduction to the Structural Econometrics of Auction Data*. Cambridge, MA: MIT Press.

Polasky, S., D.J. Lewis, A.J. Plantinga, and E. Nelson. 2014. "Implementing the Optimal Provision of Ecosystem Services," *Proceedings of the National Academy of Sciences of the United States*

of America 111(17): 6248-53. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4035974/ (accessed October 2014).

Rothkopf, M. 1969. "A Model of Rational Competitive Bidding," *Management Science* 15(7):362-73.

Schilizzi, S., and U. Latacz-Lohmann. 2007. "Assessing the Performance of Conservation Auctions: An Experimental Study," *Land Economics* 83(4):497-515.

Shogren, J.F. 2004. "Incentive Mechanism Testbeds: Discussion," *American Journal of Agricultural Economics* 86(5):1218–19.

Sill, D. K. 1994. "Managing the Public Debt," *Federal Reserve Bank of Philadelphia Business Review* July/August:3-13.

Smith, R.B.W. 1995. "The Conservation Reserve Program as a Least-Cost Land Retirement Mechanism," *American Journal of Agricultural Economics* 77(1995):93-105.

Smith, V. L. 1976. "Experimental Economics: Induced Value Theory," *The American Economic Review* 66(2):274-79.

Smith, V. L. 1982. "Microeconomic Systems as an Experimental Science," *The American Economic Review* 72(5):923-55.

Sommerville, M. M., J. P.G. Jones, and E. J. Milner-Gulland. 2009. "A Revised Conceptual Framework for Payments for Environmental Services," *Ecology and Society* 14(2):34. http://www.ecologyandsociety.org/vol14/iss2/art34/ (accessed July 2014).

Stoneham, G., V. Chaudhri, A. Ha, and L. Strappazzon. 2003. "Auctions for Conservation Contracts: An Empirical Examination of Victoria's BushTender Trial," *Australian Journal of Agricultural and Resource Economics* 47(4):477-500. http://www.ingentaconnect.com/content/bpl/ajar/2003/00000047/00000004/art00003 (accessed July 2014).

Stubbs, M. 2013. *Agricultural Conservation: A Guide to Programs*, Report R40763, U.S. Library of Congress, Congressional Research Service.

Thaler, R. 1988. "Anomalies: The Winner's Curse," *Journal of Economic Perspectives* 2(1): 191–202.

U.S. Department of Agriculture, Farm Service Agency. 2012. *CRP Fact Sheet, Dec 2012*. http://www.fsa.usda.gov/Internet/FSA_File/dec2012onepager.pdf (accessed July 2014).

U.S. Department of Agriculture, Farm Service Agency. 2014. *Conservation Programs, Conservation Reserve Program*. http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=crp (accessed July 2014).

U.S. Department of Agriculture, Farm Service Agency. 1995-2013. *Conservation Reserve Program, Confidential Program Data*.

U.S. Government Accountability Office. 2013. *Reverse Auctions: Guidance Is Needed to Maximize Competition and Achieve Cost Savings*, GAO-14-108.

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Van Noordwijk, M., B. Leimona, R. Jindal, G. B. Villamor, M. Vardhan, S. Namirembe, D. Catacutan, J. Kerr, P. A. Minang, and T. P. Tomich. 2012. "Payments for Environmental Services: Evolution Toward Efficient and Fair Incentives for Multifunctional Landscapes," *Annual Review of Environment and Resources Online* 37:389-420. http://www.annualreviews.org/doi/abs/10.1146/annurev-environ-042511-150526 (accessed July 2014).

Vickrey, W. 1961. "Counterspeculation, Auctions, and Competitive Sealed Tenders," *The Journal of Finance* 16(1):8-37.

Vickrey, W. 1962. "Auctions and Bidding Games," in *Recent Advances in Game Theory*, O. Morgenstern and A. W. Tucker, eds. Princeton, NJ: The Ivy Curtis Press.

The Wall Street Journal. September 4, 1992. "Treasury to Try 'Dutch' System at Its Auctions."

Wu, J., and B. A. Babcock. 1996. "Contract Design for the Purchase of Environmental Goods from Agriculture," *American Journal of Agricultural Economics* 78(November 1996): 935-45.

Appendix 1: Auction Experiments

Between 2010 and 2013, USDA's Economic Research Service sponsored a set of experiments examining quota and reference-price-auction mechanisms, using students as participants. One set considered quota auctions, while a subsequent set expanded on these results by also considering reference-price auctions, a greater range of choices, and the ability to select both an asking price and a level of quality.

Each of these sets comprised a number of approximately 1-hour long sessions held in the University of Maryland-College Park's experimental economics lab. Each session typically included 10 participants (sellers) completing up to 30 rounds (each round represented a single auction). After instructions and practice rounds, the subjects participated in computerized auctions for real money. During each round—which lasted between 1 and 2 minutes—each seller received one or two tickets that they could then submit for sale to the buyer.[37] When submitting a ticket, the participant chose an asking price, and in some rounds, a number of quality points (which cost them money but made it more likely that their ticket would be accepted). Depending on the choices made by the participants, tickets were either accepted or rejected. Accepted tickets were paid an amount based on the seller's asking price, minus the cost of the ticket and any quality points purchased.

Each seller was given the same *types* of tickets in each round. Each type of ticket had a range from which a cost was randomly drawn for each round. Sellers knew the types of the tickets they received, the cost range of each type of ticket, and the total number of each type (across all other sellers). However, the actual cost of each ticket was known only by the seller submitting the ticket for sale. This structure is designed to create an asymmetric environment where there are different classes of sellers and limited public information.

Quota Auction Experiments

A quota auction imposes a limit on the number of winning offers that can come from any single category (in this case, type of ticket). In these experiments, the auctioneer specified, before each round began, that he or she will accept no more than x offers from each type of ticket. Tickets that failed this test—those ranked amongst the lowest of all the tickets submitted of this type (in this round)—were rejected regardless of their overall ranking. Remaining tickets were then re-ranked, with a fraction (i.e., 50 percent) selected. Note that neither of these procedures entailed rebidding. After selections are made, sellers were told whether their tickets were accepted or rejected, and why they were rejected.

Although theoretical models of symmetric auctions are well developed, models are lacking for more complex auction structures. As described in the box, "Constrained Strategic Equilibrium" (CSE), the CSE approach was used to simulate seller behavior in a quota auction. This method shows conditions under which a quota can be an effective means of reducing procurement costs in situations with high seller asymmetry, while posing little risk of increasing procurement costs when groups of sellers are similar.

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[37] Each participant was told that the buyer was a computer and these experiments were context free—no mention was made of conservation goals or agricultural income. This approach was taken to minimize the risk that students would submit bids that expressed approval (or disapproval) of conservation as a societal goal.

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Box: Constrained Strategic Equilibrium

In order to demonstrate the effect of quotas in the simplest possible environment, consider two groups of sellers that are observably different: type A (low cost) sellers with costs ranging between C_{A0} to C_{A1}, and type B (high cost) sellers whose costs range between C_{B0} to CB_1. Sellers perceive the other group as similar to themselves but with a different average cost. The buyer will accept the lowest m offers submitted by the N total sellers.

To simulate behavior under this mechanism, a markup model was used (Higgins et al., 2014).[1] The markup strategy posits that a seller with an opportunity cost c_i will submit an offer that is some constant markup of that cost, Θc_i, the parameter Θ being chosen intelligently to maximize expected profits. By restricting attention to strategies that follow a particular functional form, Higgins et al. (2014) were able to numerically estimate bidding strategies.

Equilibrium approximations in three cases of asymmetry (low, medium, and high) were calculated with five type A and five type B sellers. In all three cases, type B sellers request lower payments than type A sellers with the same cost.[2] Moreover, as asymmetry moves from low to high (as the difference in mean costs between type A and B sellers increases), type A sellers increase their bids in response to the weaker competition provided by type B sellers. The takeaway is that low-cost sellers are extracting windfall profits because of the observable heterogeneity of the high-cost sellers. The greater the observable difference between sellers, the greater the profit extracted by the low-cost sellers.

The simulated results change under a quota auction that uses a simple rule: no more than four type A sellers and four type B sellers can be accepted. The imposition of a quota has a pronounced impact on bidding behavior. When faced with both within- and between-group competition, low-cost sellers submit bids much closer to their actual costs. The results are summarized in the following table and figure; the figure plots the bid functions before and after the imposition of a quota in the medium asymmetry case. It illustrates how type A sellers submit significantly lower bids in an auction with a quota than in an open auction, while type B sellers inflate their bids slightly to reflect their increased chances of winning under the quota regime. The table summarizes overall procurement costs, highlighting how the quota mechanism is most pronounced when asymmetry is high.

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[1] The approach is known as the Constrained Strategic Equilibrium approach (Rothkopf, 1969; Kagel and Richard, 2001).

[2] This phenomenon has been described as "weakness leads to aggression" (Krishna, 2010; p. 47).

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Box: Constrained Strategic Equilibrium—continued

Figure: Medium asymmetry auction comparison strategies
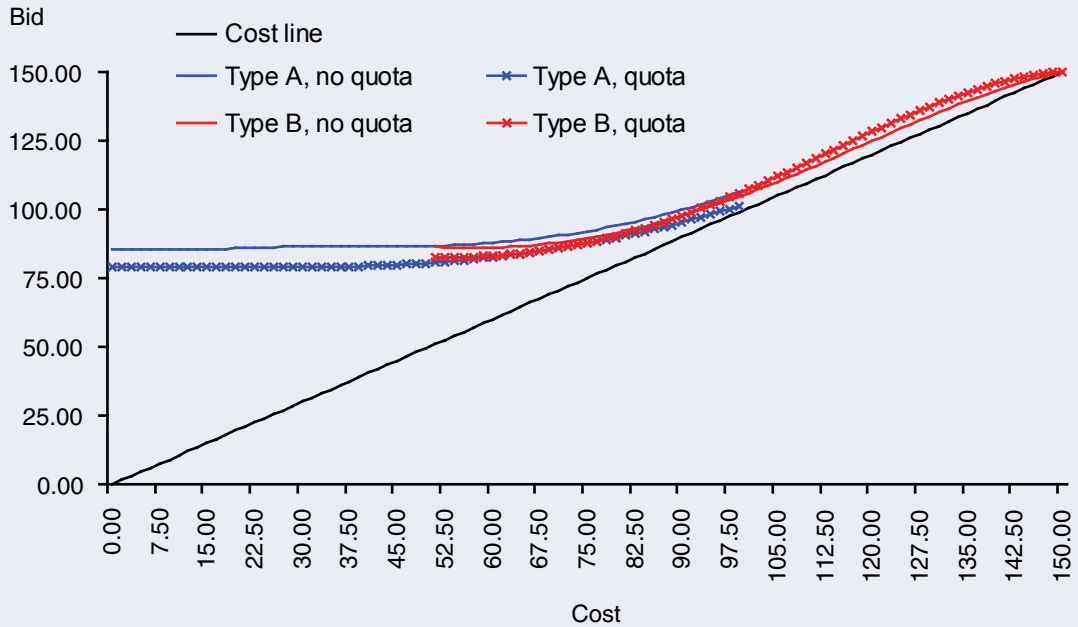
Source: USDA, Economic Research Service.

Table: Expected procurement costs from the simulations

	Open auction ($)	Quota auction ($)
Symmetric auction	381.6 (17.9)	380.4 (18.2)
Low-asymmetry auction	457.3 (16.1)	452.2 (17.3)
Medium-asymmetry auction	531.5 (13.8)	509.7 (21.3)
High-asymmetry auction	643.6 (15.7)	564.8 (24.8)

Note: Standard deviations are in parenthesis.
Source: USDA, Economic Research Service.

While potentially revealing, these models depend on numeric simulations and behavioral assumptions that are difficult to statistically measure. Experiments can offer empirical validation that complements the numerical computations provided by theoretical models and simulations. In a set of 17 experimental sessions, 5 subjects were given type A tickets and 5 were given type B tickets. All subjects knew that type A sellers drew their costs randomly, with each ticket costing between $0.00 and $100.00 and each amount being equally likely to occur, while type B sellers drew costs between $50.00 and $150.00.[38]

Each session included a number of rounds. Some of the rounds used a standard auction that simply selected the lowest 6 of the 10 offers (the ticket type was ignored). Other rounds used a quota mechanism that accepted no more than four offers from each ticket type. Because every subject participated in both treatments, we can compare how the same individual performed under both types of auctions, as well as compare the performance of different subjects.[39]

The experimental results (table A1.1) confirm our computational finding that auctions with a quota are more cost effective than auctions without a quota. The difference in total procurement cost between the experimental and simulation results is more than expected for the median asymmetry case (which contains a moderate amount of systematic differences in cost). The experimental results yielded an average procurement cost that was 8.7 percent lower in auctions with a simple quota than in standard open auctions. In comparison, model-derived predictions of average procurement costs under each type of auction were higher than the experimental results, and the quota auction was only 4.1 percent lower than the standard open auction.

These results suggest several broad conclusions. First, if the between-group heterogeneity is sufficiently high, substantial savings can be achieved by imposing a quota. Second, if between-group heterogeneity is relatively low, total procurement cost is unlikely to increase by a substantial amount through the imposition of quota. Even when between-group heterogeneity is at its lowest

Table A1.1
Experimental and simulated results from the median asymmetry case

	Experimental results: Total procurement costs		Simulated results: Total procurement costs	
	Standard auction	*Quota auction*	*Standard auction*	*Quota auction*
Average cost	$518.57	$473.30	$531.49	$509.73
Standard deviation	63.24	54.19	13.8	21.3
Number of offers	200	76	10,000	10,000

Source: USDA, Economic Research Service.

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[38] Costs and bids were denominated in e-dollars. Actual cash payments were based on $0.05 per e-dollar. Participants earned between $15 and $75 (depending on their bidding skills and on the costs of their tickets) for participating in the 1-hour session.

[39] We varied the order of treatments to control for learning effects, and in some sessions employed an "A-B-A"-type design to determine if individual bidding behavior within a treatment varied with experience. Each treatment ran for at least 10 rounds, allowing for learning in earlier rounds.

(a symmetric auction), imposing quotas does not increase costs substantially because the expected margin for offer acceptance is relatively unaffected by the exclusion of a few sellers. These results indicate that quota auctions can be a relatively safe mechanism from the perspective of the buyer.

Reference-Price Auction Experiments

Following the quota auction experiments, an additional 12 laboratory sessions were conducted, with much of the structure of the first set of auctions being retained. In particular, participants sold tickets that were classified by type, each experimental session consisted of a number of rounds, and treatments changed over the course of a session. The scope of the treatments was broadened, however. First, in addition to the open (standard) and quota mechanisms, a reference-price auction mechanism was considered. Second, in addition to selecting an asking price, sellers could choose to supply between 0 and 20 quality points for each offered ticket.[40] As detailed in table A1.2, four ticket types were used. Each seller received two tickets in each round, with one being a type A or type B ticket, and the other a type C or type D ticket.

When a reference-price auction mechanism was used, each ticket received a reference price that depended on the ticket type—all tickets of a given type had the same reference price. For each offered ticket, a score is computed that uses the asking price, the number of quality points added, and (in reference-price rounds) the reference price. Table A1.3 lists how scores were computed, with **lower** scores receiving a **higher** rank. At the end of an auction round, half of the offers were accepted, with accepted tickets paid the difference between their asking price and the ticket's cost (minus the cost of any quality points added). The reference price has no effect on earnings, it only affects the ranking (hence the probability of ticket acceptance).

The same sets of tickets were used in each round across the different sessions. This regularity facilitated the use of regression modeling using pairwise comparison (which compares two experiments

Table A1.2
Reference-price experiment, ticket details

Ticket type	Cost range ($)	Reference price ($)
A: Low cost with low variance	30- 45	39
B: Low cost with medium variance	20-65	45
C: Medium cost with medium variance	35-95	71
D: High cost with high variance	40-150	94

Notes: A ticket's actual cost is randomly drawn from the range of its type. Reference price, when used, is the same for all tickets of the same type.
Source: USDA, Economic Research Service.

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[40] Quality points were structured to resemble the cost-share improvements often found in conservation programs. Each quality point cost $0.50, and a maximum of 20 points could be obtained for each ticket. Since obtaining one quality point has the same effect on an offer's score as reducing the asking price by a $1.00 in these experiments, profit-maximizing participants should obtain the maximum number of quality points. Nonetheless, many participants under-purchased quality points. Understanding why this occurs, and how changing auction design might improve results for both buyers and sellers, is a topic for future research. We do note that introducing quality improvements does weaken the ability to focus on a pure difference between auction mechanisms.

Table A1.3
Reference-price experiment, treatment details

Treatment	Details	Score calculation (lower scores are better)
Quota	A two-stage acceptance procedure: 1: Within each ticket type, the highest scoring ticket is dropped 2: The survivors are pooled, and the best (lower scoring) are accepted	Score = BID - q *(q=quality points purchased)*
Reference price	A reference price is assigned to each ticket. • Bids below the reference price: score is reduced • Bids above the reference price: score is increased	Score = BID - 1.5q + (BID – *referencePrice*) *(q=quality points purchased)* [1]

[1] The use of a multiplier of 1.5 on q adjusts for the expenditure needed to obtain q. Otherwise, an increase in the bid to offset the cost of purchasing q would negate the value of q since such an increase would increase both the Bid and the (Bid-referencePrice) terms. In a sense, this multiplier adjusts the reference price so that it includes the cost of the quality points supplied.

Source: USDA, Economic Research Service.

that only differ in one attribute) since cross-session pairs can be formed that only differ in treatment (the cost and other attributes of the tickets depend on the round and not the session).

The net effect will be an increase in cost-effectiveness if low-cost sellers submit offers but refrain from requesting payments that are well above their opportunity costs. Conversely, if a number of high-cost sellers are accepted—due to having reference prices well above their actual costs—cost-effectiveness could decrease. Two aggregate metrics were used to measure cost-effectiveness. The first is average profit per accepted ticket in a given round. The second is expenditure efficiency of a given round, defined as the actual expenditure on the quantity (A) of accepted tickets, with q total quality points, divided by what it would cost to obtain A tickets if perfect information availability allowed the buyer to offer each seller their cost and ensure provision of q quality points across these offers. Average profit is simpler but doesn't consider quality changes; expenditure efficiency recognizes the cost of these quality improvements. The box, "Estimators Used in Reference-Price Auction Experiments" contains details on the models used to regress these metrics on treatment dummies and other explanatory variables.

Table A1.4 lists linear regressions using dummies to identify treatments.[41] Both regressions (for average profit and expenditure efficiency) show that the quota and reference-price auctions improve cost-effectiveness. Table A1.5 lists difference models, using average profit as the dependent variable and using dummies to identify treatments.

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[41] It appears that higher costs (larger uniCost) reduce acquisition costs (bids may not adjust quickly, so higher costs mean less profit), while higher variation (larger uniRatio) increases acquisition costs (perhaps because larger profits are possible when there are more low-cost tickets).

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Box: Estimators Used in Reference-Price Auction Experiments

The basic model used in the second-wave experiments is:

$$Y_{sr} = T_{sr}\,\beta_T + X_{sr}\,\beta_X + C_r\beta_c + Z_s\beta_z + \varepsilon_s + \varepsilon_r + \varepsilon_{sr}\ ,$$

Where:

s,r = session, and round within session

T = vector of treatment dummies (reference price and quota), only one of which is nonzero

X = round-specific variables (maxPrior)

Z = session descriptor (exper)

C = round-specific costs (uniCost and uniRatio—these have the same (or nearly the same) values in round r, regardless of session,

eps = error components: session specific (s), round specific (r), and observation specific (rs)

Y = average profit, ratio of actual expenditures to optimal (full information) cost, or ratio of actual costs (of enrolled parcels) expenditures to optimal cost.

The difference model:

$$\Delta Y_{s,r12}\ = \Delta T_{s,r12}\ \beta_T + \Delta X_{s,r12}\ \beta_X + \Delta C_{s,r12}\ \beta_c + \Delta\varepsilon_{r12}\ + \Delta\varepsilon_{s,r12}$$

The difference model uses all pairs or rounds in the same session for which at least one of the T variables differs. Thus, it is a panel model, where each panel consists of observations within a single session. Note that the first differencing uses all pairs of rounds within a session that did not use the same treatment (it is not a simple adjacent-round first difference). Definition of first differencing for a pair of observations in panel s:

x_s,r12 = x_s,r2 – x_s,r1 (where r1 and r2 are rounds).

The eps_s session-specific error component is conditioned out by the first differencing. The Z variables are also conditioned out. Note that delta T can be negative, which means a treatment was no longer used.

The treatment dummies (ΔT) can take three values:

- -1 : the treatment was discontinued,
- 0 : the treatment was in neither element of the pair, or
- 1 : the treatment was adopted

—continued

**Box: Estimators Used in Reference-Price
Auction Experiments—continued**

Hence, coefficients measure what happens when a treatment is adopted (or the effect of dropping a treatment).

The difference-in-difference model:

$$\Delta^2 Y_{s2,r2} = \Delta^2 T_{s2,r2}\ \beta_T + \Delta^2 X_{s2,r2}\ \beta_X + \Delta^2 \varepsilon_{s2,r2}$$

The difference-in-difference model compares pairs of rounds between sessions S1 and S2.

- Each comparison uses pairs (S2, S2) that have the same first (r1) and second round (r2).

- S1 must have a round that is identical (in terms of T) to a round in S2.

- S1 must have a round that is different than a round in S2.

Thus, the difference within a pair is compared to a difference within another pair.

Definition of difference-in-differencing for a pair of observations spanning rounds r1 and r2, in sessions S1 and S2:

  x_s12r1r2 = (x_s1,r2 – x_s1,r1) - (x_s2,r2 – x_s2,r1),

where the r2 treatments are the same, and the r1 treatments are different.

Note that the difference-in-differencing:

- Controls for Z (the first difference removes session-specific variables).

- Controls for changes in eps_r (the within-pair changes are the same).

- Controls for changes in cost structure (since r1 and r2 have very similar cost structures across all sessions), hence C is essentially conditioned out (such as uniCost and uniRatio).

- The difference-in-difference compares pairs of treatments across sessions. Each pair has the same first and second rounds. Pairs that appear in a difference-in-difference share the same treatment in the first round, but differ in the second round. Thus, the differences reflect what happens when the treatment change is different.

Table A1.4
Reference-price experiment, linear regression

	Dependent variable: Average profit per offer	Dependent variable: Expenditure efficiency
Intercept	5.7 (4.8)	1.19 (9.9)
RefPrice	-10.5 (-12.9)	-0.18 (-8.9)
Quota	-7.7 (- 8.3)	-0.14 (-5.81)
maxPrior	0.21 (7.1)	0.0054 (6.8)
uniCost	-0.33 (-6.2)	-0.018 (-13.6)
uniRatio	12.5 (3.2)	0.73 (7.3)
Exper	0.034 (.21)	-0.0041 (-0.9)
R-square [f-stat]	0.58 [< 0.001]	0.66 [< 0.001]

Notes: Numbers in parentheses are t-statistics measuring each estimator's precision; numbers in brackets are F-test probabilities measuring the probability that all coefficients are actually equal to zero (using N=206 rounds). Each observation contains the results of a round (that is, the aggregate results from all submitted and accepted offers). RefPrice and Quota are dummy variables. For expenditure efficiency, coefficients are interpreted as percent change from using this auction mechanism (compared to open auctions). MaxPrior is the max accepted score in the prior auction (which seems to have an impact on bid levels, hence acquisition costs). UniCost is what the acquisition cost would be in a uniform price auction if the price of the least-expensive rejected offer is paid to all accepted offers. UniRatio is the ratio of uniCost to the optimal (full information) cost. Exper is a measure of prior experience (number of economic classes taken and number of experiments enrolled in).

Source: USDA, Economic Research Service.

Table A1.5
Reference price experiment, difference models

	Difference	Difference-in-difference
Intercept	1.43 (109)	1.33 (7.8)
RefPrice	-9.7 (-37.2)	-6.9 (-10.1)
Quota	-7.08 (-23.0)	-5.5 (-8.1)
maxPrior	0.093 (8.1)	0.02 (1.9)
uniCost	-0.39 (-25.7)	
uniRatio	15.8 (14.1)	
Exper	3.3 (3.1)	-0.027 (-0.03)
R-square (f-stat)	0.54 (<0.001)	0.05 (<0.001)
N (number of pairs of rounds)	1822	2565

Notes: Average profit is the dependent variable in these regressions. Difference models compare difference between rounds in the same session to control for unobservable attributes of participants. Difference-in-difference compares differences between pairs of rounds across sessions to control both for the unobservable attributes of participants and variations in ticket costs. The RefPrice and Quota are dummy variables. MaxPrior is the max accepted score in the prior auction (which seems to have an impact on bid levels, hence acquisition costs). UniCost is what the acquisition cost would be in a uniform price auction if the price of the least-expensive rejected offer is paid to all accepted offers. UniRatio is the ratio of uniCost to the optimal (full information) cost. Exper is a measure of prior experience (number of economic classes taken and number of experiments enrolled in). Numbers in parentheses are t-statistics; the R-square is an overall goodness of fit, and the f-stat (in parenthesis) measures joint significance of all coefficients.

Source: USDA, Economic Research Service.

Appendix 2: Effects of the CRP's Bid Cap

This study examined Environmental Benefit Index (EBI) scores of actual offers to determine if (1) landowners with low reservation prices but relatively high EBI scores increased their bid to the bid cap when they believed their offer would still be accepted, and (2) were less likely to offer additional conservation practices as part of their bid. The EBI score can be divided into three components:

- Exogenous EBI points–strictly due to the fixed features of a parcel, such as the parcel's soil erodibility.

- Endogenous EBI points—based on the choice of conservation practices. They represent a level of environmental impacts that the landowner can choose.

- Cost points—affected by the bid. The bid cap means there are two kinds of cost points—those the landowners can control, and those they will *always receive*. Since the landowners cannot ask for more than the bid cap, they will always receive some cost points. By decreasing their bids to below the bid cap, landowners can receive more cost points.[42]

Combining the exogenous EBI points and the cost points that a landowner always receives yields what we call *automatic* points—points that a landowner has no control over and receives no matter the size of their bid or type of conservation practices installed.

To test whether landowners with a high probability of acceptance into the CRP tend to bid the maximum allowed amount, we examine the "underbid" as a function of the automatic points. Data on offers to CRP general signup 15 (in 1997) through signup 45 (in 2013) are used. The underbid is defined as the difference between the parcel's bid cap and the parcel's bid, as a fraction of the parcel's bid cap. Thus, a value of 0 means "the bid equaled the bid cap," while 0.5 means "the bid is half of the bid cap." Since the EBI's scoring formula has changed over time, the independent variable (automatic points) was normalized; it is expressed as a fraction of the maximum possible automatic points in the signup. Table A2.1 displays regression results (which are also presented visually in the figure in the box, "Drawbacks of the Bid Cap").

The regression shows a highly significant negative relationship between automatic points and under-bidding. A 1-percent increase in automatic points will (on average) reduce a parcel's underbid by about 0.12 percent. When offers are ranked by the number of automatic points they received, both the number of parcels with underbids and the average size of underbids decreased as the number of automatic points increased.

To test whether landowners with a high probability of acceptance are less likely to improve the environmental quality of their offers, we examine whether endogenous points decline as automatic points increase. As noted, both the dependent (endogenous points) and the independent variable (automatic points) are normalized; they are expressed as a fraction of the maximum possible for that signup.

Regression analysis (table A2.2) shows a highly significant negative relationship between automatic points and endogenous points—a 1-percent increase in automatic points will (on average) lead to a

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[42] The Environmental Benefits Index (EBI) computes these cost points using the following equation: cost points= a * (1 – (offer/b)). Both the "a" and "b" parameters are announced after all general signup offers have been received. Thus, landowners do not know precisely what their cost points will be. However, these parameters have been fairly constant over time so landowners should be able to reasonably approximate the cost points they will always receive and those they can control.

Table A2.1
Underbid fraction as function of automatic EBI

Constant	0.113 (288)
Automatic points (normalized)	-0.122 (-156)
R-square	0.029
F-stat	24,241 (prob <0.0001)
N (number of offers)	809,040

Notes: EBI refers to the Environmental Benefits Index, F-stat refers to joint significance of all parameters, and R-square is a goodness-of-fit measure. T-stat measures of coefficient precision are in parentheses. When each signup is separately regressed, qualitatively similar results are obtained (with the coefficient on automatic points ranging from -0.06 to -0.34).

Source: USDA, Economic Research Service using confidential program data from USDA, Farm Service Agency, Conservation Reserve Program, 1995-2013.

Table A2.2
Endogenous EBI points as function of automatic EBI points

Constant	0.457 (511)
Automatic points (normalized)	-0.297 (-166)
R-square	0.033
F-stat	27,481 (prob <0.0001)
N (number of offers)	799,712

Notes: EBI refers to the Environmental Benefits Index, F-stat refers to joint significance of all parameters, and R-square is a goodness-of-fit measure. T-stat measures of coefficient precision are in parentheses. When each signup is separately regressed, qualitatively similar results are obtained (with the coefficient on automatic points ranging from -0.09 to -0.51).

Source: USDA, Economic Research Service using confidential program data from USDA, Farm Service Agency, Conservation Reserve Program, 1995-2013.

0.297-percent reduction in a parcel's endogenous points. This supports the conjecture that the more likely an offer is to be accepted, the less likely it is that the landowner will attempt to install more environmentally beneficial practices. An auction mechanism that did not depend on bid caps (e.g., one that allowed a landowner to increase their bid to cover the cost of a more beneficial conservation practice) could counteract this effect.

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