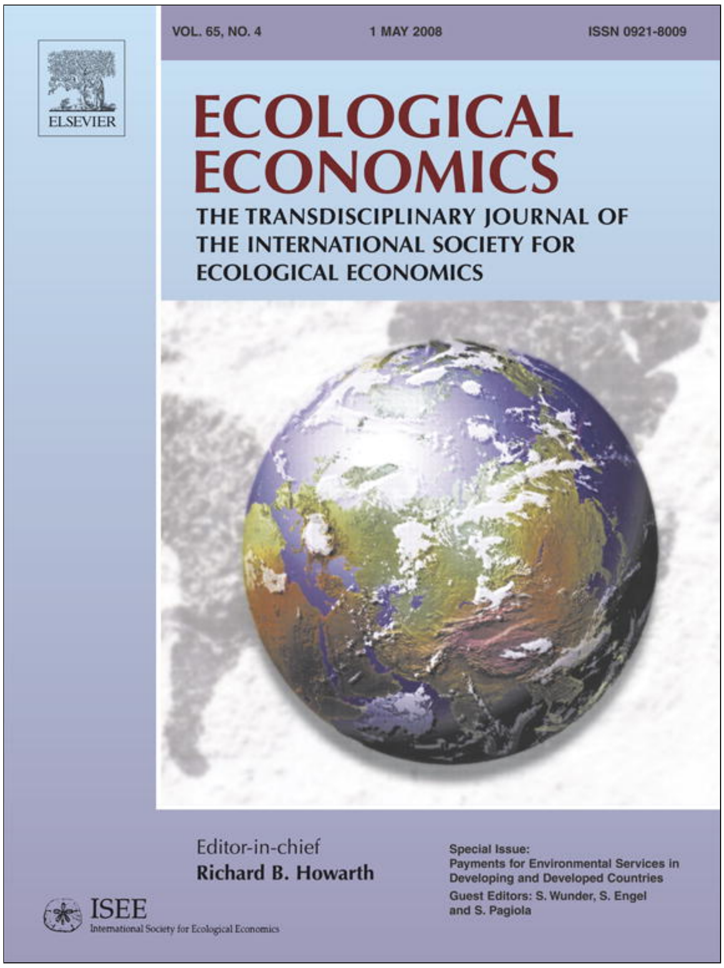
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Asymmetric information and contract design for payments for environmental services

*Paul J. Ferraro**

Department of Economics, Andrew Young School of Policy Studies, Georgia State University, P.O. Box 3992, Atlanta, GA 30302-3992, United States

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ABSTRACT

In contractual relationships involving payments for environmental services, conservation buyers know less than landowners know about the costs of contractual compliance. Landowners in such circumstances use their private information as a source of market power to extract informational rents from conservation agents. Reducing informational rents is an important task for buyers of environmental services who wish to maximize the services obtained from their limited budgets. Reducing informational rents also mitigates concerns about the "additionality" of PES contracts because low-cost landowners are least likely to provide different levels of services in the absence of a contract. Paying low-cost landowners less thus makes resources available for contracts with higher opportunity cost landowners, who are more likely to provide substantially different levels of services in the absence of a contract. To reduce informational rents to landowners, conservation agents can take three approaches: (1) acquire information on observable landowner attributes that are correlated with compliance costs; (2) offer landowners a menu of screening contracts; and (3) allocate contracts through procurement auctions. Each approach differs in terms of its institutional, informational and technical complexity, as well as in its ability to reduce informational rents without distorting the level of environmental services provided. No single approach dominates in all environments. Current theory and empirical work provides practitioners with insights into the relative merits of each approach. However, more theoretical work and experimentation in the laboratory and the field are necessary before definitive conclusions about the superiority of one or more of these approaches can be drawn.

1. Introduction

Payment schemes for environmental services (PES) generally have two common features. First, they are voluntary. Second, participation involves a contract between the conservation agent and the landowner. The landowner agrees to manage an ecosystem according to agreed-upon rules and receives a payment (in-kind or cash) conditional on compliance with the contract. In this paper, the word "landowner" denotes any entity that is in the position (de jure or de facto) to supply environmental services through its influence on an ecosystem. "Conservation agent" denotes any entity that wishes to encourage landowners to supply environmental services.

Abbreviations: CRP, Conservation Reserve Program; EPD, Environmental Protection Division; MAO, maximum acceptable offer; PES, payments for environmental services; PSA, Programa de Pagos de Servicios Ambientales.

* Fax: +1 404 651 0425.
E-mail address: pferraro@gsu.edu.

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PES contractual relationships are subject to asymmetric information between landowners and conservation agents. Information asymmetries can limit the effectiveness of PES schemes and make them expensive to implement. There is a well developed literature in "contract theory" that can provide abundant insights into the design of PES contracts (see, for example, Bolton and Dewatripont (2005) and references therein). In this article, I highlight some of these insights.

There are two important information asymmetries in the design of contracts: hidden information and hidden action. Hidden information (adverse selection) arises when negotiating the contract. Landowners have better information than the conservation agent about the opportunity costs of supplying environmental services. Landowners can thus secure higher payments by claiming their costs are higher than they are. More precisely, landowners use their private information as a source of market power to extract informational rents from conservation agents. These rents are payments above the minimum payment necessary to induce landowner participation in the PES program. Hidden information has been the subject of theoretical analyses in the context of agri-environmental payment schemes, which have much in common with PES schemes (Spulber, 1988; Chambers, 1992; Bourgeon et al., 1995; Fraser, 1995; Wu and Babcock, 1996; Latacz-Lohmann and Van der Hamsvoort, 1997; Moxey et al., 1999; Ozanne et al., 2001; Peterson and Boisvert, 2004).

Why should we care about these informational rents? When conservation agents pay informational rents, they obtain fewer environmental services per dollar spent than they could obtain in a world in which the opportunity costs of supplying environmental services are observable. Furthermore, PES programs are often funded by taxes, which involve inefficiencies (deadweight losses from the market distortions associated with taxation), and are often subject to free riding, which implies suboptimal funding levels. Thus society benefits more if the payments just compensate the landowners' opportunity costs of contract compliance. However, PES programs may also serve as an instrument for income redistribution and thus reducing informational rents to landowners may have implications for other goals associated with PES programs (see Section 6).

In contrast to hidden information, hidden action (moral hazard) arises after a contract has been negotiated. The conservation agent may find monitoring contract compliance costly and thus will be unwilling to verify compliance with certainty. Thus the landowner has an incentive to avoid fulfilling his or her contractual responsibilities. Hidden action in agri-environmental payment schemes has also been the subject of theoretical analyses (Choe and Fraser, 1998, 1999; Ozanne et al., 2001; Fraser, 2002; Hart and Latacz-Lohmann, 2004). A few authors have attempted to model hidden action and hidden information simultaneously (e.g., White, 2002). Because of space constraints, I focus only on PES contract issues related to hidden information.

2. Hidden information

Consider a simple example. A conservation agent is interested in contracting with landowners for habitat quality, h, which can be represented by numbers ranging from 0 (completely converted) to 100 (pristine). Participation is voluntary and thus contract payments must at least cover the landowner's opportunity costs (in the theoretical jargon, the "participation constraints" are satisfied). There are two types of landowners: those with high-opportunity costs (H) and those with low-opportunity costs (L). A type H landowner has the cost function $2h^2$ and a type L landowner has the cost function $2h$.

The conservation agent would like to contract with type L landowners first, and only contract with type H landowners if the agent's demand for habitat quality was not satisfied by type L landowners. All landowners, however, would like to be paid as if they were type H landowners. Consider a specific parcel of land and assume that the conservation agent wishes to contract with a landowner to keep the landowner's habitat pristine, $h=100$. In a perfect information world, the agent would offer \$200 if the landowner were type L and \$20,000 if the landowner were type H. However, if the conservation agent could not determine if a landowner is H or L, all landowners would claim they were type H in order to receive the larger payment.

As long as there is substantial heterogeneity in opportunity costs of supplying environmental services, hidden information will be a problem. Indirect evidence of informational rents going to landowners in conservation payment initiatives has been observed in the United States, Europe and Central America. For example, Shoemaker (1989) analysis of the early U.S. Conservation Reserve Program found that land values increased substantially for contracted lands, which could only occur if substantial rents were accruing to owners. These rents accrue to owners of acres with below-average returns, who receive payments based on average county returns. Similarly, Osterberg (1999), in an analysis of a German agri-environmental payment program, found that the flat rate payments led to a concentration of contracts on unproductive lands run by farmers with the lowest land use intensities (in other words, farmers with the lowest opportunity costs). In a review of Costa Rica's Programa de Pagos de Servicios Ambientales (PSA), Hartshorn et al. (2005, p.12) found that 71% of PSA forest protection contracts were on land designated for the lowest-value uses, while the payment rates were set to be above average returns from cattle pasture. Commenting on the same program, Ortíz et al. (2003, p. 64) report average returns to land classes for a variety of activities and find that forest protection contracts compete favorably on only one type of land-marginal lands with zero opportunity cost of conservation (for another example, see The Economist (1999) report on the California Headwater Forest purchase).

Policy mechanisms that reduce informational rents can be broadly classified into three categories: (1) gathering more information on landowners in the form of costly-to-fake signals; (2) relying on screening contracts (self-selection mechanisms); or (3) harnessing competitive forces through procurement auctions. The basic idea of the latter two approaches is to design the contracting system to induce landowners to reveal their hidden information (called revelation mechanisms).

3. Gathering information from costly-to-fake signals

The simplest, and coarsest, approach to address the hidden information of landowners is to gather information on observable landowner attributes that are correlated with opportunity costs and use these attributes to establish contract prices. With this information one can create eligibility requirements for receiving a given contract type and price. This approach is common in U.S. agri-environmental schemes where posted contract prices differ geographically to reflect regional differences in opportunity costs. Soil type, distance to roads and markets, forest type and assessed value are other examples of attributes that are often correlated with opportunity costs and, importantly, are impossible or costly for landowners to fake.

Regional and local intermediaries with better information about field conditions can facilitate the designation and collection of information on these attributes. If the gains to contracting are substantial, high-cost landowners may find ways to express costly-to-fake signals on their own (e.g., hiring a forester to certify the value of their timber). More sophisticated methods for categorizing cost types include using economic models of agricultural returns based on observable characteristics (e.g., Bogetoft, 2000; Naidoo and Adamowicz, 2006). One can also establish minimum eligibility criteria to ensure that low opportunity cost landowners cannot participate in auction (e.g., eligible lands must be located no more than 5 km from a road).

Collecting information on costly-to-fake signals of opportunity costs is technically less challenging than developing screening contracts and procurement auctions (see below). Note, however, that collecting information about landowner characteristics can still be costly and the ability of this information to reduce information rents without distorting the conservation outcome will only be as good as the strength of the correlations between the characteristics and landowner types. Moreover, using returns to land to estimate potential payments for land use restrictions may be quite inaccurate (too high) if farmers are risk-averse and expect capital gains from the land, or if land-use benefits are uncertain (Parks, 1995).

4. Screening contracts

An alternative approach to gather information on landowner characteristics is to induce landowners to reveal their type by offering a contract for each of the different "types" of landowners believed to exist. Contracts are designed so that a landowner could never be better off choosing the contract intended for another type.[1]

Consider the numerical example from above with type H and type L landowners. The essential insight of models of hidden information is that two types of contracts should be offered: a high-output contract for type L landowners and low-output contract for type H landowners. In addition to the requirement of choosing payments to at least cover all landowners costs (i.e., "participation constraints" are satisfied), the contract design puts restrictions on the payments so that landowners pick the contract intended for their type (in the jargon, the "incentive compatibility constraints" are satisfied). For example, the following menu of contracts satisfies the landowners' participation constraints and incentive-compatibility constraints: (1) $382 for $h=100$; and (2) $201 for $h=10$.[2] A type L landowner prefers contract (1) and a type H landowner prefers contract (2). Thus their contract choices reveal their types.

Note that although landowners reveal their types, this revelation comes at a cost compared to the situation in which the conservation agent knows each landowner's type with certainty (in the jargon, it is a "second-best" rather than a "first-best" outcome). To encourage type L landowners to reveal their type, the conservation agent must compensate them at a level above their opportunity costs. This overcompensation is a rent from the private information held by the low-cost landowner. Through the use of screening contracts, the conservation agent has reduced the informational rents paid to the low-cost landowners, but has not eliminated them.

Moreover, reducing the informational rent comes at a cost of fewer environmental services supplied compared to the perfect information case. The low-cost landowner still supplies the same amount of habitat quality as in the perfect information context (in jargon, the "no-distortion-at-the-top rule" holds), but in order to reduce the attractiveness of low-cost landowners claiming to be high-cost, the contracts aimed at high-cost landowners require a lower level of habitat quality. This distortion in the contracted output of environmental services grows with the difference in costs between the low-cost and high-cost landowners and the proportion of landowners who are low-cost (as does the informational rent paid to the low-cost landowners). Under certain parameterizations, the best a conservation agent can do is offer a single contract to which only low-cost landowners would agree. Adding more landowner types does not change the basic result: inefficiently low supply of environmental services (except for the lowest-cost landowner) and positive informational rents (except for highest-cost landowner).

Despite the appeal of screening contracts, their design is not straightforward in the field. Designing a menu of contracts that satisfy the participation constraints and the incentive compatibility constraints and maximize the conservation agent's objective function requires knowledge about the distribution of landowner types and sophisticated calculations by conservation practitioners. As the authors of a popular textbook on contract theory state (Bolton and Dewatripont, p.3), "More often than not, research articles in contract theory are hard to penetrate even for a well-trained reader."

While there are many proposed incentive-compatible contract designs in the literature that might be adapted by practitioners to PES schemes, the ability of conservation practitioners to do so is questionable. Despite much theoretical work on incentive-compatible contracts in the context of agri-environmental programs, I know of none offered by an existing agri-environmental payment scheme. Although this absence in the field does not necessarily imply that screening

[1] In theory, screening contracts can induce information revelation in multiple dimensions (e.g., costs and biophysical attributes of ecosystems). I assume, however, that conservation agents have better information about environmental attributes of landowner parcels and thus the relevant hidden information is landowner costs.

[2] These contracts are merely examples of two contracts that induce risk-neutral landowners to sign a contract and choose the one appropriate for their type. Solving for a second-best menu of contracts requires more information.

contracts are too difficult to apply in practice, it is worth noting that even in the sophisticated markets of high income nations, evidence of the use of screening contracts as specified by economists is mixed. For example, in their analysis of the U.S. term life insurance market, Cawley and Philipson (1999) found that the pricing schedule was incompatible with sorting across contracts in the separating equilibrium predicted by theory.

In the next section, I consider an alternative mechanism through which conservation agents can reduce landowners' informational rents with theoretically less distortion in the contracted environmental services than observed under screening contracts: procurement auctions in which landowners competitively bid for conservation contracts.

5. Procurement auctions for PES contracts

5.1. *What are they?*

Procurement of goods and services for which there are no well-established markets is commonly performed using auctions. A PES contract procurement auction is a process through which a buyer of environmental services invites bids (tenders) from suppliers of environmental services for a specified contract and then buys the contracts with the lowest bids (for a non-technical introduction to auction theory, see Klemperer (2004); for a longer review of conservation auctions, see Latacz-Lohmann and Schillizi (2005)). Box 1 defines commonly used terms relevant to PES procurement auctions.

Procurement auctions use bidding rules and market competition to reduce the incentive for sellers to inflate their contract prices. Procurement auctions can be for single units or multiple units (in the PES context, multiple contracts are the norm). These units can be divisible or indivisible, homogenous or heterogeneous. In some auctions, bidders can only bid once (simultaneous), whereas in others they can bid more than one time (sequential). In some auctions, bidders can see others' bids when making their own bids (open bid), whereas in other auctions the bidders each make their bids without knowing what other bidders are choosing (sealed bid). Payments for winning bidders can be based on their own bids (discriminative-price auction) or on a rejected bid (uniform-price auction, which often uses the lowest rejected bid to set the price). The buyer may wish to buy a given number of contracts or service quantity, may have a maximum reservation price per contract, or may have a fixed budget. These buyer attributes may be common knowledge or only known by the buyer. Each combination of auction attributes can give rise to different bidding behavior (see discussion below).[3]

[3] The relevant auction environment for PES contracting is the "private value auction," where each bidder knows his or her own value but not others' values. In contrast, bidders in common value auctions have the same value for the auctioned contract, but no bidder knows the true value. In their early phases, PES contract auctions may have some aspects of common value auctions because landowners may have similar costs of supplying environmental services, but they are unsure of what these costs are.

Box 1

PES procurement auction vocabulary

Bidding units: In the case of PES auctions, the relevant units are contracts that specify, for a period of time, a level of environmental services or an observable set of land uses that are offered in exchange for a payment. Landowners may be allowed to offer single or multiple units, which may be divisible or indivisible, homogenous or heterogeneous.

Discriminative-price auction: Winning bidders are paid their own winning offer prices.

Uniform-price auction: Winning bidders are all paid the same price. This price may be the highest winning offer price or, more typically, the lowest rejected offer price.

Simultaneous auction: Each bidder makes offers only once.

Sequential auction: Each bidder has the opportunity to revise his or her offers.

Single-shot auction: The auction is conducted once and will not be repeated (i.e., the same units will not be procured again in the future).

Repeated auction: The auction is repeated over a sequence of time periods. The results are binding for each time period, but there will be future opportunities to tender offers on the same or similar units.

Sealed-bid auction: Bidders make offers without being able to observe competitors' offer prices.

Open-bid auction: Bidders can see competitors' offer prices when formulating their own offers.

Private value auction: Bidders have perfect information about their own opportunity costs of offering the auctioned unit, but they do not know competitors' costs. These private values may be independent or affiliated (the latter implies that changes in one bidder's offer price affect other bidders' offer prices and thus are often considered as an auction having elements of private and common values).

Common value auction: Bidders have imperfect information about their own opportunity costs of offering the auctioned unit and these costs are the same for all bidders. The true value of the opportunity costs is determined by external factors such as alternative markets for auctioned units.

Unlike screening contracts, auctions do not require the conservation agent to specify the distribution of landowner types. Landowners reveal this distribution through their bids. Like PES screening contracts, PES auctions do not eliminate informational rents to landowners; they merely reduce these rents. In contrast to screening contracts, however, auctions theoretically reduce these rents with fewer distortions to the supply of environmental services. Whereas auctions use competitive bidding to reduce the attractiveness of low-cost landowners claiming to be high-cost, screening contracts accomplish this goal by specifying a low level of environmental services from contracts aimed at high-cost landowners.

Auctions also have the advantage of revealing to the conservation agent any changes in the cost distribution over time, which is useful when contracts are periodically purchased or renewed. With more commonly used take-it-or-leave-it prices in conservation initiatives, such changes can only be inferred indirectly by excess supply, implying that the price is too low, or excess demand for contracts, implying the price is too high. For example, the U.S. Conservation Reserve Enhancement Program in some areas is experiencing excess supply, where few landowners wish to sign up at current prices. Costa Rica's PSA is experiencing excess demand for its contracts: more landowners are interested in obtaining contracts at the current price than there is money available to pay for them.

Auction mechanisms can also be used as research tools to make ex ante estimates of the payments or to reveal costly-to-fake signals associated with cost types (see Ferraro, 2004b for a discussion). Note, however, that the use of auction mechanisms as a research tool to induce landowners to reveal their private information, which can then be used "against them," has ethical implications that have not yet been explored.

Of course, there are also disadvantages of using auctions to allocate PES contracts. Auctions require a large pool of bidders to induce competitive pressures and to reduce incentives to collude or otherwise behave strategically. How many participants constitute a "large" pool will depend on local conditions and the auction environment. Moreover, whereas the theory of screening contracts offers some clear predictions about landowner responses to menus of PES contracts (albeit often under stylized assumptions), auction theory does not offer clear predictions for PES contract auctions because they tend to have unusual attributes, such as multiple units, risk-averse bidders, budget-constrained buyers, and repeated auctions over time.

In the only published theoretical treatment of an auction for environmental service contracts, Latacz-Lohmann and Van der Hamsvoort (1997) develop a model of a discriminative-price, multiple-unit procurement auction in which the conservation agent has a maximum acceptable price per contract. They show that the optimal offer (from the landowners' perspectives) increases linearly with the landowner's opportunity costs and the landowner's expectation about the maximum acceptable price. Thus the offer reflects more than just opportunity costs, which implies that the auction is an imperfect revelation mechanism. However, the auction does appear to be an improvement over a posted-price (take-it-or-leave-it) contracting program for two reasons: (1) although low-cost producers gain informational rents, they are smaller than in the posted-price context; and (2) landowners with opportunity costs above the posted payment level, who would not participate under the posted-price payment scheme, can now bid a value that covers their costs. With the same budget, the buyer can accept some of these high-cost farmers into the program via the cost savings provided by the low-cost participants. The efficiency gains increase with the degree of heterogeneity of the landowners. Simulations conducted by the authors yield gains in efficiency that range from 16 to 29%, depending on the rules and parameters.

While such gains are substantial, they might easily be diminished by the administrative cost of an auction. Auctions are more administratively complex than posted take-it-or-leave contract schemes (but not more complex than bargaining with each landowner, as many land trusts do).[4] Whether they are more complex than screening contracts is debatable. On the surface, auctions look more complex because of the many elements that one must consider in their design (Sections 5.3–5.6), but practitioners may find addressing these elements less technically challenging than addressing the smaller number of important elements in screening contracts. In fact, whereas I could find no examples of screening conservation contracts, several well-known auctions for conservation contracts exist.

5.2. *Conservation auctions in practice*

The best-known conservation auction is that of the Conservation Reserve Program (CRP), which pays farmers to take land out of production in order to achieve agri-environmental objectives. Landowners make offers to receive payments in return for a contractual obligation to retire their land for a fixed period of time and, in many cases, to make environment-enhancing investments. The auctions from 1986 to 1990 tendered offers, ranked them from lowest to highest price, and then secured contracts until an acreage objective was achieved. In more recent CRP auctions, the contracts are ranked through an index that includes bids as well as measures of environmental benefits.

In Georgia (United States), the Flint River Drought Protection Act (2000) mandated that the state's Director of the Environmental Protection Division (EPD) use an "auction-like" process during severe droughts to reduce the number of acres under irrigation.[5] Farmers submit offers to suspend irrigation for the remainder of the calendar year on all lands covered by a water-use permit. For reasons explained below, auction theory does not provide clear recommendations for the design of the EPD's auction. Thus, faculty at Georgia State University did what generally must be done for PES auction design: they used laboratory and field experiments as "test-beds" to choose appropriate auction rules for the policy context (Cummings et l., 2004).[6] In 2001, the Director of the EPD declared a severe drought and implemented an auction based on the experimental results. At 8 sites around the state of Georgia, 194 farmers assembled to make offers for 347 permits (ranging from 4 to 1442 acres). They submitted offers to auction

[4] Bilateral bargaining turns a game of one-side hidden information, in which the uninformed party (conservation agent) has the bargaining power and thus can appropriate some of the informational rents of the informed party (landowner) at the expense of achieving the first-best output of environmental services, into a two-sided hidden information game. In this case, each side will try to reduce the informational rents from the other side and trading will be inefficient, incur high transaction costs, and may ultimately end without a mutually beneficial trade (for theory, see Myerson and Satterthwaite (1983)).

[5] A more recent example of an auction for water conservation is the Deschutes Water Exchange auction, which was designed to allocate groundwater mitigation credits.

[6] Field experiments with landowners can ensure landowners understand the language and rules in the same way that conservation agents do, and allow one to observe the relevant social norms that may be invoked in the setting.

monitors (faculty and students, and EPD employees), who then inputted the prices into a computer and sent them via the internet to a centralized site at which all offer prices could be compared and contracts accepted.

Note that farmers in Georgia have no ability to sell or lease their irrigation permits (the permits are tied to the property).[7] Thus, as will often be the case for suppliers of environmental services, farmers could not look to a competitive market to infer the value of giving up their irrigation activities for a year. Instead, they had to calculate their willingness to accept a payment in return for not irrigating their fields for a year, which is a function of alternative uses of the land, and landowner risk and time preferences.

In Australia, auctions have been proposed to solicit landowner participation to achieve salinity control, nutrient control and biodiversity conservation (Stoneham et al., 2003). A pilot auction, called Bush Tender, was conducted for biodiversity conservation contracts. A field ecologist assessed the quality of the native vegetation on participant sites and discussed management options with the landowner. Landowners submitted sealed proposals including their proposed conservation activities and their required payment. Each proposal was awarded a score based on the expected environmental benefits from the management plan, and offers were ranked based on the cost per unit score (Australia is also home to two other conservation auctions: EcoTender and the Auction for Landscape Recovery).

Since an auction is no more than a set of rules for determining how resources will be allocated, it can be tailored to the objectives and characteristics of a PES program. Each of the three auctions described above differs along key dimensions of the auction environment. For example, some allow bidders to submit multiple units (CRP, Georgia), some recognize contracts as being heterogeneous in the environmental services they provide (CRP and Bush Tender), and one (Georgia) allows bidders to revise their offers sequentially. Unfortunately many of these characteristics violate the standard assumptions in auction theory. Auction theory thus does not give unambiguous answers about the appropriate rules for a PES auction and designers thus often turn to experiments and agent-based modeling (simulations) to explore the performances of alternative auction environments (see below).

5.3. *Pricing rules*

In discriminative-price auctions, like the ones described in Section 5.2, winning landowners each receive their offer prices as payment. In contrast, all sellers in a uniform-price auction receive the same price. This price is typically determined by the lowest rejected offer. To readers unfamiliar with these auctions, the discriminative auctions might appear to be the clear choice for a conservation buyer interested in achieving an environmental objective at least cost.

However, a seller in the discriminative price auction earns no surplus (profits) if she submits an offer equal to her opportunity cost. Thus she has an incentive to inflate her offer. In formulating their offers, landowners trade off gains from winning with an inflated offer to the risks of not winning a contract with an inflated offer (losing a contract to a competitor).

In simple uniform-price auctions, there is no such tradeoff: a seller can do no better than telling the truth because the price paid is not determined by an accepted offer. Inflating one's offer only serves to decrease the probability of acceptance; it does not change the price received. However, in order to induce landowners to reveal their opportunity costs, the buyer must pay a price higher than the landowners' opportunity costs (i.e., information rents).[8]

Whether informational rents are higher under a uniform price based on true opportunity costs or under differentiated prices based on inflated opportunity costs is an empirical question. Under standard assumptions, such as bidder risk-neutrality, the two auctions yield the same expenditures for the procurer (Milgrom, 2004). The characteristics of PES auctions, however, are unlikely to result in expenditure neutrality. For example, results from Riley and Samuelson (1981) suggest that the discriminative-price auctions can yield lower expenditures when landowners are risk-averse because the conservation payment is a nonstochastic income component and therefore would lower the landowners' income uncertainty. To obtain this decrease in uncertainty, risk-averse landowners have an incentive to reduce their offer prices below what risk-neutral landowners would offer. The greater the risk aversion and the greater the dispersion in opportunity costs, the more likely the discriminative-price auction would require lower expenditures for a given level of procured environmental services (risk aversion does not affect the incentives in the uniform-price auction).

Because theory does not offer clear guidance on appropriate pricing rules, economists have turned to experiments and, more recently, agent-based modeling (simulations with automata that bid and learn according to simple rules). In laboratory experiments, McKee and Berrens (2001) and Cason and Gangadharan (2005) find discriminative auctions are less costly than uniform-price auctions for a given environmental objective. In an auction that allows bid revisions, Cummings et al. find that average prices are initially lower in the discriminative auction, but the difference disappears as

[7] Permits can legally be revoked at any time, but a voluntary procurement auction avoids political conflict. However, the EPD made it known that if not enough landowners volunteered, it reserved the right to force irrigation to stop. Such a regulatory threat may increase auction participation, but it has unknown effects on bidding. Implicit and explicit regulatory threats are an integral part of voluntary schemes like PES contracting and research into the effect of such threats on the landowner behavior is warranted. For example, if landowners view contracting as part of a dynamic regulatory game in which the information acquired in the first-stage via the contract can be used against landowners in future stages, the rent-reducing powers of revelation mechanisms may diminish.

[8] When multiple bids are allowed, sophisticated bidders have an incentive to truthfully reveal their opportunity costs for the first contract, but they have an incentive to increase their valuations for additional contracts. However, there is a variant of the uniform-price auction, called the generalized Vickery auction, which encourages truth telling for all contracts (see List and Lucking-Reilly, 2000 for more details).

bidders revise their offers. Using agent-based modeling of multi-unit auctions, Hailu and Thoyer (2005) find that over-bidding made the discriminative-price auction more expensive than a uniform-price auction.[9] Auction outcomes are thus sensitive to the bidding rules and the characteristics of the contracts and bidders.

Two other relevant aspects of pricing rules are fairness and information richness. In some cases, like Costa Rica's PSA, paying everyone the same price may be considered fairer than discriminating by opportunity cost, which may "punish" public-spirited landowners who managed their ecosystems for the public good in the absence of payments (less publicly-spirited landowners are "rewarded" with higher payments). In other cases, like Georgia's irrigation auction, paying everyone the same price regardless of their opportunity costs may be considered unfair (or a waste of taxpayer money).

With regard to information richness, the auctions used in Cummings et al. (2004) and Cason et al. (2003) allow sellers to revise offers after learning whether any of their units are tentatively accepted. These authors argue that announcing tentative acceptances and allowing offers to be revised provide useful information to bidders and allow them to avoid costly mistakes from strategic bidding. Theory often assumes that bidders have independent private values, which implies that each landowner knows the opportunity costs of accepting a conservation contract and these costs do not depend on the costs of the other landowners (i.e., learning the costs of other landowners may change one's bid, but not one's costs). In reality, however, landowners may have only a rough sense of what their reservation prices ought to be and thus can benefit from information provided through multiple rounds.

Cummings et al. (2004) also believe that reducing the likelihood of poor choices by the landowners reduces the likelihood that landowners will be angry about the auction process and that policymakers will be unhappy about higher-than-expected prices as well as participant anger. Cason et al. suggest that the chance to revise offers, as opposed to a single binding offer, may also be seen as "fairer" by the landowners. Allowing revisions (or using a uniform-price auction) can make many bidding errors costless. However, the advantages of allowing revisions have to be weighed against the administrative costs of channeling information between the buyer and bidders. Moreover, allowing for feedback and revision can make collusion easier.

5.4. *Targeted auctions when contracts vary in quality*

Landowners are likely to vary not only in their opportunity costs, but also in the quality of the environmental services they supply. This quality may depend on the landowner's actions or the biophysical characteristics of the land. A targeted auction (or a "score" auction) ranks bids by both price and quality. Such auctions theoretically are more efficient than the ones that ignore the heterogeneity of contract quality (Che, 1993; Latacz-Lohmann and Van der Hamsvoort, 1997). How much more efficient depends on the nature of the heterogeneity. If opportunity costs and environmental benefits are strongly negatively correlated or if the relative spatial variability of costs is much higher than that of benefits, an auction that ignores benefits will secure much of the environmental benefits that could be secured through a targeted auction (Ferraro, 2003b). Otherwise, there are potential gains from implementing a targeted auction.

The simplest way to target an auction is to separate bidders into different auctions where bidders are roughly homogenous with respect to the ecological values of their land. A more sophisticated approach would assign an environmental benefit value to each contract. Given the difficulties associated with assigning a dollar value to environmental services, conservation agents are likely to use some kind of scoring rule to assign a value to each contract. For example, the CRP uses an index that assigns points to each land parcel's attributes. Scientists working with the Bush Tender auction also created an index score for each site. Contracts were then ranked by their score per dollar. Ferraro (2004a) describes a nonparametric method by which conservation investment opportunities can be ranked when the conservation agent cannot convert multiple biophysical attributes into a one-dimensional measure of environmental benefits. This method can be integrated into a targeted auction.[10]

An important question is whether the benefit valuation rules should be shared with landowners. Announcing these rules can provide incentives for landowners to submit costly-to-fake signals of the environmental quality of their proposed activities about which the conservation agent may by uncertain or unaware (e.g., submitting a third-party certified management plan). However, quality differentiation may also offer landowners another source of rents that can be extracted from the conservation agent. Theoretical analyses of auctions with quality-differentiated goods show that heterogeneity of the auction items can influence the bid functions in a discriminatory auction (e.g., Milgrom and Weber, 1982).

In a laboratory auction experiment, Cason et al. (2003) find that when discriminative-price auction participants know the environmental value of their land, high-value landowners substantially inflate their offers. This strategic behavior increases conservation expenditures. Note, however, laboratory subjects in the no-revelation treatment had absolutely no information about how the buyer valued their units. In reality, landowners have reasonably accurate prior beliefs about the attributes of their land that are valued and thus the cost of revealing information might not be as high as implied by Cason et al.

Even if revealing the benefit valuation rules did raise expenditures, it is unclear whether obscuring the rules is politically feasible (lacks transparency, increases actual or perceived corruption) or practical (over time landowners are bound to figure it out or local advocates will help them). Revealing the rules may increase the perceived fairness of a discriminative-price auction because few people will publicly argue against the conservation agent seeking out the low-cost, high-quality contracts. As noted by Cason et al., revealing information about environmental benefits can also educate

[9] More precisely, the generalized Vickery auction was the cheapest.

[10] Bogetoft and Nielsen (2004) describe the properties of such a targeted auction.

landowners about the most beneficial land use changes and encourage investment in conservation.

If the value of a contract is determined not only by the landowner's ecosystem characteristics, but also by the characteristics of the portfolio of contracted parcels, one can consider a computer-assisted, combinatorial procedure to rank contracts. A combinatorial procedure can account for substitutability among contracts (e.g., by combining with maximum-coverage algorithms), or can incorporate the value of contiguity or the presence of thresholds (e.g., Ferraro, 2003a). Such values and thresholds can also be incorporated into the auction heuristically by using Geographical Information Systems software to compare different portfolio arrangements (e.g., alternative paths for a biological corridor). Another approach is to pay bonuses for parcels that are contiguous or meet certain area thresholds (e.g., Parkhurst et al., 2002). Such an approach would encourage joint bidding, but the theoretical properties of such bidding are unknown (Australia's Auction for Landscape Recovery allows joint bidding).

Incorporating the benefits of contiguity and the presence of thresholds may not only increase environmental services; it may also decrease the costs of monitoring because contracts are spatially concentrated. Conservation agents may also be able to take advantage of group contracts that can reduce the rents arising from hidden action through peer pressures exerted on members. There may, however, be a disadvantage to publicly seeking contiguous lands or minimum areas: collusion and holdouts are more likely.

5.5. *Repeated contracting*

Repeated PES auctions are likely to be the norm because buyers have administrative and information constraints that prevent them from contracting with every landowner simultaneously, and because buyers use contracts that are subject to expiration and renewal. Depending on the details about past auctions that are revealed publicly and on how well participants are able to communicate, landowners can extract information from previous auctions to recapture informational rents that were dissipated in early rounds of the auction. Such information includes the maximum accepted offer and the distribution of submitted offer prices.

Say, for example, a landowner finds out that her offer is lower than most others in a discriminative-price auction. She risks little by raising her price a little in the next auction. In the limit, everyone below the maximum accepted offer (MAO) will raise their price to that level and everyone above it will not participate: The auction will collapse to a posted-price scheme. If low-cost landowners knew of this potential outcome, many might refrain from participating in early rounds if contracts were of a greater duration than the auction cycle (in order to obtain a higher price in later rounds). A similar problem could arise in uniform-price auctions with multiple units because the marginal seller can exert some market power. With repeated auctions over time, the marginal sellers may be able to identify their position and power.

There is empirical evidence that farmers learned the MAOs over time in the CRP auctions in the 1980s (Shoemaker, 1989 and references therein). In simulations based on their theoretical model, Latacz-Lohmann and van der Hamsvoort show that neither complete uncertainty nor complete certainty about the maximum acceptable offer (MAO) is desirable in the discriminative-price auction. With high levels of uncertainty about the MAO, bidders tend to make high offers, while with high levels of certainty, low opportunity cost bidders make offers near the MAO and high-opportunity cost bidders do not participate. The authors suggest that, in the early auctions, bidders should be given some guidance as to the range of realistic payments. In later auctions, however, the bid acceptance mechanism should be concealed. In agent-based modeling (simulations), Hailu and Schilizzi (2004) also demonstrate that if bidders learn from previous outcomes, auctions are less able to reduce landowner informational rents.

Note that the "informational" problem associated with repeated auctions does not mean an auction is less efficient than a posted-price scheme, but rather that the auction's efficiency advantages may dissipate over time. This dissipation may potentially be delayed or eliminated through the use of a targeted auction. In a targeted auction, there is no maximum accepted offer price, but rather a minimum benefit–cost ratio, which is much harder to infer from public information about offer prices and expenditures (particularly if the environmental scoring method is not fully disclosed to landowners or changed periodically). Even more difficult to strategically manipulate would be a targeted auction that uses distance functions to rank contracts (Ferraro, 2004a) because a landowner would need to know (1) the distribution of offer prices, (2) the budget (if the program is budget constrained), (3) the distribution of contract attributes used in the distance function and (4) how to calculate the efficient frontier. How well such targeted auctions preserve an auction's rent-reducing powers is an empirical issue, which must be tested through laboratory and computational experiments.

5.6. *Other issues in PES auction design*

Because of space constraints, I cannot discuss in detail other relevant aspects of PES auction design, but these include: (1) revealing versus not revealing the buyer's budget (or a range of potential expenditures) prior to beginning a budget-constrained auction (Schilizzi and Latacz-Lohmann, 2006); (2) sealed-bid (landowners submit offers privately) versus open-bid auctions (landowners see others' offers), where one trades off the open format's information richness, which helps landowners estimate appropriate offers, with the format's susceptibility to collusion (Athey et al., 2004) and manipulation by local power structures and the format's cost of assembling landowners in a common location, virtual or real; (3) indivisible versus divisible offers, where land units may be divisible and thus increase bidders' strategy space and make predictions of bidding behavior more difficult (Back and Zender, 1993; McKee and Berrens, 2001; Wang and Zender, 2002); (4) rules to handle ties in multi-unit auctions (Kremer and Nyborg, 2004); (5) rules for closing the bidding period (Roth and Ockenfels, 2002); (6) the implications of PES contract bids involving both a *price* and a *promise* to perform a land-use activity, where bids will also depend on the consequences of not carrying out contractual commitments (Spulber, 1990); and (7) the performance of sub-optimal screening contracts (e.g., menus which do not consider all types) versus procurement auctions.

6. PES contracting in low and middle-income nations

Within the context of low and middle-income nations (and rural areas of high-income nations), PES programs may have two competing objectives: supplying environmental amenities at least cost and providing income redistribution to the rural poor. In such cases, one might reasonably ask if reducing informational rents should be a priority.

There are several responses to this question. First, as we have seen in the discussion above, reducing landowner informational rents is possible, but eliminating them for all landowners is not. Thus rent reduction does not imply rent dissipation. Second, it is not clear that low opportunity cost individuals are necessarily poor. Research in Costa Rica, for example, suggests that many of the PES contract recipients are absentee landlords who are neither poor nor likely to use the land in the absence of the PES program (Miranda et al., 2003). Third, in cases of fixed budgets for PES programs, reducing informational rents implies a tradeoff between larger payments for fewer people and smaller payments for more people. From a poverty-reduction point of view, it is not clear which outcome is more desirable. Given that budgets for ecosystem protection in low and middle-income nations are quite limited, one would need to make a careful case for paying information rents as a means of helping the rural poor.

My personal experience working in low and middle-income nations on conservation contracting leads me to believe that administrators in such nations are much more averse to payment differentiation than their counterparts in high-income nations. They perceive that large payments to a small group of landowners provide the necessary political support for a PES program. Moreover, there is a concern that landowners will perceive differentiated payments as unfair or manipulated to satisfy political constituencies or corruption rather than to meet environmental goals at least cost.

Given the institutional, informational and technical complexity of the three approaches to reducing rents, one might also wonder whether any of them are feasible in low-income nations. Targeting according to costly-to-fake signals requires human capital capable of identifying signals that are positively correlated with opportunity costs, and then organizing this information spatially. The ability to acquire and analyze biophysical information within Geographic Information Systems is quite widespread, ranging from low-income nations like Madagascar to middle-income nations like Costa Rica. It would be hard to imagine a nation that is capable of running a PES contracting program, but not capable of acquiring information on costly-to-fake signals and allocating contracts accordingly. Naidoo and Adamowicz (2006) demonstrate how practitioners can use even coarse data to produce maps of opportunity costs for conservation. These maps can be used, in combination with biophysical data, to more cost-efficiently target conservation activities.

Given the absence of conservation screening contracts in high-income nations, one might infer that the ability of administrators in low and middle-income nations to design them is questionable. That may be true, but the implementation (as opposed to the design) of such contracts seems well within the institutional capacities of many middle-income nations.

In contrast, auctions require substantial human capital to design and implement. However, auctions are used in low and middle-income nations for timber and forest products (e.g., Bhutan, Costa Rica, India, Indonesia, Thailand). Although such auctions are not necessarily functioning well or free from corruption, their existence does imply that administrators in low and middle-income nations are capable of implementing a PES procurement auction. Whether they are capable of designing and implementing a well-designed auction remains to be seen. Note, however, that PES procurement auctions are a relatively recent phenomenon in high-income nations and thus, like many institutional innovations, lessons may be learned and eventually borrowed and adapted for use elsewhere.

Whether one uses costly-to-fake signals, menus of screening contracts, or procurement auctions, the decision to differentiate payments rather than to use a uniform posted-price system typically involves greater transaction costs. These costs can be high in low and middle-income nations where buyers of environmental services are likely to be contracting with many small, often semi-literate, landowners (often without legal title) dispersed in remote rural areas. Costa Rica, however, has demonstrated how institutional innovations can reduce these transaction costs (e.g., using better informed, local nongovernmental organizations as intermediaries between small landowners and service buyers).

One final consideration is the prevalence of corruption in low and middle-income nations. Opportunities for differentiating payments may also provide opportunities for private gain by corrupt officials and their partners. Auctions will certainly be less effective in the presence of corruption that facilitates bid rigging,[11] but so too will the other two approaches because of the difficulty in verifying that the differentiation observed is based on the implementation of transparent rules.

7. Conclusion

The two dominant forms of price setting for PES contracts are bilateral bargaining and posted prices (i.e., fixed take-it-or-leave-it prices). However, these two methods may result in highly inefficient outcomes because information between contract buyers and sellers is highly asymmetric. More precisely, landowners in such circumstances use their private information as a source of market power to extract informational rents from conservation agents.

Reducing informational rents is an important task for buyers of environmental services who wish to maximize the services obtained from their limited budgets. Any approach that reduces informational rent also mitigates concerns about additionality (a situation in which a PES contract results in environmental

[11] Moreover, in low-income nations with common knowledge of corruption, the conservation payment may not be viewed as non-stochastic and thus the offer-reducing effects of discriminative auctions with risk-averse bidders (Section 5.3) may not be observed.

Table 1 – Approaches to addressing hidden information in PES contracting

Approach	Institutional complexity	Informational complexity	Technical complexity	Rent reduction	Distortion to contracted services	Comments
Target based on costly-to-fake signals	+	++	+	+	++	Good when correlations between signals and landowner costs are strong; information acquisition can be costly; field examples exist
Screening contracts	++	+++	+++	++	+++	Theoretically powerful; technically challenging; no field examples
Procurement auctions	+++	+	++	++	+	Rent reduction requires competition among sellers; ability to reduce rents in a repeated contract environment is unknown; field examples exist

+Low; ++Medium; ++ High.

services beyond the level of services that would have been provided in the absence of the contract). By paying less for contracts to low opportunity cost landowners, who are least likely to provide different levels of services in the absence of a contract, buyers free up money to contract with higher opportunity cost landowners, who are more likely to provide substantially different levels of services in the absence of a contract.

In Sections 2–5, I highlighted three general approaches for reducing informational rents: (1) gathering more information on landowners in the form of costly-to-fake signals; (2) relying on screening contracts (self-selection mechanisms); or (3) harnessing competitive forces through procurement auctions. Table 1 summarizes these approaches along five important dimensions. No single approach dominates the others.

Would any of these approaches be worth their administrative costs? The net gain from reducing landowner informational rents through payment differentiation will depend on the degree of asymmetry of information (the less informed the buyers, the greater the gain) and the heterogeneity of costs among suppliers (the more heterogeneous, the greater the gain). Differentiated payments are better suited for PES programs with many potential contracts. In a spatially concentrated program with few landowners, the administrative costs for implementing differentiated payments would likely swamp the reductions in informational rents (particularly for auctions, which require competition among bidders to perform effectively).

Most nations capable of implementing PES schemes have the capacity to differentiate along costly-to-fake signals. The design and implementation of screening contracts and procurement auctions, however, poses more challenges and there is little field experience to guide novices. In the short-term, experimentation with screening contracts and procurement auctions is more desirable in high-income nations, although experimentation in middle-income nations like Costa Rica and Mexico will also be beneficial.

Moreover, current efforts in PES contracting suffer from a number of other problems in addition to asymmetric information. It is not clear that investing in mechanisms to reduce informational rents is more important than, for example, investing in methods to measure ecosystem services themselves. PES contracts are often based on land-use activities (or lack of activities) rather than the quantity of ecosystem services provided.[12] Such contracts provide landowners with few incentives to invest in cost-reducing innovations (e.g., finding cheaper ways to grow endangered species habitat). Some approaches to reducing informational rents might provide tangible incentives for innovation (e.g., uniform-price auctions because the potential gains in rents from innovation are large), but it may be that expenditures could be reduced even more by tying payments to outputs rather than inputs, which would encourage landowners to innovate and supply the services at a lower cost (of course, asymmetric information may prevent buyers from benefiting from cost decreases).

Because of space constraints, I have ignored other important issues such as dynamic adverse selection (commitment problems when landowner types are constant; tradeoffs between intraperiod risk sharing and intertemporal consumption when landowner types may change from exogenous shocks), adverse selection with multidimensional types (in particular the issue of bundling, which may be relevant to PES programs), and incomplete contracts (contracts that do not explicitly deal with all possible contingencies). Because of space constraints, I have also ignored the problem of hidden action.[13] None of these issues should be ignored.

In conclusion, contract theory offers relevant insights into the design of PES programs, but it is worth remembering the simplified nature of the theory's models, the way in which results depend on parameters and institutional assumptions, and the complexity of the prescriptions that are often revealed by the models. More theoretical work, combined with laboratory test-bed experiments and small-scale field experiments, will be necessary to improve the design of PES contract systems.

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[12] Australia's new EcoTender program, which uses an auction, is experimenting with basing part of the payment on outcomes rather than inputs.

[13] Theory implies that the solution to the hidden action problem is to reward landowners most for outcomes that are most likely to arise when they put in the required effort and punishing them the most for outcomes that are most likely to occur when they shirk (e.g., Bolton and Dewatripont, 2005).

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