

# Comparing the Economic Efficiency of a Procurement Auction Under Different Information Revelation Assumptions

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## **Abstract**

The management of biodiversity is made complicated by the existence of information asymmetries. Generally, the purchaser of biodiversity services (the Government) has a greater capacity to estimate the value of biodiversity, while the landholder knows their opportunity cost of providing the land use change or management services. Latacz-Lohmann and Van der Hamsvoort (1997) have argued that auctions are useful in this situation. One of the reasons for this is that auctions may be cost effective from the procurer's (government's) point of view. However, a government may be interested in criteria other than budgetary cost effectiveness; it may be interested in whether an auction chooses those sellers that have a low 'economic' cost of provision; economic efficiency. In this paper we use testbed laboratory data collected by Cason, Gangadharan and Duke (2002) [CGD] to test the economic efficiency of two auctions: one where information about the value of the environmental good is hidden from sellers; and one where this information is revealed. We use measures of efficiency that differ to CGD. One of our measures is the economic cost ratio, which focuses on the relative economic cost of obtaining a given quantity of environmental good. Using the economic cost ratio, we find that there is no significant difference in economic efficiency between the "information revealed" and "information hidden" treatments.

**Key Words:** auctions; information; environmental quality; efficiency.

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**Disclaimer:** The opinions herein are those of the authors, and not of the following: the Department of Primary Industries, the Department of Treasury and Finance, and the Government of Victoria

## 1. Introduction

Almost 59 percent of the Australian landscape is used for agricultural purposes.<sup>1</sup> This means that many environmental goods (including native vegetation management, salinity, and water quality) are affected by the activities of private landholders. Hence, an environmental agency that hopes to affect the production of environmental goods needs to be able to engage private landholders.

One approach that could be used by an environmental agency is auctions for conservation contracts. Latacz-Lohmann and Van der Hamsvoort (1997) were the first to formally advocate the use of auctions as a tool for procuring conservation contracts. They argue that if an environmental agency wants to procure environmental services from landholders, then auctions are a cost-effective mechanism, relative to fixed-price schemes. This is due to the fact that auctions deal better with the problem of asymmetric information – landholders know the cost of providing environmental goods on their land, but an agency does not. Auctions ensure that landholders must compete to supply environmental services, and competition helps to promote truthful revelation about costs from landholders.

In a practical application of the Latacz-Lohmann and Van der Hamsvoort idea, the then Victorian Department of Natural Resources and the Environment (NRE) used an auction approach to secure contracts with landholders to provide improved management of native vegetation on their land. This scheme is called BushTender© (Stoneham, *et al.* 2003). BushTender was first trialed in two areas in northern Victoria in 2001/02 and was further extended to parts of Gippsland in 2002/03.

The BushTender trial not only placed landholders in a competitive setting, as Latacz-Lohmann and Van der Hamsvoort advocated, it also allowed NRE to share information with landholders about the goods they were providing. That is, the agency was able to impart information to landholders about native vegetation management.

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<sup>1</sup> As at June 30 2000. Australia Bureau of Statistics, Year Book Australia 2002

Yet NRE did not reveal all information to landholders. The agency ranked landholders by using a biodiversity benefits index (BBI), which is a combination of three elements:

1. A biodiversity significance score (BBS) that is a measure of the value of native vegetation on a site.
2. A habitat services score (HSS) that is a measure of the work that a landholder agrees to do such as controlling weeds, or excluding stock.
3. A landholder's bid (\$ bid).

The BBI was used to rank bids according to the value for money that they were estimated to provide.<sup>2</sup> However, NRE revealed only revealed the HSS score to landholders. Hence, landholders did not know their exact BBI value. NRE chose not to reveal the BBI score based on the assumption that that if some information were kept hidden from landholders, then the auction would be relatively cost effective. This result was confirmed in an experimental setting by Cason, Gangadharan and Duke (2003).

Cason, Gangadharan and Duke (hereafter CGD) used an experiment to measure the 'market performance' of two types of procurement auction, an information revealed (IR) and an information hidden (IH) auction. In the IR auctions sellers were provided with complete information about their index value – both cost and quality. In the IH auctions sellers knew only their cost of supplying a product; they did not know anything about quality.

The experiment by CGD is a more extreme construction of the situation in BushTender since in their experiment, the IH scenario does not reveal any information to sellers about their product quality whereas in BushTender, sellers did know part of their index score.

In CGD's analysis, auctions were used to buy an environmental good. CGD suggested that this good be thought of as being nitrogen mitigation from diffuse sources in Port Phillip Bay.<sup>3</sup> The results of their experiment were used to inform the

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<sup>2</sup>  $BBI=BSS*HSS/\$ \text{ bid}$

<sup>3</sup> Melbourne is located on Port Phillip Bay in Victoria, Australia.

design of BushTender, where improvements to biodiversity are the environmental good being purchased.

CGD compared the two auction formats using measures of 'market performance'. These measures are:

1. Holding the budget constant, the total abatement of an auction relative to the total abatement that could be achieved in the “maximal” case<sup>4</sup> (PMAR);
2. The quantity of abatement per dollar spent in the auction, relative to the quantity of abatement per dollar in the “maximal” case (POCER); and,
3. Total profits (bid minus true cost) of successful sellers in an auction.

Essentially the above measures of market performance are about the ‘distribution’ of rents. The first two measures signal the degree to which an agency can appropriate rents, and the third measure is a direct estimate of seller rents (these concepts are discussed further in Section 2).

CGD found that, in the absence of collusion, the IR treatment raised the variance of the offers. Sellers in the IH treatment had higher mark ups *on average* but sellers in the IR treatment had higher mark ups for only high-quality products. This resulted in a higher cost per unit of quality for the IR treatment.

The market performance measures used by CGD varied over time. There was no difference between the treatments in the early periods, but the differences across treatments increase as sellers gain experience: in later periods, the IH auction format outperformed IR.

Chan, Laplagne and Appels (2003) were somewhat critical of CGD’s analysis, commenting that unfortunately the sources of the quality gains are not directly addressed by the study. They contend that IH aggravates strategic pricing—relative to IR—because it hides information about bidder’s quality from them. They believe that this strategic behaviour will result in more items with high true marginal costs being selected, reducing efficiency.

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<sup>4</sup> The “maximal” case refers to the level of environmental quality, given the budget constraint, that would be purchased if the buyer knew seller costs (perfect information).

This assertion about strategic behaviour is the basis for Chan *et al* (2003) contention that “auction outcomes may involve trade-offs between efficient allocation and payment savings”. They believe that the benefits the IH auctions achieve from increased budgetary effectiveness are partly offset by allocative efficiency losses. However, they do not provide evidence that this trade-off exists. They make the observation that the “cost mark-ups for high-quality items are significantly lower (implying smaller amounts of bid shading) in quality concealed auctions than in quality-disclosed auctions”. While this may not imply allocative efficiency gains using IH auctions, neither does it imply allocative efficiency losses. Allocative efficiency relies on choosing the bidders with the lowest true cost/quality ratios.

It should be noted that in the case of perfect information, ie, for an auction that obtains truthful revelation (bids lie on the true marginal cost curve) an auction achieves both maximum cost effectiveness and economic efficiency. Truthful revelation is a precondition for achieving maximum budgetary cost effectiveness.

We are concerned about whether or not there is a trade-off between economic efficiency and budgetary cost effectiveness because it will have some important consequences for government when it is designing an auction for natural resource management (see Section 5).

In this paper, we use the data from CGD’s experiments to measure economic efficiency. The measure used in this paper considers the actual economic cost of the environmental quality purchased in each auction against the minimised cost of obtaining the same level of environmental quality. This measure is referred to as 'economic cost ratio' (ECR), and is used to determine the validity of Chan *et al.* claim that there is a trade-off between economic efficiency and budgetary cost effectiveness in the CGD experiment.

The following section (Section 2) provides the theoretical underpinning for budgetary cost effectiveness and economic efficiency and explains how a trade-off between the two could occur. Section 3 explains how the experimental data used in this paper was collected by CGD. Section 4 outlines the method by which economic efficiency was

measured and it presents the results of this analysis. Section 5 contains a discussion of how the results should be interpreted, their limitations, and why an agency needs to be aware of the trade-off between cost effectiveness and efficiency. Conclusions are presented in Section 6.

## **2. Cost Effectiveness versus Efficiency: A Basic Explanation**

In this section, Figure 1 is used to depict some hypothetical auctions in order to illustrate the difference between cost effectiveness and efficiency. Methods for estimating cost effectiveness and efficiency are also considered to illustrate how a trade-off between the two could occur.

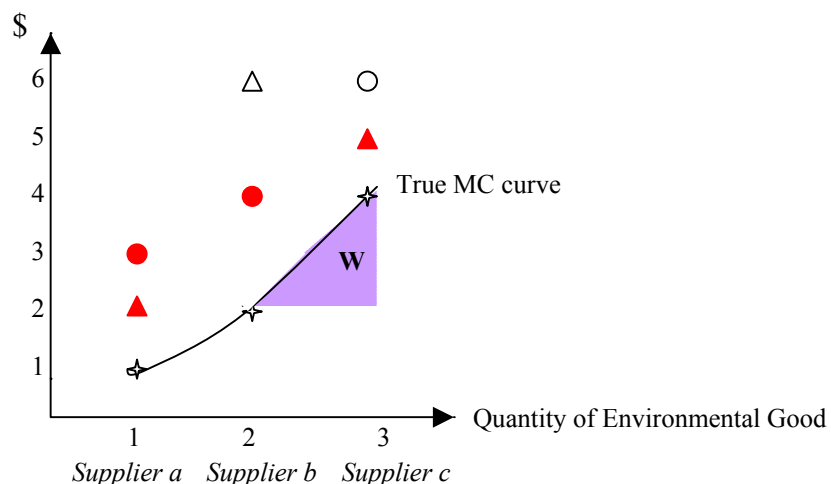
In the auctions described in the following section assume for simplicity that:

- each supplier produces one unit of environmental good.
- the agency (a single/monopoly buyer) accepts bids based on the following decision rules:
  - (i) it runs a pay-your-bid auction;
  - (ii) it awards contracts to suppliers from lowest-to-highest bid; and
  - (iii) the cost of the accepted bids can equal but not exceed the agency's budget constraint.
- the agency cannot observe the true marginal cost curve; it only sees suppliers' bids.
- two different auctions are run, auction C (circles) and auction T (triangles), which differ in just one variable: for example, auction C may be IH while auction T may be IR, or vice versa. In an auction, each supplier would bid a certain amount to provide one unit of the environmental good. The amount bid would vary according to auction design. The circles (triangles) represent the bids entered by suppliers in auction C (auction T).

### **Difference in Efficiency Holding Budget and Quantity Constant**

For the auctions depicted in Figure 1, assume the goods are purchased with a pre set budget of \$7, all of which must be used with no reserve price set.

**Figure 1: Difference in Efficiency Holding Budget and Quantity Constant**



Supplier *a* is the most efficient (produces one unit of environmental good at least true marginal cost), and supplier *c* is the least efficient. The true marginal cost curve of the bidders, True MC curve, is obtained by lining up the suppliers in order from least to highest cost. Therefore each point on this True MC curve represents the cost of a supplier providing the next unit (unlike standard supply curves that are a horizontal summation of all suppliers' willingness-to-supply functions). So, for example in Figure 1, the true cost to supplier *a* to produce one unit of environmental good is \$1, while the price that supplier *a* charges the buyer of the one unit of environmental good is \$3 in auction C (or \$2 in auction T).

The accepted bids in the two auctions are shown as the shaded shapes. Both auctions use the same budget (\$7) and purchase two units of environmental good, therefore both auctions are equally cost effective.<sup>5</sup>

Calculating the efficiency of each auction is not as straight forward as the standard method of estimating efficiency using the economic 'surplus' from trade measure because the demand curve of the purchaser in the two auctions is unknown.<sup>6</sup>

<sup>5</sup> This is highlighted by the measures used by CGD. In this case PMAR would equal 0.666 (=2/3) as two units is the quantity purchased in both the circle and triangle auction, while three units is the quantity that would be purchased if the buyer knew the marginal cost. POCER would equal 0.571 (=2/7)/(3/6) where two divided by seven represent the quantity purchased per dollar in both auctions and three divided by six represents the maximal abatement per dollar.

<sup>6</sup> The 'surplus' is the area below the demand curve and above the true marginal cost curve.

In this case auction C is the more efficient auction as it purchases the same quantity of environmental good as auction T but from the two lowest cost providers. One proxy for estimating which auction is the most efficient in this case (budget and quantity are held constant) is the true cost of supply: the most efficient auction will have the lowest true cost of supply (see Table 1).<sup>7</sup>

An auction is economically inefficient if it is possible to produce the output (environmental benefits) at a lower cost (true economic cost to supplier not bid price). In auction T the good purchased from supplier *c* has a higher true cost but lower bid supplier *b*'s good. The difference between the true costs of two suppliers is the inefficiency loss of the auction. This money can be considered economically "wasted" because it is unnecessarily spent producing a good (in this case environmental benefit) that could be produced by another supplier at less total cost to the economy.

In this example it is also possible to imply a demand curve for the two auctions and measure efficiency by considering the change in the 'surplus' from trade.

The amount paid for any product purchased can be divided into three amounts:

- the economic cost of supplying the product,
- the rent to the purchaser; and
- the rent to the supplier.

The sum of the rent to the purchaser plus the rent to the supplier can be referred to as the surplus from trade.<sup>8</sup> An inefficient auction reduces the surplus from the trade.

In Figure 1, it is possible to imply a demand (or willingness to pay) for another unit of environmental good of \$5.50. Then if an agency were to procure the second unit from supplier *c* (as in the T auction), instead of supplier *b* (as in the C auction), there would be an efficiency loss equal to the area, 'W', which equals 1(see Table 1).

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<sup>7</sup> This is the concept behind the ECR, see Section 3

<sup>8</sup> Money paid to land holders above their cost of production is not considered, in economic terms, 'wasted' because it is used by the landholder in a way that maximises their welfare (for example,

### **Comparing Auctions with Constant Quantities and Variable Budgets**

The previous simple example demonstrates the potential for a trade-off between budgetary cost effectiveness and economic efficiency.<sup>9</sup> However, a simple adjustment to the bids in the Triangle auction (shown in Figure 1) demonstrates how a trade-off between economic efficiency and budgetary cost effectiveness can occur.

Now assume that in the triangle auction, Supplier *a* offers his/her item for \$1 instead of \$2, and that the agency only spends \$6 (instead of its entire budget of \$7). Since the cost price of the items have not changed, the Circle auction is still more economically efficient because its items are purchased from the lowest cost suppliers. However, now the Triangle clearly provides superior budgetary cost effectiveness because, it procures the same number of items (two units) at a lower cost to the agency (\$6 instead of \$7).

Hence in this case, a tradeoff between efficiency and cost effectiveness occurs: auction T is more budgetary cost effective while auction C is more economically cost efficient (see Table 2).

### **Comparing Auctions with Variable Quantities**

In the examples above, quantity was held constant, however judging which auction is the most efficient is problematic when they purchase different quantities of environmental good and the demand curve is not given. Using the lowest true cost of supply per unit of environmental good purchased as a proxy for efficiency is problematic when quantity is not constant because the upward sloping supply curve biases against auctions that purchase higher quantities, when compared to auctions that purchase lower quantities. For example, consider the Circle auction presented in Figure 1. The two units of environmental good are purchased from the two lowest cost suppliers. The true cost per unit of good is  $3/2 = 1.5$ . Compare this to result if the auction purchases only one unit of environmental good from the lowest cost

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through purchasing private goods and services). Assuming interaction with competitive markets, these goods will be efficiently produced and purchased.

provider. The true cost per unit of good in that case is  $1/1 = 1$ . The true cost per unit of environmental good, even for an auction that purchases from lowest cost providers only, is higher for an auction that purchases a higher quantity. Thus, if quantity is not held constant this measure is biased in favor of auctions that purchase less quantity.<sup>10</sup>

### 3. Data

The data are explained fully in CGD (2003) so we provide only a brief explanation here.

The testbed laboratory auction used by CGD was designed to be policy-oriented rather than to test any specific auction theory. The auction treatments evaluated in their paper employed multiple rounds of sealed bids and a discriminative pricing rule. The aim was to encourage private sellers to reveal their opportunity cost of land management changes that mitigate the environmental impacts of nitrogen loads.

CGD conducted 11, two hour sessions, each with eight seller subjects who could offer items. The participants (sellers) were students from the University of Melbourne and Purdue University and were paid for their participation.<sup>11</sup> Sessions were divided into periods, with each period representing an auction. Each auction (period) consisted of multiple rounds (Figure 2 summarises the auction structure). The auction (period) was declared final when one of the following two conditions occurred:

1. The set of successful sellers was unchanged from the previous round; or
2. An arbitrary number of rounds had been reached, with the arbitrary number being determined by the roll of dice.<sup>12</sup>

#### Figure 2: Experimental Auctions

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<sup>9</sup> In theory this trade-off would not occur as bidding structures would result in the lowest marginal cost items being selected first.

<sup>10</sup> This problem is pertinent for the analysis undertaken in paper as the level of environmental quality purchased varies in most of CGD's observations. The ECR (explained in Section 4) addresses this difficulty.

<sup>11</sup> Sellers received a show-up fee of \$US 10 (\$AUD 20) and were also paid for the profits made on successful sales (if any). Experimental dollars were converted into real dollars using a ratio that varied depending on the amount won. Payouts ranged between \$US 15 and \$US 40 with an average payout of \$US 25.

<sup>12</sup> This number was not revealed to the sellers.

Session
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Period 1			Period ...			Period i		
Round 1	...	Round x	Round 1	...	Round y	Round 1	...	Round z

Box 1 outlines the rules that applied to buyers, sellers and the auction.

<b>Box 1: Auction Rules</b>					
<b>Buyer</b>	<p>The experimenter is the only buyer.</p> <p>Had a budget of 35,000 experimental dollars, which is concealed from sellers.</p> <p>Knew the environmental quality of every item but not the sellers' true cost of providing that item.</p> <p>Could purchase a maximum of one item from any given seller.</p>				
<b>Sellers</b>	<p>Eight heterogenous sellers.</p> <p>Each had between two and three items – with each item providing one of three levels of environmental benefit.</p> <p>Sellers had items from at least two and possibly all three levels of environmental benefit.<sup>13</sup></p> <p>All sellers knew their true unit cost of providing each item they possessed.</p> <p>Both the exact costs and qualities of seller items were drawn independently from a uniform distribution to ensure seller heterogeneity. (Sellers did not know the cost and quality distribution.)<sup>14</sup></p>				
	<table border="1" style="width: 100%;"> <tr> <td style="text-align: center;"><b>Information Hidden Sessions</b></td> <td style="text-align: center;"><b>Information revealed Sessions</b></td> </tr> <tr> <td>Sellers only know their own projects' costs.</td> <td>Sellers know their own projects costs and environmental quality.</td> </tr> </table>	<b>Information Hidden Sessions</b>	<b>Information revealed Sessions</b>	Sellers only know their own projects' costs.	Sellers know their own projects costs and environmental quality.
<b>Information Hidden Sessions</b>	<b>Information revealed Sessions</b>				
Sellers only know their own projects' costs.	Sellers know their own projects costs and environmental quality.				
<b>Auction Rules</b>	<p>Multi-round auction.</p> <p>Sellers make sealed bids.</p> <p><u>A ratio of offer price over environmental quality was used to rank offers from lowest to highest.</u></p> <p><u>Projects with the lowest ratio were accepted first.</u><sup>15</sup></p> <p>Sellers were informed if any of their items were provisionally accepted at the end of each round.</p> <p>Sellers are allowed to communicate between periods but not reveal their costs.</p> <p>Given the decision rules (underlined above), the budget was allocated up to but not without exceeding the 35,000 constraint.</p> <p>Discriminative price rule was used (each seller receives her offer price for her sold item).</p>				

<sup>13</sup> Items were assigned a colour depending on the level of environmental benefit they provided, sellers knew the colour of the items they had. However, only in the IR treatment did the sellers know the environmental benefits their items provided.

<sup>14</sup> The distribution of items cost and quality are the vary between periods within a given session, but are the same between the corresponding periods of each session (ie the MC curve is the same for Period 1 in all eleven Sessions but differs between Period 1 and Period 2 within each Session.)

<sup>15</sup> This decision rule means that projects with lower environmental quality may be accepted when the offer price is also low.

CGD chose to use sealed bids to minimise collusion and thereby encourage entry by (potentially weaker) bidders (p12). They also chose to use a discriminative rule because it can lower procurement expenditures when compared to a uniform price auction in the presence of risk aversion (p.13). Multiple rounds were chosen to provide the sellers with more feedback in the hope that it would “improve efficiency by allowing the regulator to select least costly, high quality projects” (p.13).<sup>16</sup>

Of the 11 sessions run, six were quality (information) revealed (IR) and five were quality (information) hidden (IH). Six sessions were conducted at the University of Melbourne and the other five at Purdue University. Between five and ten periods were completed per session. Collusive agreements between sellers only significantly varied the behaviour and market outcomes of one of the 11 sessions.<sup>17</sup>

## **4. Method and Results**

### ***Method***

In Section 1 we outlined the measures used by CGD to compare the market performance of the auctions with their experimental data. However, we presented an additional, complementary, measure that concentrates on whether an auction chooses those suppliers who can supply at low economic cost. In this section, we explain our method for concentrating on economic efficiency.

### **Data Manipulation**

As with the CGD, the analysis undertaken in this paper focuses on the final round of the first five periods of each session. While this approach limits the overall number of observations, as discussed by CGD it enhances comparability across sessions and treatments. Furthermore, we have also chosen to present results both including and excluding the collusive session (MU3).<sup>18</sup>

### **Economic Cost Ratio (ECR)**

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<sup>16</sup> The concept of efficiency as used by CGD will be discussed in more detail in the follow section of the paper.

<sup>17</sup> The collusive session was an information revealed auction.

CGD use ‘market performance’ measures to assess their two auction formats. These measures are different from standard allocative efficiency, or economic surplus, measures. The reason for this is that in CGD’s experiments an aggregate demand curve for all the auctions is not implied. Rather, in each auction the best quality products are purchased until the budget has been exhausted. Therefore, the standard allocative efficiency measure (calculating the area above the supply curve and below the demand curve) is not possible without making some additional assumptions.

Furthermore, the ability to measure efficiency was made more complex by two other elements of the auction design. The first is that every item offers a different level of environmental benefit and second is that only one item could be selected from any given seller. This had the effect of making the marginal cost curves shift around and cross over each other when they were compared.

To overcome these difficulties we employ a measure that holds the level of environmental quality constant and will be referred to as the Economic Cost Ratio (ECR). The ECR is calculated by dividing the total economic cost of the items purchased in auction by the minimised economic cost of purchasing the same quality.

$$ECR = \frac{EC_i}{EC_{min}|_{q_i}}$$

$EC_i$  = economic cost in auction  $i$

$q_i$  = total environmental quality purchased in auction  $i$

$EC_{min}$  = minimised economic cost for which the  $q_i$  can be attained in auction  $i$

What’s best! 4.0 Professional© 1999 solver program was used to calculate the minimised economic cost ( $EC_{min}$ ) for each period. The program was set to find the outcome that provided the same or greater level of environmental quality for the lowest economic cost.<sup>19</sup> In cases where the program selected a level of environmental quality that exceeded the auction quality (i.e.  $q_{min} > q_i$ ),<sup>20</sup> the last item selected would be split to equate the level of environmental quality with that purchased in the auction (i.e.  $q_{min} = q_i$ ) (see Box 2 for an example of calculating ECR).

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<sup>18</sup> Our views regarding the relevance of collusion in the BushTender context are provided in Appendix 1.

<sup>19</sup> The program was not restricted to find solutions within the auction budget constraint used in the experiment. It also does not consider offer prices of the items.

**Box 2: Calculating the ECR**

Assume that there are four items that could be purchased in an auction, A, B, C and D.

Item	Total Economic Quality per Unit (a)	Cost of Item (b)	Marginal cost of item (=b/a)
A	40	\$30	\$0.75
B	40	\$31	\$0.78
C	40	\$32	\$0.80
D	60	\$70	\$1.16

Now assume that in the experimental auction only items A and D are selected.

Total environmental quality purchased in the auction ( $q_i$ ) equals 100 units (40+60).

Total economic cost of the auction ( $EC_i$ ) equals \$100 (30+70).

However, the program would have selected items A, B and C yielding 120 units of environmental quality ( $q_{min}$ ) at a total economic cost of \$93.

To calculate the  $EC_{min}$ , item C, which is the last item selected due it having the highest marginal cost of the selected items, is split to equate the amount of environmental quality selected with the auction outcome. Only 20 units of item C would be selected at the marginal cost of (\$0.8). Therefore,  $EC_{min}$  equals \$77 (30+21+(20\*0.8)).

The ECR for this example is 1.29 (100/77).

ECR results must be equal to or greater than unity as  $EC_{min}$  represents the lowest economic cost for which the given quantity ( $q_i$ ) can be attained.<sup>21</sup> An ECR of one is the optimal result because it means that total economic cost of the auction ( $EC_i$ ) is equal to  $EC_{min}$ . A larger ECR represents a relatively inefficient auction.

## Results

### Empirical Analysis

Table 3 presents the ECR for each auction. Figure 3 provides a graphical representation of the means of the ECR by auction treatment (IH and IR) for each period. The ECR measures for the IH treatment has been separated further so that the impact of the collusive session (MU3) is made evident. The results are presented in this manner to provide consistency with CGD Figures 4 (provided in Appendix 2 of this paper).

<sup>20</sup> For this to occur the total economic cost of the selected items would be lower than the economic cost of the auction (i.e.  $EC_{min} < EC_i$ ).

<sup>21</sup> This method of calculating  $EC_{min}$  has a bias toward matching the level of environmental quality ahead of the cost minimisation constraint. Different methods of calculating  $EC_{min}$  have been estimated (both using alternative programming and manual checking), however the results are not significantly different from those calculated. The advantage of using the method employed in our analysis is that it can be applied in a consistent manner across all observations.

Analysis of Figure 6 suggests that on average the IR auction treatment is more economically efficient in the initial two periods than the IH treatment. However, in periods three, four and five the IH auction treatment (excluding collusive sessions) provides superior economic efficiency. This outcome is generally consistent with the outcomes for PMAR, POCER and seller profit presented in CGD's paper (figure 4).

An interesting difference between the ECR and the two CGD measures is that with the ECR the IR auction appears to be more economically efficient for periods one and two.

For period one, closer inspection of the data suggests that at least some of the difference in the treatments is driven by which of Seller 6's items is selected. In period one both of Seller 6's items offer very similar levels of environmental quality per dollar. However, one item provides a much higher total quality than the other. Selecting the item that provides less quality has a significant negative impact on the economic efficiency of the auction. The IH auction chose this item more often: it was selected in three of the five IH sessions, but only one of the six IR sessions.<sup>22</sup> This problem was not evident for periods two through five.

In periods three, four and five, Figure 3 suggests that the IH treatment offers superior economic efficiency, as the average ECR over these periods is closer to one than in the IR treatment. However, as Table 3 illustrates, this outcome is the results of variation of a single ECR observation in both periods three and four, and two observations in period five.

Another outcome worth considering is that the average by period of total environmental quality purchased was lower for the IR treatment (see Figure 4). This result suggests that the IH treatment is more budgetary cost effective. This outcome is also consistent with the hypothesis of this paper that the level of environmental quality attained does not determine whether or not an auction is economic efficiency.

## Econometric Analysis

For consistency with CGD this paper uses a set of panel regressions based on random effects structure, with session representing the random effect. The analysis has been undertaken using both a random effects tobit model and a general ordinary least squares with random effects model. The variables employed in the analysis are also the same as those used in the CGD paper.

$$ECR = \alpha + \beta_1 \ln(Period) + \beta_2 \ln(Round) + \beta_3 DV_{IR} + \beta_4 DV_{Purdue} + \varepsilon$$

$DV_{IR}$  = Dummy Variable for Information treatment, (= 1 iff treatment is information revealed)

$DV_{Purdue}$  = Dummy Variable for Location (= 1 iff location is Purdue)

The ECR is regressed against a dummy variable for site, to ensure that any cultural or demographic differences as a result of physical location are captured. A log of periods and a log of rounds variable are used to determine if learning impacts on the efficiency of the auction. The log of period variable, determines whether performance changes across periods, while the log of rounds variable determine if the length of the auction affects its efficiency.

As Table 4 shows, only the intercept term is significant (at the 1% level). None of the other variables are significantly different from zero. Furthermore, the overall regressions do not appear to be statistically significant. This suggests that the information treatment does not have a significant impact on economic efficiency, nor that there is a relationship between efficiency and learning either within or across auctions.

Next, we tested whether revealing information impacted upon early and late market performance differently. Again we employed the same model as CGD, which used variables of:

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<sup>22</sup> The average offer/cost ratios for Seller 6's items in period one do not reflect the trend shown in figure 7 of CGD's paper. In this case the offer/cost ratio for the item offering lower quality is greater on average than the item offering the higher quantity in the IR treatment.

- $\left(\frac{1}{Period}\right)$  variable measures market performance in the first period because it will equal one for the first period and declines across periods;
- $\left(\frac{Period-1}{Period}\right)$  variable measures market performance in later periods by placing a greater weight on period five than period one; and
- the above two variables are then interacted with a dummy variable for information treatment ( $DV_{IR}$ ). This is done to determine whether there is a significant difference between early and late market performance due to the information treatment.

$$ECR = \beta_1\left(\frac{1}{Period}\right) + \beta_2\left(\frac{Period-1}{Period}\right) + \beta_3\left(DV_{IR} * \left(\frac{1}{Period}\right)\right) + \beta_4\left(DV_{IR} * \left(\frac{Period-1}{Period}\right)\right) + \varepsilon$$

The results presented in Table 5 suggest that the efficiency of the IH auction treatment improves marginally across the periods. The coefficient for early market performance (1.076) is greater than the coefficient on the variable that measure performance for later periods (1.043) (an outcome that is consistent with Figure 3). However, the *p-values* for the interactive variables are not statistically significant. This suggests that the information treatment does not have a significant impact on the early or late run market performance of auction.<sup>23</sup>

## 5. Discussion

The discussion is presented in two main sections. First we discuss why an agency might care about the trade-off between efficiency and cost-effectiveness, and what this might mean for the agency when it is making decisions. Following this, we explain why we think the results using CGD's experimental data should be interpreted with caution; there may be additional indirect, but potentially significant, benefits to the auction treatments that have not been measured in this paper.

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<sup>23</sup> Note that the signs on the coefficients do reflect the results shown in Figure 6. The negative sign on the coefficient for the early market performance interactive variable suggests that the IR treatment is initially more efficient, while the positive value on the long run coefficient suggest that the ECR is further from one in later IR auctions.

### **The Potential Trade-Off Between Efficiency and Cost-Effectiveness**

Unlike a private firm, which is primarily driven by maximising budgetary cost effectiveness (value for money) when it purchases goods or services, a government may prefer an economically efficient auction because it can enhance the welfare of society as a whole. However governments must be aware of the trade-off between budgetary cost effectiveness and economic efficiency to ensure that its method for attaining environmental benefits meets other policy objectives or political constraints.

Policy makers may choose to sacrifice economic efficiency for increased budgetary cost effectiveness for a number of reasons, including:

- Political pressure (for example, on the Environment Minister) to achieve a specified environmental benefit given a strict budget constraint.
- Society may prefer taxpayers' money to be spent on public goods rather than on private goods (i.e. society may prefer it if all the given budget is spent acquiring the specified level of benefit, rather than having that same level of benefit being purchased at the same price, but with a portion of the money being profit to the service provider which can then be spent on private goods).
- The benefits from using the economically-efficient, but not cost-effective, auction are lower than the costs. These costs may be transaction and/or political costs of generating additional revenue to purchase a given level of environmental quality.

The size of the 'waste' or efficiency loss will be important to governments making decisions about whether to trade-off some efficiency for increased budgetary cost effectiveness. If the loss in efficiency is small compared to the gain in budgetary cost effectiveness, efficiency may not be an important criterion by which the auction design features are determined. However, if the loss in efficiency is large and the cost of the decrease in budgetary cost effectiveness (for example, the cost of increasing taxation and the size of the budget, or political costs) are relatively small, efficiency may be the dominant criterion by which auction design is determined.

### **Cautions when Interpreting Results**

Our analysis of the CGD dataset indicates that, generally, the IH treatment is more budget cost-effective, and that there is no significant difference in the economic efficiency of the two treatments. Hence, this study finds that there is no trade-off between budget cost-effectiveness, and economic cost effectiveness.

However, we urge caution in interpreting these results for several reasons.

First, an IR auction better informs landholders about the priorities of the agency. This could have beneficial effects that we cannot examine using the CGD dataset: landholders with better assets may self-select into the auction, because they know that the agency values their goods. That is, in general participants will enter an auction, or not, depending on their expected revenue and costs in the auction. As Meyer (1993) notes,

*"one would expect an economic agent to compare the expected costs and profitability of a particular auction market with those of other investment opportunities. Thus, one could argue that it is more appropriate to model the number of auction participants as a variable that is endogenously determined"*

This is not a one-way story however, since landholders that perceive they have low-value assets and may be less inclined to enter the auction, lowering competition for these types of sites. It is unclear, a priori, what the impacts of such self-selection will be.

Second, the experimental data used in this analysis was related to an auction to procure a single good: nitrogen abatement. However, auctions could potentially be used to purchase multiple environmental goods, for example salinity mitigation and biodiversity. The rationale for using one auction to purchase both goods is two-fold: there may be transaction cost savings from visiting each landholder once; and because one action may produce multiple outcomes (both water quality, and terrestrial biodiversity together, for instance). If this were the case then a landholder participating in a multiple outcomes auction would want to know about the agency's preference for one good versus the other (the water quality versus biodiversity trade-off), and he would also want to know about how much he can contribute to each good. A landholder may be more willing to (say) volunteer biodiversity actions if he can produce much more biodiversity for a given effort, even if biodiversity were ranked

relatively lower by the agency. In essence, this is another type of potential self-selection advantage of the information revealed approach.

A third beneficial effect of IR auctions, that we cannot examine using experimental data, is that in the long-run other markets may start to react to the agency's preferences. If auctions were run as part of a comprehensive program, with a large budget, then (say) land prices may be affected; land with high-quality sites may fetch higher prices in the land market. Prices may more accurately reflect the agency's preferences if the auctions were run using an IR format. This would be beneficial because the owners would have a higher incentive to maintain their environmental assets, even if they were not currently under contract with the agency.

## **6. Conclusion**

Latacz-Lohmann and Van der Hamsvoort (1997) were the first to show that auctions provide a cost-effective means of procuring environmental services, relative to fixed-cost schemes. Stoneham *et al* (2003) provided empirical analysis of BushTender that supported Latacz-Lohmann and Van der Hamsvoort (1997) contention. CGD have then examined the impact of revealing information on the budgetary efficiency of auction systems and have shown that the IH treatment provides greater cost-effectiveness than the IR treatment.

This paper explains how a trade-off between budgetary cost-effectiveness and economic efficiency can occur. We also suggested that governments may be willing to sacrifice some of the financial benefits of budgetary effectiveness for the welfare benefits that can stem from greater economic efficiency. The questions that this paper sought to address were, whether the information treatment (IR versus IH) influenced the economic efficiency of the auction; and whether or not there may be a trade-off between budgetary cost-effectiveness and economic efficiency depending on the type of information treatment chosen.

This paper proposed the use of the ECR to measure economic efficiency. The ECR measures the extent to which the economic cost of the environmental quality purchased in the auction exceeds the minimum economic cost of purchasing that same

level of environmental quality. Our analysis found that there is no significant difference in the economic efficiency of the two auction treatments. Therefore, we do not support the contention that there was a trade-off between economic efficiency and budgetary cost-effectiveness in CGD's experiment.

In the experiment examined, the IH auction treatment could be preferred due to its superior budgetary cost-effectiveness. However, as discussed in Section 5, caution is required applying these conclusions more broadly due to the fact the results are based on a laboratory experiment with a specific auction design. Therefore, it would be useful to consider this trade-off concept under different auction designs, including:

- having each provide only a single item; or
- removing the multiple-bid constraint;
- ensuring that the marginal cost curve (as defined in this paper) is consistent across all auctions;<sup>24</sup> and
- Making the information revelation system more dynamic, allowing information to influence the participants decision to enter the market.

Ultimately the aim of any further analysis in this area should be to ensure that the auctions that governments employ will ensure both budgetary and economic efficiency in the procurement of environmental services.

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<sup>24</sup> This would also affect what types of efficiency measures can be employed.

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## Figures and Tables

**Table 1: Difference in Efficiency Holding Budget and Quantity Constant**

Supplier	Marginal Cost	Circle Auction		Triangle Auction	
		Offer Price	Accepted	Offer Price	Accepted
<i>a</i>	1	3	✓	2	✓
<i>b</i>	2	4	✓	6	X
<i>c</i>	3	5	X	5	✓
Total Budgetary Cost		7		7	
Total Economic Cost		3		4	
Total Surplus from Trade*		8		7	

\*assumes an implied demand curve at \$5.50

**Table 2: Comparing Auctions with Constant Quantities and Variable Budgets**

	Circle Auction	Triangle Auction
Supplier		
Marginal Cost		
Offer Price		
Accepted		
Offer Price		
Accepted		
	<i>a</i>	
	1	
	3	
	✓	
	1	
	✓	
	<i>b</i>	
	2	
	4	
	✓	
	6	
	X	
	<i>c</i>	
	3	
	5	
	X	
	5	
	✓	
Total Budgetary Cost		
	7	
	6	
Total Economic Cost		
	3	
	4	
Total Surplus from Trade*		
	8	
	7	

\*assumes an implied demand curve at \$5.50

<b>Table 3: Economic Cost Ratio</b>					
<i>Information Reveal (IR) auction results</i>					
	<b>PERIOD</b>				
<b>Session</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>MU1</b>	1	1	1	1	1
<b>MU2</b>	1	1	1	1	1.067338

MU6	1	1.064518	1	1	1
PU1	1	1	1	1	1
PU3	1	1	1.670647	1.839086	1
PU5	1.105983	1	1	1	1.189163
Mean IR	1.017664	1.010753	1.111775	1.139848	1.04275
<i>Information Hidden (IH) auction results</i>					
	<b>PERIOD</b>				
<b>Session</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
MU3	1.105983	1.143291		1	1.566471
MU4	1.125181	1.159331	1	1	1
MU5	1	1.09573	1	1	1
PU2	1.125181	1	1	1	1
PU4	1.035572	1	1	1	1
Mean IH(with MU3)	1.078383	1.07967	1	1	1.113294
Mean IH(w/o MU3)	1.071483	1.063765	1	1	1

**TABLE 4: Regressions models for Market Performance Measures**

Variable	Tobit Model		GLS Model	
	All Sessions	Excluding MU3	All Sessions	Excluding MU3
Intercept	1.018** (0.177)	0.950** (0.336)	1.0472** (0.0890)	0.9858** (0.0885)
Dummy = 1 iff quality revealed	0.002 (0.154)	0.036 (0.171)	0.0018 (0.0738)	0.0374 (0.0651)
Dummy = 1 iff site = Purdue	0.029 (0.136)	0.057 (0.151)	0.0293 (0.0737)	0.0581 (0.0638)
Ln(Period Number)	0.024 (0.181)	0.015 (0.118)	0.0201 (0.0325)	0.0103 (0.0332)
Ln(Total number of Rounds in Period)	0.005 (0.320)	0.030 (0.325)	-0.0152 (0.0427)	0.0020 (0.0443)
Observations	54	50	54	50
Significance of Regression (p-values)	0.25	0.54	0.288	0.640

\*\* Significantly different from zero at the 1% level.  
Standard errors in parentheses.

**TABLE 5: Regressions models for Early and Long-Run Market Performance**

Variable	Tobit Model	
	All Sessions	Excluding MU3
1/Period	1.0770* (0.5468)	1.081** (0.19633)
(Period -1)/Period	1.0434** (0.2562)	0.9819^ (0.5212)
(Information Revealed Dummy)X(1/Period)	-0.0703 (0.1301)	-0.0747 (1.113)
(Information Revealed Dummy)X((Period-1)/Period)	0.0669 (0.130144)	0.1278 (0.4831)
Observations	54	50
Significance of Regression (p-values)		

\*\* Significantly different from zero at the 1% level.

\* Significantly different from zero at the 5% level

^ Significantly different from zero at the 10% level

Standard errors in parentheses.

Analysis only conducted using Tobit model with random effects by session.

Figure 3: ECR Average by Period

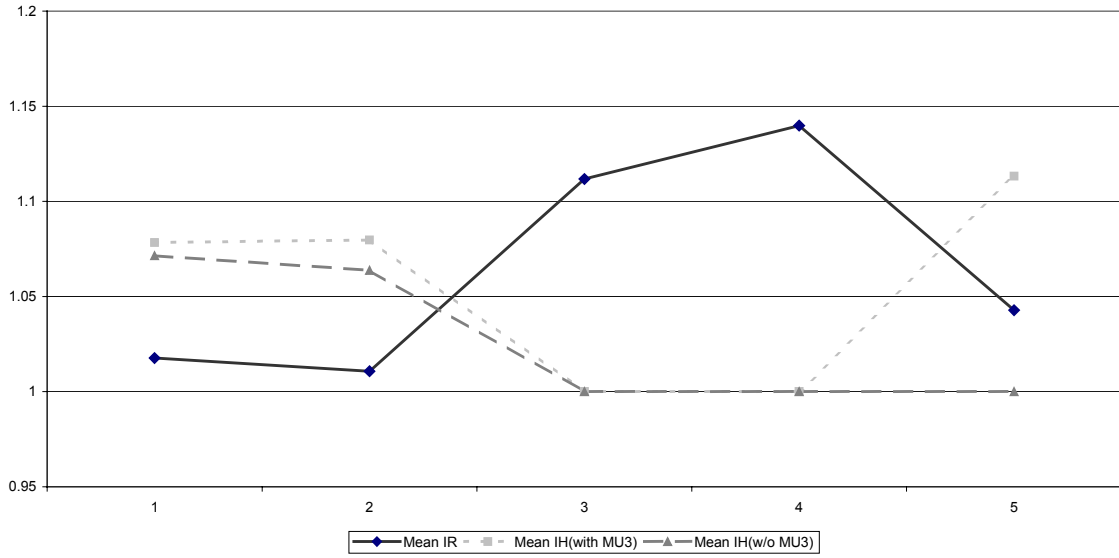
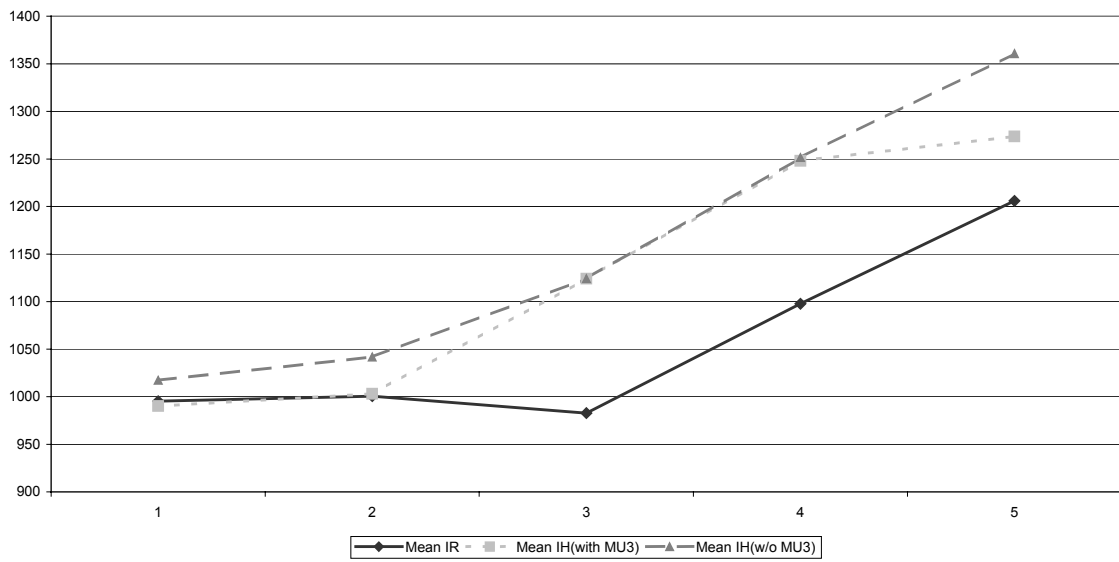


Figure 4: Average Total Quantity Purchased by Period and Auction Treatment



## **Appendix 1: The collusive session**

We do not believe that the collusive session is a good representation of what may happen in the field. This is mainly due to the fact that in the field, bidders incur a larger transaction cost of participating.

In the experiments, colluding bidders simply agreed to some stated value (often a rounded number, such as \$100,000 experimental dollars). This involved talking between the eight participants in the room (between periods). Losing in the auction caused a small financial loss in terms of lost payouts.

However, in the field, a landholder stands to lose a more substantial amount. If the auction were akin to BushTender, then a landholder would need to contact the agency, receive a visit from a regional officer and draw up a management plan, in conjunction with the agency. Then the landholder would need to organise a discussion with other landholders who were associated with the auction, to agree on their collusive behaviour. Further, it is likely that there would be substantially more competition in the field, the laboratory auctions had eight participants, but there were approximately 70 (or more) bidders in the BushTender auctions.

The results presented in this paper have shown to show the impact of the collusive session. However, given the reasoning above and the fact that the inclusion of the collusive data does not have an great impact on the analysis, the discussion in this paper has focused on the results excluding MU3.

## Appendix 2