Auctioning biodiversity conservation contracts: an empirical analysis

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Abstract
This paper reports on the design and implementation of an auction of conservation contracts on private land in Victoria, Australia. We demonstrate that is possible to create at least the supply side of a market for nature conservation and in conjunction with a defined budget, to discover prices and allocate resources to biodiversity conservation. The paper compares a discriminative price auction with a hypothetical fixed-price scheme showing that an auction could offer large cost savings to governments interested in nature conservation on private land. As a result of the pilot, a number of important auction and contract design problems have emerged which deserve further investigation including: multiple complementary environmental outcomes, site synergies, reserve prices, sequential auction design and the role of new technology in contract design. Nevertheless, the paper does show that auctioning conservation contracts for environmental outcomes is an important new policy mechanism that performs according to theoretical expectations and deserves closer examination by government and environmental groups.

Key words: auction, conservation, contract, asymmetric information, pilot.

1. Introduction

A century ago in Australia food and fibre were scarce relative to the supply of habitat. Today the opposite could be argued. Governments now face the problem of encouraging landholders to provide public goods, such as habitat conservation, in the face of an economic environment that facilitates the production of private goods.

Governments, both in Australia and overseas, have used a wide range of policy mechanisms to influence private land management including fixed-price grants, tax incentives, voluntary schemes etc. Latacz-Lohmann and Van der Hoomsvoort (1997) propose, however, that auctioning conservation contracts as a means of creating markets for public goods has many theoretical advantages. They argue that competitive bidding, compared with fixed-rate payments, can significantly increase the cost effectiveness of conservation contracting because of the cost revelation advantages of bidding processes.

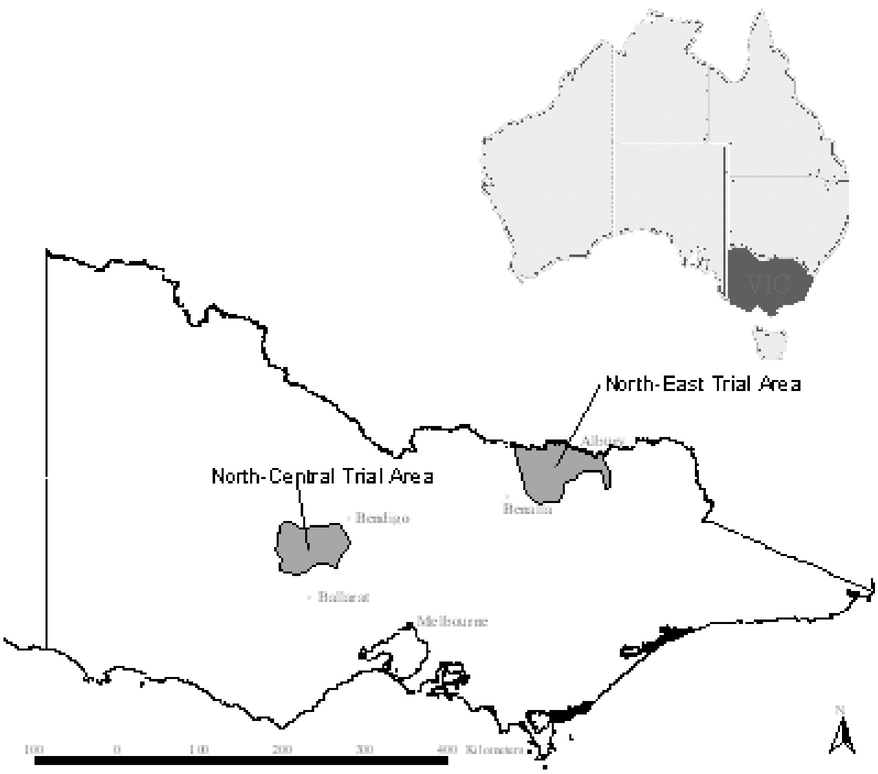
This paper examines the performance of an auction of nature conservation contracts conducted in the North East and North Central regions of Victoria (Figure 1). Run as a pilot, this auction differs from existing conservation programs in Australia, the U.S. and the U.K. in that it was specifically designed for nature conservation purposes, drawing on the now extensive auction and contract design literature and incorporating new approaches to measuring habitat quality.

2. Conservation of biodiversity on private land

In Victoria (Australia) there is over one million hectares of native vegetation remaining on private land. Much of it is of high conservation significance providing habitat for native plants and animals as well as generating other environmental services. Approximately 15 per cent of Victoria's threatened vegetation types rely solely on private land for their survival. An additional 29 per cent of threatened vegetation types occur largely on private land, making private land conservation an imperative if these species are to be conserved. Conserving biodiversity on private land has been an important, but elusive, objective for government agencies. Generally, it has not been feasible to include remnant vegetation on private land in the national reserve system. This is because remnants are often of small scale and are spatially dispersed so that incorporating them into the reserve system would involve high maintenance and protection costs and would not take advantage of local knowledge, expertise and resources. Fitzsimons and Wescott (2001) argue that public reservation is unlikely to be successful from a biodiversity point of view anyhow, they state: ‘it is …increasingly recognised that strict reservation alone will not conserve all, or even most, biodiversity’, and that ‘effective off-reserve conservation measures are needed to ensure the effective conservation of species, communities and ecosystems’.

Despite government programs, many important biodiversity assets on private land remain subject to degradation due to land-use practices such as livestock grazing, firewood collection and weed and pest invasion. NRE (2000) concluded that the existing programs employed to achieve biodiversity conservation objectives have ‘failed to engage landholders, particularly commercially oriented farms’.

Figure 1: Location of the auction of conservation contracts



2.1. Nature conservation programs

In Australia, it is State governments that have legislative and administrative responsibility for private land. All state, for example, have legislation controlling clearing of native vegetation and various programs have been developed to arrest decline in the stock and condition of native vegetation. Both State and Commonwealth Governments provide funding for these programs. At the Commonwealth level, around $3.9bn has been allocated to a seven-year program intended to improve environmental management (including nature conservation). These funds are administered through the Natural Heritage Trust and The National Action Plan for Salinity and Water Quality. State governments separately contribute to these and other nature conservation programs employing a range of mechanisms including community and catchment-based planning, voluntary programs, fixed-price subsidies and grants (eg. fencing grants), education programs and capital works programs.

Although there is general acknowledgment that these programs have altered community awareness about environmental issues, there is not a widespread belief that they have cost-effectively achieved significant on-ground outcomes. For example, the Australian National Audit Office (2001) commented on the Natural Heritage Trust by saying that the program has been successful in 'raising awareness and empowering communities, fostering integrated planning…but few projects have the potential to lead to broad scale long term landscape outcomes…and is…poor in monitoring, administration and cost shifting'. Thus, while achieving attitudinal shift, these programs have been less effective at delivering and demonstrating improvements in the environment.

3. The Economics of Nature Conservation on Private Land

It is widely acknowledged that existing markets and institutions misallocate resources to environmental goods and services. Markets are generally efficient in allocating resources to 'exploitation activities' but may be ineffective or nonexistent with respect to environmental conservation. Commodity markets, for example, provide clear signals to individual landholders about the value of clearing land for agricultural production, yet markets for conservation actions are often missing or inefficient.

Ideas about why markets are missing or inefficient have changed over time. Coase (1960) argued that when property rights are clearly defined, market players will bargain to achieve an efficient solution (create a market), assuming that transaction costs are zero. However, when transaction costs are positive, the institutional arrangement that minimises these costs should be preferred. Thus the boundaries of the firm, and by extension, the market, are found by finding the organizational form that minimizes transactions costs.

The basic idea that information asymmetry affects the way markets operate was introduced by Akerlof (1970). Subsequently, many economists have refined our understanding of how the distribution of information affects market players, and how these players may or may not respond to the problem (see, for example, Laffont 1990). The literature on information economics has forced economists and policy makers alike to reassess policy mechanisms employed for many public policy problems. Likewise, there are new insights into policy mechanism design that arise from the application of information economics to environmental problems. Latacz-Lohmann and Van der Hamsvoort (1997) explain how information asymmetry affects the functioning of markets for environmental goods and services associated with private land. They note that there is a 'clear presence of information asymmetry in that farmers know better than the program administrator about how participation (in conservation actions) would affect their production plans and profit'. Likewise, environmental experts not landholders, hold information about the significance of environmental assets that exist on farm land. Further, landholders may not have all the relevant information about government priorities and are unlikely to understand how this information might influence subsequent contracts. Hence, although flat-rate Pigouvian taxes and subsidies may 'correct' market failures in circumstances where information asymmetry is not evident, other policy mechanisms will be needed when information is hidden. Latacz-Lohmann and Van der Hamsvoort (1998) conclude 'that some institution other than a conventional market is needed to stimulate the provision of public goods from agriculture'. They argue that auctions are 'the main quasi-market institution used in other sectors of the economy to arrange the provision of public-type goods by private enterprises'.

Auctioning conservation contracts is, therefore, a means of creating missing markets for nature conservation. The basic proposition is that markets for nature conservation are missing because of the asymmetric information problem and that policy mechanisms can be designed to reveal hidden information needed to develop meaningful contracts between government and landholders. It is contended that this process will facilitate price discovery and allow resources to be allocated where this has been difficult and inefficient in the past. The following sections draw on auction and contract design literature to identify the key features of this approach.

3.1. Auction design

Formal analysis of auctions in the economic literature is relatively new. While a complete literature review on the many design aspects of auctions is beyond the scope of this paper, a broad understanding of the underpinnings of current theory is instructive. Early work on auctions stems from the seminal papers of Friedman (1956) for the case of a single strategic bidder, and Vickrey (1961) for the equilibrium game theoretic approach. The development of appropriate game theoretic tools has made auction theory an increasingly researched topic. The three broad models studied are: the independent private value model of Vickrey (1961), the symmetric common value model of Rothkopf (1969) and Wilson (1969, 1977) and the asymmetric common value model of Wilson (1967). Several survey articles summarise the auction design literature (see McAfee and McMillan 1987), Wolsfstetter (1996), and Klemperer (2002)). Latacz-Lohmann and Van der Hamsvoort (1997) apply this literature to the identify the key features of an auction of conservation contracts.

The possibility of collusion between landholders bidding in an auction is always an important consideration in the choice of auction format. Repeated open, ascending and uniform-price auctions are generally more susceptible to collusion than a sealed-bid approach (see

Klemperer 2002). Moreover, where bidders are risk-averse, as we might well expect with private landholders, a first-price sealed bid auction will facilitate lower bids because landholders can reduce commodity and weather related income variability by adding a regular income stream from conservation payments (Riley and Samuelson 1981).

Latacz-Lohmann and Van der Hamsvoort (1997) note that a single round of bidding is preferred to multiple rounds because landholders are assumed to have independent private values rather than common values. In a private values model, each agent knows their own valuations with certainty but makes predictions on the values of others, while in the common values world, players have identical valuations but form their estimate on the basis of private information. In a common values world, agents will be able to learn about the 'common value' of the asset through the bidding strategies of all the other agents (as each agent has private information on the value of the asset). Thus, multiple rounds of bidding can facilitate information aggregation in the market and enable bidders to get a better sense of the true (common) value of the asset. This can help to mitigate the 'winner's curse'—the situation where an item is allocated to the most optimistic bidder, rather than the bidder who values it most. However, where values are private and specific to each individual, information aggregation does not yield superior outcomes. Variation from farm to farm with respect to soil quality, rainfall, production systems etc. suggests that each landholder would base their bid on private, rather than common information about opportunity costs and would be unlikely to alter this bid when given information about other landholders' valuations.

Where bidders draw valuations from different distribution functions, Myerson (1981) argues that optimal auction design is achieved by assigning contracts to the lowest bidders. Note that the performance of the auction format can be thought of from two perspectives. Firstly, as in the Myerson (1981) case, which format maximises the value created and secondly, how does the auction divide value between the buyer and the suppliers? These questions lead to consideration of whether a one-price or price discriminating auction should be employed. Though the theory on optimal bidding strategies in a discriminatory price auction versus a one-price auction is inconclusive, it is worth noting that in the event that both formats are successful in achieving truthful revelation, a discriminatory price auction is analogous to a first degree price-discriminating monopolist. As such, there will be a change in the distribution of value, not the quantum of value created. Similarly, in the context of an auction of nature conservation contracts, the discriminatory price auction would, subject to the caveat highlighted above, achieve the same outcome as the one price approach, but at lower cost. However, because of asymmetric information, the ranking of bids may change because the bids of agents in an auction may include information rents (see section 3.3 for a technical exposition) whereas agents in a one-price scheme will enter bids based on opportunity cost.

Cason *et al.* (2003) used laboratory experiments to examine bidder behaviour in an auction when the value of their output was known, compared with when it was not. These experiments indicate that when bidders did not know the value of output, their bids tended to be based on the opportunity costs of land-use change. By contrast, when bidders were given information about the significance of their biodiversity assets, they tend to raise bids and appropriate some information rents.

A reserve price strategy is a key element of auction design. However, reserve prices are less important where there is a budget constraint (see Myerson 1981, Riley and Samuelson 1981). However, in repeated auctions, a reserve price strategy would become more important. In a repeated auctions situation it would be possible to transfer funds between rounds of auctions to maximise the nature conservation outcomes presented in other regions, or in subsequent auctions. In particular, an appropriately designed reserve price would have implications for inter-temporal resource allocation, from both the State's, and farmers' perspective.

In summary, the key design elements relevant to auctioning nature conservation contracts to private landholders include: *first-price, sealed bid, single round, price minimising and price discriminating format.* A severe budget constraint applied to the auction and a reserve price was not formulated *a priori*. In the pilot auction, the exact value of the landholder's biodiversity asset was withheld from the landholder to improve the auction's cost-effectiveness. There are, however, other considerations that may influence this strategy. These are discussed later in the paper (see section 6).

3.2. Contract design

There are many design issues that arise in the development of contracts between government (the principal) and landholders (agent) to conserve biodiversity on private land. From contract theory, the main problems of contract design relate to incentives and asymmetric information. Specifically these problems are manifested as *adverse selection*, *moral hazard* and *observability*. Other problems of contract design include commitment, credibility and incomplete contracts (Salanie, 1997).

Adverse selection refers to situations where agents have private information on their types that would be valuable to the principal in terms of contract design. In the case of nature conservation contracts, the opportunity cost of land-use is hidden from the principal but will be important in the selection of successful contracts and in the price associated with conservation services offered. The problem with adverse selection here is the payments of *information rents* to induce the agent to reveal private information (Salanie, 1997).

Moral hazard refers to the problem of agents hiding their actions. It leads consideration of contracts that mitigate against agents 'shirking' their commitments (Laffont and Martimort, 2002). Even if contracts can be designed to prevent adverse selection and moral hazard, outcomes may still be un-*observable*. Observability has implications for monitoring and enforcement of contracts and their subsequent incentive effects on agents' behaviour (Laffont and Martimort, 2002). Observability is a problem with nature conservation contracts because it is difficult to measure and monitor the status and resilience of habitat for native plants and animals. For example, monitoring the impact of changes to land management in terms of the improvement in the stock and quality of fauna and flora would be very costly and subject to dispute. An alternative strategy would be to specify a contract on the basis of inputs that can be expected to improve habitat quality, such as fencing, weed control, understorey protection etc. These inputs are known to improve habitat status and resilience, but the transformation function that maps these actions (inputs) into outcomes is not known with certainty, even if the actions were carried out diligently. Further, the effect of unexpected events, such as drought and floods, could not reasonably be predicted by the agent (landholder), nor the principal (government).

These two problems (unobservability of outcomes and imperfect knowledge about the transformation function) were considered by Ouchi (1979), and explained in the context of the public sector by Wilson (1989). Williamson (1985) has characterised this as the problem of 'measurement'. The principal-agent literature has considered one or both of these problems to varying degrees (see for example, Holmstrom and Milgrom 1991, 1994). This literature has recommended a host of ways to deal with these difficult problems, including: organising activities inside the firm; using fixed pay arrangements (again inside the firm); and contracting on the basis of inputs.

Conservation contracts for the pilot were developed based on inputs rather than outcomes. This was because there were no low-cost means of measuring outcomes on which to base (enforce) these contracts. Because environmental benefits vary from site to site (non-standard benefits)), *individual management agreements* specifying a schedule of management commitments were employed with *progress payments* made on the basis of *inputs*. This allowed the government scope to identify what actions were valuable, from a nature conservation perspective, and for landholders to choose a menu of actions that they prefered. For example, on some sites regenerating understorey was an imperative, whereas on others agreeing not to collect firewood (this action disturbs habitat) was relatively important. Contracts extending over three years were developed with approximately one third of participants *monitored* each year. This provided government with a simple sanction in the case of non-performance: ie. funds can be withheld or withdrawn.

This type of contract has implications for risk bearing. Specifically, the government agency bears most of the risk associated with structural parameters where contracts are specified in terms of inputs. This was considered sufficient for the pilot, where the main purpose was to test the auction mechanism and the supporting information systems. However, improvements in knowledge (for example, new technology that allows lower cost monitoring of species prevalence) may enable a government agency to base at least part of its payments on output.

3.3. A bidding model for nature conservation on private land

It is possible to represent an auction for nature conservation contracts as a model of optimal bidding behaviour. In this model, an agency such as the government, wishes to purchase remnant vegetation using a first-price sealed bid auction from N landholders (indexed by $i = 1, 2, 3, \ldots, N$). The government purchases remnant vegetation from private landholders based on three factors:

The biodiversity significance of remnant vegetation. - Landscapes that have been modified for agricultural purposes will not necessarily retain a representative mix of habitat types. One way of expressing the conservation value of different types of habitat is with a Biodiversity Significance Score (BSS) where BSS_i represents the biodiversity value of i's remnant vegetation. The Biodiversity Significance Score draws on information about the scarcity of vegetation types and its Ecological Vegetation Classification[11] (NRE, 1997).

The improvement in habitat associated with landholder actions - There are a number of actions that landholders can take to improve the condition of habitat on private land. These include fencing to exclude stock from remnant vegetation, controlling environmental weeds and pests, minimising habitat disturbance by not harvesting firewood etc. The value of these habitat management actions can be expressed as a Habitat Services Score (HSS) where HSS_i represents the change in quality of habitat of i's habitat management actions (Parkes *et al.*, 2003).

A bid - The nominal bid (b_i) submitted by i to protect and enhance the remnant vegetation offered into an auction.

This information is summarized in a Biodiversity Benefits Index (BBI) for each landholder i:

$$BBI_i = \frac{BSS_i \cdot HSS_i}{b_i} \qquad (1)$$

Assume for simplicity each i has only one site of remnant vegetation to offer in the auction. This means, in the following discussion that i can be referred to as site i or landholder i interchangeably.

The government purchases i on the basis of (1). The higher the BBI_i, the more desirable it is from a biodiversity perspective and a budgetary cost-minimization perspective. BBI_i is positive in BSS_i and HSS_i but negative in b_i. So, by using BBI to explicitly measure the desirability of i, the government rewards high BSS_i and HSS_i but punishes high b_i. Landholder i knows HSS_i and determines b_i endogenously. Following Cason *et al.* (2003), BSS_i is not revealed to i. This means i faces uncertainty of BBI_i. Given this, we can rewrite (1) as:

$$E[BBI_i] = \frac{E[BSS_i] \cdot HSS_i}{b_i} \qquad (1')$$

Where $E[\bullet]$ denotes expectations of the variables in square brackets.

The government also has a fixed budget allocated to the auction of some amount M; and purchases the most valuable i on the basis of (1) until the budget constraint binds. From landholder i's perspective there are two sources of uncertainty: 1) uncertainty of BBI_i as given by (1'); and 2) whether or not the addition of i to the government's purchases violate the budget constraint. We can summarize the probability of b_i being accepted by government as:

$$\Pr(b_i \; accepted) = 1 - F(b_i) \qquad (2)$$

Where, $F(b_i)$ is the cumulative probability distribution function of b_i. In writing (2), we make the simplifying assumption that landholder i bases expectations on succeeding in the auction on the choice of b_i and not on HSS_i or $E[BSS_i]$. This may be plausible if landholders do not have any way of determining the *relative* value of HSS_i or $E[BSS_i]$. Given (2), i will submit b_i if the expected utility from participation exceeds reservation utility:

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[1] Ecological Vegetation Classes indicate whether vegetation is presumed extinct, endangered,

$$U_i\left(\pi_i^0 + b_i\right)\cdot\left(1 - F\left(b_i\right)\right) + U_i\left(\pi_i^0\right)\cdot F\left(b_i\right) > U_i\left(\pi_i^0\right) \qquad (3)$$

Following Latacz-Lohmann and van der Hamsvoort (1997), U_i is a von Neumann-Morgenstern utility function for i that is monotonically increasing and twice differentiable. π_i^0 and π_i^1 is reservation profit (eg, agriculture on site *i*) and profit of conservation of site *i* respectively. Assume $\pi_i^0 > \pi_i^1$ and so by the monotonicity of $U_i(\bullet)$, $U_i\left(\pi_i^0\right) > U_i\left(\pi_i^1\right)$. In (3), the first term on the left-hand side is the expected utility of succeeding in the auction, and the second term on the left-hand side is expected utility of not succeeding. (3) can be seen as the *participation* condition; for *i* to participate in the auction, expected utility of participation must be strictly greater than non-participation. If we assume all *i* are risk-neutral we can rewrite (3) as:

$$\begin{aligned} &\left(\pi_i^1 + b_i\right)\cdot\left(1 - F\left(b_i\right)\right) + \pi_i^0 \cdot F\left(b_i\right) > \pi_i^0 \\ &\left(1 - F\left(b_i\right)\right)\cdot\left(\pi_i^1 + b_i - \pi_i^0\right) > 0 \end{aligned} \qquad (4)$$

(4) follows from the definition of risk-neutral agents: such agents do not care about the variablity of utility, only the net utility gain. If we assume *i* is risk-averse, the main findings do not significantly alter (Latacz-Lohmann and van der Hamsvoort, 1997). (4) can be viewed as the optimization problem for *i* where the choice variable is b_i. Taking derivatives of (4) with regard to b_i yields:

$$\left(1 - F\left(b_i\right)\right) - f\left(b_i\right)\cdot\left(\pi_i^1 + b_i - \pi_i^0\right) = 0$$

$$\pi_i^1 + b_i - \pi_i^0 = \frac{\left(1 - F\left(b_i\right)\right)}{f\left(b_i\right)} \qquad (5)$$

$$\therefore b_i^* = \pi_i^0 - \pi_i^1 + \frac{\left(1 - F\left(b_i^*\right)\right)}{f\left(b_i^*\right)}$$

$f(b_i)$ is the probability density function associated with $(1\text{-}F(b_i))$. An economic interpretation of $f(b_i)$ is that it represents the marginal change in probability of *i*'s bid being accepted with a

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vulnerable, depleted etc.

change in b_i. b_i* is the optimal bid submitted by a risk-neutral landholder. b_i* is increasing in opportunity cost of protecting and enhancing site *i* (ie, $\pi_i^0 - \pi_i^1$) and information rents (ie, (1-$F(b_i^*)$)/$f(b_i^*)$). Note that (5) is not the solution to the landholder's bidding problem but merely provides us with a convenient way of analysing the composition of bids (for the solution to this problem see Latacz-Lohmann and Van der Hamsvoort, 1997). Landholders will submit higher bids the more costly conservation is on their property. The intuition behind information rents may not be so obvious. Information rents arise where there is asymmetric information; in this case, *i* holds information that is valuable to the government, the opportunity cost for *i* of remnant vegetation conservation. The government in effect 'bribes' *i* to reveal this information through the payment of information rents. From (5), information rents are represented by the quotient of probability of b_i being accepted and the marginal change in probability with regard to b_i; in other words, information rents depends on the trade off between the probability of acceptance and the marginal change in probability. Also from (5), information rents deviate from the first-best, perfect information outcome by (1-$F(b_i^*)$)/$f(b_i^*)$. Formally, the first-best outcome is:

$$b_i^{FB} = \pi_i^0 - \pi_i^1 \qquad (6)$$

The first-best bid is purely dependent on the opportunity cost of conservation (for a more general explanation see Laffont and Martimort, 2002). A comparison of (5) and (6) suggests that asymmetric information imposes costs on the government and hence, the use of a first-price sealed bid auction may be a second-best solution. To see this, note that information rents are increasing in the probability of b_i being accepted by the government. Landholder *i* will increase information rents if the probability of acceptance is higher. Information rents are decreasing in $f(b_i)$, the marginal change in (1-$F(b_i)$) due to a change in b_i. So, the more sensitive the probability of acceptance is to b_i, the lower are information rents. The general idea that bids are greater than opportunity cost (because of information rents) is supported by experimental economic studies such as Cason, *et al.*(2003).

4. Results

A total of 126 expressions of interest were received from landholders within the regions in which the pilot was conducted (see Table 1). These landholders were visited by a field ecologist who assessed the quality and significance of the native vegetation (Biodiversity Significance Score) on the site and discussed management options (in terms of actions and Habitat Services Score) that might be considered by the landholder. Following field visits, 98 bids were received in which landholders nominated conservation actions and an offer price submitted as a sealed bid. All bids were ranked according to a Biodiversity Benefits Index (see (1)) and contracts were allocated up to a budget constraint. A total of 73 of these bids were allocated contracts.

Table 1: Participation in the Auction

Variable	Expression of interest	Bids	Contracts
Participation (no.)	126	98	73
Sites assessed (no.)	223	186	131
Area of sites (ha)	3,845	3,478	3,160

Contracts allocated in the auction were written against a sequence of inputs and actions specified in management agreements over a three-year period. An initial payment was made to successful bidders to cover capital costs, where specified (eg. for constructing fences) with annual progress payments made on the basis of performance. A budget of $400,000 enabled contracts to be established for 3,160 hectares of habitat on private land. Table 2 summarises the management actions included in the successful contracts. From this table it can be seen that most of the budget was allocated to improving remnant vegetation rather than to recreation of habitat through supplementary planting. Revegetation actions were selected on only 37% of sites offered to the auction.

A survey of both participants in the auction and non-participants in the pilot region (sample of 380) was conducted to provide information about the characteristics of bidders. The major conclusion to be drawn from these data is that participants in the nature conservation auction were a random draw of the rural population in the pilot areas with respect to age, education attained, agricultural enterprise mix etc. (Ha *et al*., 2002). Participants were more likely than the population to be environmentally-aware (signified by membership of an environmental organisation) and to operate relatively less intensive agricultural enterprises.

Table 2: Actions Undertaken by Landholders

Landholder commitments	Number of sites	% of sites
Retain large trees	182	81.6
Retain other standing trees	174	78.0
Exclude stock	195	87.4
Retain fallen timber	194	87.0
Control rabbits	202	90.6
Control weeds	136	61.0
Supplementary planting or revegetation	82	36.8

The mean and coefficient of variation for selected bio-physical characteristics are shown in Table 3. Area of site, HSS and HSS/Bid are highly variable. In contrast, BSS and Bid have relatively lower variability. Five vegetation classes were represented in the bids, these are: lower slopes hills or woodlands; box-ironbark forests and woodlands; riverine grassy woodlands or forests; plains grassy woodlands or forests; and dry forests.

Table 3: Bio-physical Characteristics of Landholders

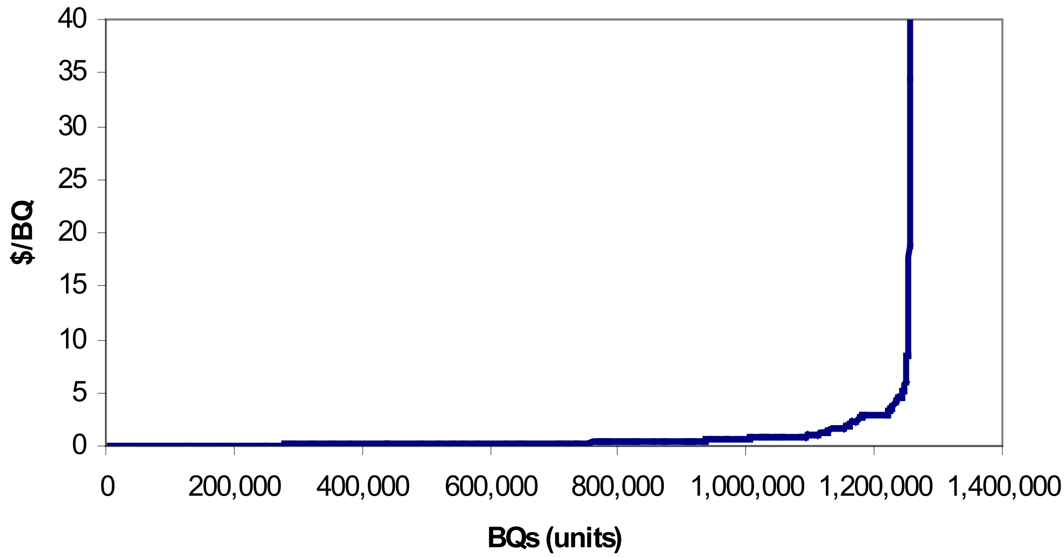
Variable	Mean	Coefficient of Variation
Area (ha.)	27.07	1.51
BSS (units)	36.17	0.31
HSS (units)	250.83	1.61
Bid per farm ($)	4,607.29	0.67
HSS/Bid	.052	1.46

4.1. Analysis of bids

Drawing on information from the bids, Figure 2 illustrates the cost of generating additional units of biodiversity. The horizontal axis depicts the total quantity of biodiversity supplied, weighted by biodiversity quality (BQ). These units are the numerator of the BBI as given in (1): the biodiversity significance score times the habitat services score. The bids shown in Figure 2 are *inclusive* of any 'information rents' that landholders may have included in their bid price[2] as in (5): we assume here that opportunity costs and information rents make up bids. However, we will henceforth refer to this curve as a marginal cost or supply curve for biodiversity from the auction inclusive of the social cost of information rents. This is different to the characterisation of Latacz-Lohmann and Van der Hamsvoort (1998), who differentiate the supply curve on account of it being *exclusive* of rents.

As shown in Figure 2, the supply curve for biodiversity is relatively flat over much of the quantity range, but then transforms to relatively steep as the quantity of BQs exceeds 1.2 million units. Further analysis of marginal and unsuccessful bids revealed that these bids were uncompetitive because of the low conservation status and or habitat services nominated rather than the bid price offered.

Figure: 2 Marginal Cost Curve



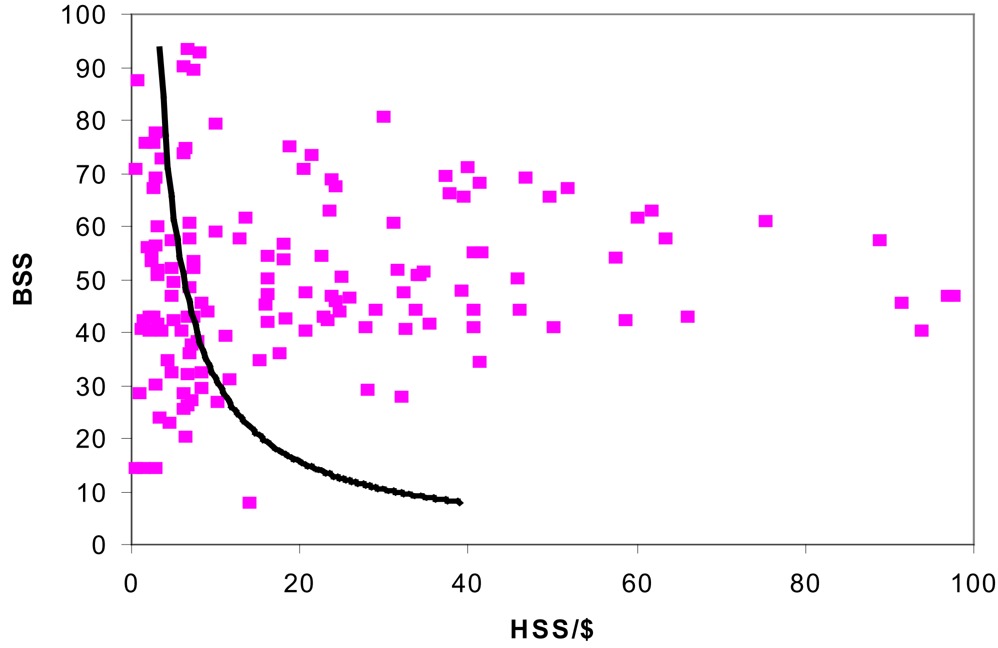
Although the pilot auction was conducted without a reserve price, future nature conservation auctions would benefit from a reserve price strategy, particularly if run sequentially. The marginal cost curve for biodiversity provides information that would be useful in formulating a reserve prices strategy. With experience the government agency could withhold some funds from one auction in anticipation of more cost-effective bids in the next round.

[2] Thus the farmers may have information about the Government's willingness to pay for biodiversity on their land, and adjust their bids accordingly.

One of the theoretical attractions of an auction of conservation contracts noted by Latacz-Lohmann and Van der Hamsvoort (1997) was that competitive bidding would reveal information about the opportunity cost of individual landholders thereby leading to improved cost effectiveness of nature conservation programs (see (5). Information about individuals' opportunity costs is particularly important when agents are heterogeneous and hold private information of relevance to policy makers. Figures 3 plots the actual bids received in the auction expressed in terms of the improvement in habitat per dollar of bid (HSS/$ on the horizontal axis) and the biodiversity significance of each bid as measured by the Biodiversity Significance Score (BSS see section 3); both axis are scaled from 0 to 100. Bids at the top-right of the diagram represent high biodiversity significance and low offer price - the preferred bids. This figure illustrates that there was in fact a large variation in both the price of improvements to habitat quality and the significance of biodiversity represented on each site. While the average bid was around $4,600 with relatively low variation between bids (coefficient of variation 0.67) the variation between bids is magnified when bids are compared on the basis of the habitat service provided per dollar of bid. From Table 3, HSS/$ has a coefficient of variation of around 1.46. Revelation of otherwise hidden information about costs and the conservation service offered allowed program administrators to take advantage of this diversity and increase the quantum of biodiversity improvement for the given budget.

A budget line has been identified in Figure 3. This budget line was constructed equalising all bids' BBIs with the last successful bid. This was done by changing all the bids until all BBIs were equal to the last successful BBI. All bids to the right of the budget line were successful while those to the left were unsuccessful. The horizontal distance between the threshold BBI and any successful bid represents a surplus or rent to the government agency running the auction. Holding all else constant, this is the gain to the government agency from this contract. Note, again, that value is maximized by allocating the contracts to the lowest bidders. Choosing to do so at the bid, or offered price (i.e. adopting a discriminatory price auction) implies that value was apportioned favourably for the State.

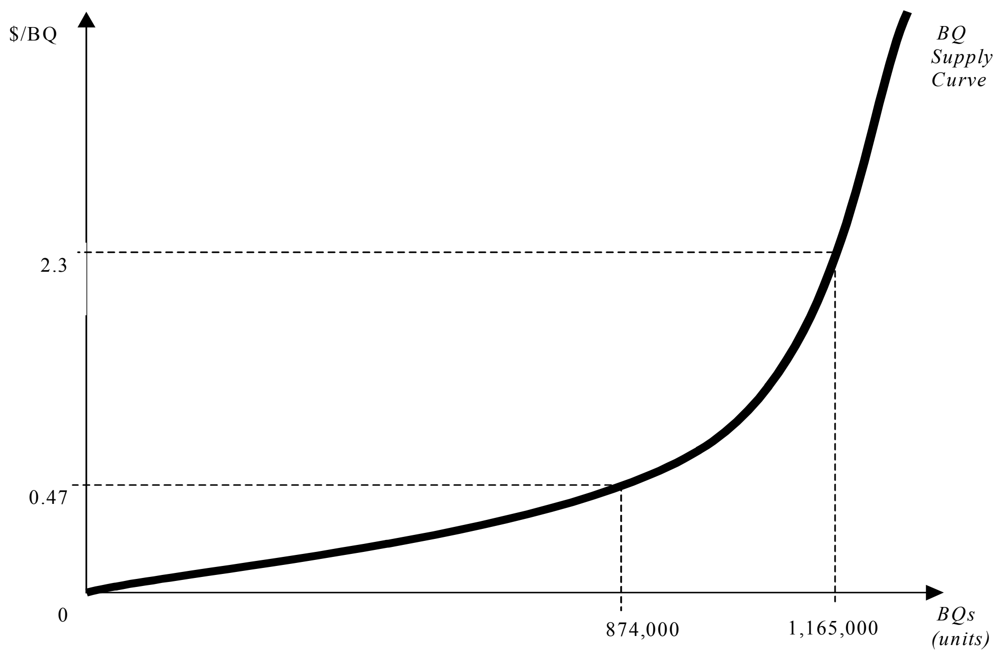
Figure 3 Threshold-BBI and Bid Data



Although it is difficult to compare the results from the auction with other mechanisms, it has been possible to examine how a hypothetical fixed-price scheme would perform compared with the discriminative price auction used in the pilot. To make this comparison, we must assume that bidder behaviour would not change if a fixed-price scheme were used. Specifically, we assume that the ordering of bidders would not change with different schemes which means the marginal bidder does not change and, as a result, the value created does not change between the schemes. We justify this assumption by first recognising that it is likely that individual landholders' behaviour is likely to change with different schemes but *a priori* theory or empirical evidence does not allow us to assume how the supply curve changes.

Figure 4 illustrates that in a fixed-price scheme, an agency would pay each successful landholder the same price: the price of the marginal offer. 'Price' here is dollars per BQ. For the last unit of biodiversity purchased in the auction, this marginal price is approximately \$2.30 (see Figure 4). This is the price that an agency would need to offer to all landholders to generate the same supply of biodiversity made available from the price discriminating auction (approximately 1.16 million units of biodiversity). A fixed-price scheme would require a budget of approximately $2.7 million (almost seven times more than the actual budget) to elicit the same quantity of BQ units as the discriminative price auction. Looked at another way, Figure 4 shows that - for the same budget of around $400,000 - a fixed-price scheme would give an agency approximately 25 per cent less biodiversity. The supply of biodiversity falls from 1.165 million to 0.87 million units of biodiversity with a fixed-price scheme compared with the discriminative price approach.

Figure 4: Comparison on Fixed-Price versus Discriminative Price Auction



4.2. Monitoring and enforcement

There are a range of design problems that arise with conservation contracts. Amongst these is the problem of optimal monitoring and enforcement strategy. Conservation contracts are difficult to design because government (the principal) cannot easily observe the actions of landholders on their farms. Enforcement of contracts is also problematic because conservation contract generally involve modest payments (average of $4,600 per farm) and there are likely to be significant administration and legal costs of enforcing these contracts. This means that enforcement may not be credible if landholders believe that transaction costs limit government's ability to take action to enforce contracts. Ha, *et al.* (2004) explore conservation contract design in more detail.

Experience in the field (Todd 2004), has shown that there are few enforcement problems. All contract holders are required to lodge a progress report each year and around one-third of participating landholders are visited each year by a field ecologist. As noted in section 3, progress payments are made on the basis of these reports and inspections. Over the two years since the auction, only two contracts have been terminated. Around 50 per cent of landholders lodged reports on time, 25 percent were lodged within a short time of the due reporting date and another 25% required some follow-up eventually lodging reports. Compliance has tended to improve as time goes on. In the most recent year of monitoring, many landholders tended to over, rather than under-comply and a number of landholders completed detailed written reports in excess of standard reporting requirements, often including photographic evidence of progress made with habitat regeneration or habitat quality improvement. Two farms with conservation contracts have changed ownership within the contract term. One of these continued with the contract and one discontinued the contract.

Initial concerns about adverse selection and moral hazard problems with conservation contracts have proven to be less important than first imagined. Self-selection into conservation contracts may be one reason for this. Ha *et al.* (2002) found that participants in the auction were more likely to belong to a conservation organisation and self-selection into conservation programs may ameliorate adverse selection and moral hazard.

Contract design, monitoring and enforcement issues are an important component of the auction approach trialed in Victoria. There remains significant scope for research into these issues. Technology could offer some interesting approaches to some of the outstanding design questions. For example, photographic evidence could be employed as a self-reporting mechanism by landholders to improve varifiability of the existing input-based contracts. At a minimum, landholders could be required to take digital photos of completed capital works as evidence of completion of these actions. Of more interest, however, is the prospect to use photographic evidence to shift contracts towards an outcomes rather than inputs basis. Landholders could, for example, be required to take photo shots of specific sites at intervals through the term of the contract to record the change in habitat quality. Linking progress payments to these outcomes (as opposed to inputs as is the case at present) would substantially change the incentive structure and efficiency of conservation contracts. Another contract design issue raised by the pilot is the scope and design of contract amendments where landholders identify additional actions that represent cost-effective habitat improvements.

5. Discussion and Summary

The pilot auction has shown that it is possible to create at least the supply side of a market for nature conservation and in conjunction with a defined budget, prices can be discovered and resources allocated. Characterising nature conservation on private land as a problem of asymmetric information has improved our understanding of why this and related environmental markets are missing or ineffective and has introduced an alternative policy mechanism to those currently available. Auctioning nature conservation contracts offers many advantages over planning, command and control, voluntary approaches and fixed price policy mechanisms. This is not to suggest that auctions are always a viable replacement for these other mechanisms. It does, however, add a new mechanism to the environmental policy tool kit.

The standard observation that environmental policy must deal with missing markets by adopting coarse policy tools such as taxes, regulation and voluntary programs has been questioned in the context of the information problems inherent in environmental landscapes. A new set of policy tools, such as auctions, that aggregate information efficiently are likely to yield efficiency advantages and have implications for other environmental problems.

Many important design issues have been addressed in the process of implementing the auction. Besides choices about auction format, contract design and the specification of biodiversity preferences, many practical choices arise concerning communication with landholders, skills required to successfully run an auction and timing of activities. These factors all influence the performance of the auction.

Perhaps the most important finding from the pilot auction of nature conservation contracts is that, where there are heterogeneous agents and non-standard environmental benefits, an auction offers significant cost-savings over fixed-price schemes, such as subsidies and tax concessions. This comparison is made on cost-effectiveness, rather than economic efficiency grounds. For the budget available and the bids received, it has been shown that a price discriminating auction would reduce by seven times, the cost of achieving the same biodiversity improvement using a fixed-price approach. Moreover, a fixed-price approach essentially reveals the wrong information from the parties involved. A grants based approach (eg. a subsidy) requires the landholder to reveal the actions that they believe will improve the environment (when this information is perhaps held by environmental agencies); and agencies reveal the price that will be paid for these actions (when this information is often held by landholders).

The attraction of an auction of nature conservation contracts rests on the value of information revelation. The pilot auction was designed to reveal specific but previously hidden information from the agency responsible for nature conservation and from landholders. As part of the auction, the government agency revealed information about the improvement in biodiversity associated with changes in land management (the Habitat Services Score) and the relative conservation status of different areas of vegetation (the Biodiversity Significance Score). This information would significantly improve priority setting for nature conservation, whatever the mechanism employed. Landholders, likewise revealed information about their opportunity costs allowing government to take advantage of heterogeneity in landholders' opportunity costs. Hypothetically, if a landholder was conservation minded, the pilot provided an opportunity for the landholder to share the cost of conservation.

6. Future Directions

The pilot auction of conservation contracts, by its very nature, was necessarily simplistic. It was constructed essentially as a one-shot game between the government and private landholders. Before this approach could be applied more generally auctions would need to be designed within a repeated game context and indeed across multiple outputs (e.g. biodiversity, salinity, water quality etc.).

Design of a sequential auction, however, would be more complicated than the pilot because landholders could be expected to learn through rounds of the auction. Under these circumstances, landholders could change their bidding strategies and raise the cost of nature conservation to the agency. For example, Riechelderfer and Boggess (1998) found that bidders in the Conservation Reserve Program (a sequential auction) revised bids from previous rounds by offering bids at the reserve price. The reserve price in this case was set on a per-hectare rate and when landholders learnt this reserve price, they anchored their bids accordingly.

Another interesting development would be to design auctions capable of dealing with multiple environmental outcomes from landscape change where these outcomes are complementary and or competing. Revegetation of parts of the landscape may, for example, improve habitat and address land degradation. Auction theory is starting to make inroads into questions of how complementarities make market design difficult. Milgrom (2000) shows that complements to some bidders but not to others poses a threat to the existence of equilibria. Roth (2002) also notes that this problem arises in labour markets, such as the medical internship placement system, where couples prefer co-placement.

One of the most interesting design issues with the pilot auction of conservation contracts was the extent to which information was made known to landholders prior to formulation of their bids. For the pilot auction, information about the Biodiversity Significance Score was withheld from landholders but the Habitat Services Score was fully revealed to bidders. As noted earlier, this strategy was empirically supported by the findings of (Cason *et. al.* 2003).

Although the strategy to withhold information was adopted for cost-effectiveness reasons, other considerations suggest that full disclosure of information about biodiversity significance may be appropriate. In the short-run, withholding some information limits the scope for landholders to extract information rents from the auction. Clearly, landholders who know that they have the only remaining colony of some plant or animal, will be able to raise their bids well above opportunity cost, compared with a situation where this information was not known by the landholder. The alternative strategy also has merit in that (i) the information rents that accrue to landholders would influence land markets and encourage investment in nature conservation; and (ii) landholders would know exactly what scarce biodiversity assets they have and could self-select into the auction process, ie, there *may* be a better matching between government priorities and the bidders in an auction.

A number of contract design issues have also been highlighted through the field pilot including scope to use new technology to improve efficiency of contracts with respect to verification, incentives and risk sharing.

Finally, other indirect benefits could arise from the application of auctions and other market approaches to environmental management. For example, information about the marginal cost of habitat conservation would assist public sector decision-makers in allocating resources between conservation investments on public (eg. national parks) and private land. Similarly the emergence of more formalised and quantitative methods of expressing relative preferences for alternative environmental actions may facilitate development of more robust offset and trading schemes.

7. References

Akerlof, G.A. (1970), 'The Market for 'Lemons': Quality Uncertainty and the Market Mechanism', *Quarterly Journal of Economics,* vol. 84, 488-500.

Australian National Audit Office (2001), Performance Information Commonwealth Financial Assistance under the Natural Heritage Trust Audit Report No.43, Commonwealth Government of Australia, Canberra.

Cason, T., Gangadharan, L. and Duke, C. (2003), 'A Laboratory Study of Auctions for Reducing Non-Point Source Pollution*', Journal of Environmental Economics and Management*, Forthcoming.

Coase, R. (1960), 'The Problem of Social Cost', *The Journal of Law and Economics* **3**, 1-44.

Cooper, J.C. (1997), 'Combining Actual and Contingent Behaviour Data to Model Farmer Adoption of Water Quality Protection Practices', *Journal of Agricultural and Resource Economics*, vol. 22, 30-43.

Fitzsimons, J. and Wescott, G. (2001), 'The Role and Contribution of Private Land in Victoria to Biodviersity Conservation and the Protected Area System', *Australian Journal of Environmental Management*, vol. 8, 142-57.

Friedman, L. (1956), 'A competitive bidding strategy', *Operations Research*, vol. 4, 104-112.

Ha., A, O'Neill, T., Strappazzon, L. and Stoneham, G. (2002), 'BushTender Participation in First Bidding Round: What are the Characteristics of Rural Landholders who Participated?', *Paper presented to the 47th Annual Conference of the Australian Agricultural and Resource Economics Society, Fremantle.*

Ha., A, Strappazzon, L., Crowe, M. and Todd, J. (2004), 'Contract design and multiple Environmental Outcomes: an Economic Perspective, Economics and Policy Research Branch Working Paper, Department of Primary Industries, January 2004.

Holmstrom, B. and Milgrom, P. (1991), 'Multitask Prinicipal-Agent Analyses: Incentive Contracts, Asset Ownership, and Job Design', *Journal of Law, Economics, and Organisation*, vol. 7(Special Issue), 24-52.

——— (1994), 'The Firm as an Incentive System', *American Economics Review*, vol. 84, no. 4, 972-91

Klemperer, P. (2002), 'What really matters in auction design', *Journal of Economic Perspectives*, vol. 16, no. 1, 169-89

Laffont, J. (1990), *The Economics of Uncertainty and Information*, MIT Press, Cambridge.

Laffont, J. and Martimort, D. (2002), *The Theory of Incentives: The Principal-Agent Model*, Princeton University Press, Princeton.

Latacz-Lohmann, U. and Van der Hamsvoort (1997), 'Auctioning Conservation Contracts: A Theoretical Analysis and an Application' *American Journal of Agricultural Economics*, vol. 79, 407-418.

——— (1998), 'Auctions as a means of Creating a Market for Public Goods from Agriculture', *Journal of Agricultural Economics*, vol. 49, no. 3, 334-45.

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

Milgrom, P. (2000), 'Putting Auction Theory to Work: The Simultaneous Ascending Auction', *Journal of Political Economy*, vol. 108. 245-272.

Myerson, R. B. (1981), 'Optimal auction design', *Mathematics of Operations Research*, vol. 6, 58-63.

NRE (1997), *Victoria's Biodiversity: Directions in Management*, The State of Victoria, Department of Natural Resources and Environment, Melbourne.

——— (2000), *Restoring our Catchments: Victoria's Draft Native Vegetation Management Framework*, The State of Victoria, Department of Natural Resources and Environment, Melbourne.

Ouchi, W. (1979), 'A Conceptual Framework for the Design of Organizational Control Mechanisms', *Management Science*, vol. 25, no. 9, 833-48

Parkes, D., Newell, G. and Cheal, D. (2003), 'Assessing the quality of native vegetation: the habitat hectares approach', *Ecological Management and Restoration*, vol. 4, S29-S38.

Riechelderfer and Boggess (1988), ‘Government decision making and program performance: The case of the Conservation Reserve Program’, *American Journal of Agricultural Economics*, vol. 70, 1-11.

Roth, A. E. (2002), ‘The Economist as Engineer: Game Theory, Experimental Economics and Computation as Tools of Design Economics,’ Fisher Schultz lecture, *Econometrica*, vol. 70, no. 4, July, 1341-1378.

Rothkopf, M. (1969), ‘A model of rational competitive bidding’, *Management Science*, vol. 15, 774-777.

Riley, J. and Samuelson, W. (1981), ‘Optimal auctions’, *American Economics Review*, vol. 71, 381-92.

Salanie, B. (1997), *The Economics of Contracts: A Primer*, The MIT Press, Cambridge.

Todd, J. (2004), Pers. Comms., Department of Sustainability and Environment, Victoria.

Vickrey, W. (1961), ‘Counter-speculation, auctions, and sealed tenders’, *Journal of Finance*, vol. 16, 8-37.

Wiebe, K., Tegene, A., and Kuhn, B. (1996), ‘Partial Interests in Land - Policy Tools for Resource Use and Conservation’, Agricultural Economic Report, 744, USDA.

Williamson, O. (1985), *The Economic Institutions of Capitalism*, Macmillan, Inc., New York.

Wilson, J.Q. (1989), Bureaucracy: What Government Agencies Do and Why They Do It, Basic Books, New York.

Wilson, R. (1967), ‘Competitive bidding with asymmetric information’, *Management Science*, vol. 13, 816-820.

Wilson, R. (1969), ‘Competitive bidding with disparate information’, *Management Science*, vol. 15, 446-448.

Wilson, R. (1977), ‘A bidding model of perfect competition’, *Review of Economic Studies*, vol. 44, 511-518.

World Commission on Environment and Development (1987), ‘Our common future’, Oxford University Press Oxford.

Wolfstetter, E. (1996), 'Auctions: an Introduction', *Journal of Economic Surveys*, vol. 10, no. 4, 367-420.