# Assessing the performance of conservation auctions: an experimental study

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## ABSTRACT

Building on available theory, this work uses controlled laboratory experiments to investigate the budgetary and the economic performance of competitive tenders for allocating conservation contracts to landholders. Experiments have been replicated in two different countries to check for robustness of results. We find that auctions outperform the more traditional fixed-price programs only in the one-shot setting. With repetition, the auctions quickly lose their edge. The budget-constrained auction performs similarly to the target-constrained in the one-shot setting but appears more robust to repetition. Our results suggest that previous estimates of conservation auction performance are too optimistic, and we propose a method for improving such estimates.

# I. INTRODUCTION

There has been growing interest by governments in contracting with landholders for the provision of environmental goods and services in the countryside. Such contracts may be seen to create ‘quasi-markets’ in these goods in that farmers voluntarily enter into agreements to produce some predefined public environmental good in return for a payment. Examples include the US Water Quality Incentives Program, the English Countryside Stewardship Scheme, the German MEKA program, the French ‘La prime à l'herbe’, and the Environmental Services Scheme in New South Wales, Australia. Schemes are implemented at different geographical scales, from local to national, pursue different objectives and involve a wide range of management prescriptions.

The increased importance of environmental contracting has, to date, not been reflected in innovative policy design or implementation. It remains the norm in most conservation programs to offer a single, fixed payment for compliance with a predetermined set of management prescriptions. One proposal that has been made to that effect is to allocate conservation contracts on the basis of competitive bidding, whereby farmers are asked to bid competitively for a limited number of conservation contracts. Such bidding mechanisms have, to date, been set up as discriminatory-price auctions where landholders are paid their own bid. In formulating their bids, they thus face a trade-off between a higher net gain from a higher bid and a reduced chance of winning. Producers facing competition are less likely to ‘overbid’ relative to their true compliance costs. The expectation thus is that competitive bidding will reduce information rents and increase cost-effectiveness.

The diffusion of auctions into the practice of conservation management has been slow, but interest in auctions for purchasing conservation services from landholders has recently grown. At a large scale, auctions have only been used in the Conservation Reserve Program (with a 2004 budget of $ 1.9 billion) and the Environmental Quality Incentives Program (with a 2004 budget of $0.9 billion) (Johansson, 2006; Babcock et al., 1996).. Interest in conservation auctions has recently increased throughout Australia, especially after the BushTender biodiversity trial auctions in Victoria (Stoneham et al., 2003). In the BushTender trials, conducted from 2001 to 2003, landholders were asked to bid for biodiversity conservation contracts. Currently, several additional auction trials are underway in Australia as part of the federal government's market-based instrument (MBI) pilot program. In Europe, a conservation auction has been trialed in the state of North Rhine-Westphalia, Germany. The focus there has been on the maintenance of low-intensity grazing systems (Holm-Müller and Hilden, 2004). Auctions have also been used in the state of Georgia, USA, to buy back water abstraction licenses from farmers in order to preserve minimal in-stream flows in rivers for environmental or recreational purposes (Cummings et al., 2003). In Scotland, the Challenge Fund Scheme relied on an auction mechanism to encourage further afforestation on private land. Finally, contracts for the decommissioning of fishing vessels are usually allocated through competitive bidding: fishers are asked to nominate in a sealed-bid process the amount of compensation required for permanently removing their vessel from the fishery (Holland et al., 1999; Walden et al., 2003; Larkin et al., 2004).

There is, to date, very little (and conflicting) evidence about the cost-effectiveness gains of auctions vis-à-vis fixed-payment programs. Stoneham et al. (2003) argue that the amount of biodiversity benefits acquired through the first round of BushTender auctions would have cost the government agency about seven times as much if a fixed-price program had been used instead. Latacz-Lohmann and Van der Hamsvoort (1997) simulate farmers' bidding behaviour in a hypothetical conservation program and find cost-effectiveness gains ranging from 16 to 29%, depending on how the auction was implemented and how winners were selected. CJC Consultants (2004) report budgetary cost-effectiveness gains of 33 to 36% for the Scottish Challenge Fund Scheme. By contrast, White and Burton (2005) report gains between 200 and 315% for the Auction of Landscape Recovery (ALR) pilot in Western Australia. Note that none of these studies, safe for that by Latacz-Lohmann and Van der Hamsvoort (1997), measure auction performance against a theoretically rigorous benchmark of what we shall term “equivalent fixed payments”. The findings are thus sensitive to the assumed fixed prices used in the comparisons.

The objective of this paper is to investigate the performance of conservation auctions vis-à-vis a benchmark of “equivalent fixed payments”. This benchmark requires complete knowledge of the underlying opportunity costs of service provision and is therefore not available for empirical analyses of field trials or full scale implementation. The comparison was therefore made with the use of economic experiments where opportunity costs are perfectly controlled for and known to the experimenter. The experiments were carried out both at the University of Kiel, Germany, and at the University of Western Australia, Perth, Australia. Because conservation auctions come in two possible formats, as budget-constrained (BC) or target-constrained (TC) auctions, we investigate whether this choice affects the performance of the auction relative to an equivalent fixed payment. In addition, since conservation contracts are usually offered in multiple bidding rounds, we further examine whether auction performance is affected by repetition.

The remainder of the paper is organized a follows. Section two summarizes the role of controlled laboratory experiments in relation to existing theory for allocating conservation contracts. It also sets out a conceptual framework for comparing the performance of conservation auctions vis-à-vis “equivalent fixed payments”. Section three describes the economic experiments; section four provides and discusses the results. Section five draws conclusions for policy and highlights areas warranting further research

## II. THEORY AND EXPERIMENTS FOR STUDYING CONSERVATION AUCTIONS

The use of laboratory experiments to study auction outcomes originated in the fundamental complexity of the auction institution. Following Vickrey's seminal work in 1961, it was soon recognized that a large number of parameters influenced auction performance and that outcomes were very sensitive to the values of these parameters. These included, to name but a few, the distribution of information (private-value versus common-value auctions), auction format (sealed-bid versus open call), and payment format (first-price versus second-price) (Klemperer, 1999, 2002, 2004; Milgrom, 1989). Theoretical investigations, which are constrained by analytical tractability, could only investigate the effect of one or a small number of parameters at a time, assuming all others constant. Major reviews of this literature include Cassady's book (1967) and survey papers by Engelbrecht-Wiggans (1980), McAfee and McMillan (1987), Milgrom (1985, 1989), Wilson (1992), and Klemperer (1999). As a result, the theoretical literature on auctions remained divorced from the practical needs of auction implementation. This is well reviewed by Rothkopf and Harstad (1994) and Klemperer (2002).

Economic experiments were called upon to bridge the gap between theory and practical implementation. Kagel's review, in Kagel and Roth's (1995) *Handbook of Experimental Economics*, remains a key reference for the contributions of the experimental effort up to that date. A forthcoming book, the *Handbook of Experimental Economics Results* (Plott and Smith, 2008), will provide a very welcome update.

The situation is exacerbated in the case of conservation auctions, as these are procurement, multiple-unit and usually repeated auctions. They are procurement auctions in that the auctioneer (the government agency) buys rather than sells environmental services. They are multiple-unit auctions in that landholders sell units of different quality (environmental services per unit area vary across the landscape), they can sell several units each, and there is more than one winner. Conservation auctions are also repeated over time, as is the US Conservation Reserve Program (CRP) auction which has been run as a multiple sign-up scheme (Riechelderfer and Boggess, 1988). Auction theory is less well developed for procurement than for direct auctions, for multiple-unit than for single-unit auctions, and for repeated than for one-shot auctions. The main reason, on which we shall not dwell here, is the level of complexity involved by the characteristics of conservation auctions.

Latacz-Lohmann and Van der Hamsvoort (1997) propose a bidding model which caters for this complexity. In their model, landholders' bidding strategies are predicated on the belief that the conservation agency will decide on a maximum acceptable bid, or payment level. This is a common practice when the agency is subjected to a constrained budget. This maximum bid is determined *ex post*, after all bids have been received, as the last (highest) bid accepted within the available budget. The budget constraint thus is effectively modeled as a reserve price per unit of environmental service, unknown to bidders. Latacz-Lohmann and Van der Hamsvoort (1997) assume that bidders will form expectations about this reserve price and submit a bid that balances out net payoffs and probability of acceptance. The optimal bid is the one that maximizes the expected utility gain from the auction. They demonstrate that the optimal bidding strategy in a discriminatory-price auction is one of overbidding: the auction creates room for bidders to shade their bids above their costs of service provision and thereby to secure themselves an information rent. Overbidding is highest for the lowest-cost bidders, whereas the highest-cost bidders will bid closest to their true costs. To the best of our knowledge, Latacz-Lohmann and Van der Hamsvoort's model is, to date, the only extension of auction theory which captures the particular features of conservation auctions.

Given the lack of sufficient theoretical backdrop, conservation auctions have begun to be studied experimentally. This refers, strictly speaking, to controlled laboratory experiments, but can also be understood in a broader sense to mean the sequential combination of laboratory experiments and small-scale field trials. This was done in Australia in connection with the BushTender trials in the state of Victoria. Here certain design problems, in particular the amount and choice of the information to be communicated to landholders before the bidding session, was investigated experimentally (Cason et al., 2003). In the State of Georgia, USA, auctions for buying back water abstraction licenses from irrigators in times of drought were not implemented before a number of controlled laboratory experiments had been carried out (Laury, 2002). Cason and Gangadharan (2005) report the results of an economic experiment to investigate the outcome properties of uniform versus discriminatory-price auctions for reducing non-point source pollution. They find that although overbidding was more pronounced in the discriminatory-price auction, the discriminatory format had superior overall market performance.

The present paper contributes to the experimental effort in the field of conservation auctions. In contrast to previous studies, which have investigated the outcome properties of alternative auction design options, the focus of this paper is on comparing the auction (as an institution) to the more traditional system of centrally decided fixed-rate payments.

Such comparisons can be made against either a fixed budget or a fixed target. In the first case, the budget is given and known; the risk is whether the target will be achieved. We term this the budget-constrained (BC) auction. In the second case, the target to be achieved is given and known; the risk is with what it might end up costing. This we call the target-constrained (TC) auction. For each of the two auction formats we define an equivalent fixed payment. For the BC auction, this is the minimum uniform payment rate that would have resulted in the same total expenditure as the auction. In the TC case, the corresponding uniform payment is computed as the minimum uniform payment that would have been needed to achieve the same outcome as the auction. It should be clear that, since this requires the knowledge of the underlying opportunity cost (OC) curve, it is only possible in an experimental setting, not in a policy setting.

Figure 1 illustrates the conceptual framework for assessing the performance of discriminatory price auctions. Consider first the BC auction (Frame A) and the corresponding fixed-price program. It is important to understand that the opportunity cost curve (representing the landholders' true costs of service provision) is the relevant supply curve when a fixed payment is offered. Then all landholders with opportunity costs below the fixed payment stand to gain from participation. The marginal participant is the one whose opportunity cost is equal to the payment rate offered. Thus, with a fixed payment rate $p_F$, $X_F$ units of service will be traded. The total budget cost is represented by area $OECX_F$. Under a discriminatory-price auction, by contrast, the ordered bids (not the opportunity cost curve) represent the supply curve. The auction creates room for bidders to shade their bids above their true opportunity costs and thereby to secure themselves an information rent, as predicted by Latacz-Lohmann and Van der Hamsvoort's (1997) model. Bidders are accepted in the order of their bids until the budget is exhausted. The total budget cost is represented by area $OABX_D$. Assuming the same budget as under the fixed-price program (i.e. area $OABX_D$ = area $OECX_F$), $X_D$ units of service can be bought – more than under the fixed-price program.

Figure 1 about here

Frame B of Figure 1 illustrates the equivalent framework for TC auctions. Here the units of service to be purchased (rather than the budget) are set, say at $X_D$ in Frame B. An auction is held to acquire $X_D$ units. The resultant budget outlay is reflected by area $OABX_D$. To assess auction performance, one must determine the equivalent fixed payment that would have yielded the same outcome as the auction, i.e. $X_F = X_D$. To do this, we set the price such that it intersects the OC curve at the level of the target. This price is shown as $p_F$ in Frame B. The corresponding budget outlay is reflected by area $OECX_F$. Frame B has been drawn such that the auction buys the same quantity of environmental benefits at a lower budgetary cost (area $OABX_D$) as the equivalent fixed-price program (area $OECX_F$). The auction thus turns out to be the more cost-effective mechanism.[1]

The cost-effectiveness of the auction thus depends upon the degree of bid shading. One would normally expect bid shading to be low and the auction to be superior to the fixed-price program (as shown in the figures). However, if bidders have learned the bid caps from previous auction rounds, bid shading can be significant, resulting in poor auction performance.

## III. THE EXPERIMENTAL SETUP

The purpose of the experiments described below was to compare the performance of two auction formats, the budget-constrained (BC) and the target-constrained (TC) auctions, against the benchmark of a budget-equivalent and an outcome-equivalent fixed-price program. We thus use two benchmarks, one for each auction format. Both auctions were designed as discriminatory-price tenders, which pay successful bidders their bid.

### *Setup common to both auction formats*

Both auction formats were submitted to a common experimental testing. They were first carried out at the University of Kiel, Germany, in January of 2004, then, in October, at the University of Western Australia in Perth, Australia. The Perth experiment replicated the Kiel experiment, in order to check for the robustness of results.

The Kiel experiment was carried out with first-year students in agricultural economics. The total number of students was about 88 (the number varied slightly across sessions). They were divided into two groups, one for each of the two auction formats. The auction setup referred to reductions in nitrogen fertilizer on a wheat crop, in order to meet EU regulations regarding limits to nitrate concentration in groundwater (50 mg/liter). This is a serious concern in rural areas of northern Germany, and one which students in Kiel would be aware of and sensitive to. Participants were offered would-be contracts for committing themselves to reduce applications of nitrogen fertilizer from their currently most profitable level down to a predefined constrained level, equal to 80 kg per hectare. Each participant was given a different production function for nitrogen fertilizer in wheat production and thus faced a different opportunity cost resulting from the adoption of the nitrogen reduction program. Opportunity (or participation) costs were spread uniformly between €5 (the lowest-cost farmer) and €264 (the highest-cost farmer). The cost range was not given, but bidders were told that costs were uniformly distributed. Bidders knew their own opportunity costs but not those of rival bidders. They were given a rough estimate of where he or she stood compared to rival bidders in terms of opportunity costs. This was done by informing bidders in which cost quartile they belonged: upper quarter, upper half, lower half, lower quarter.[2] It was assumed that bidders could look around and estimate the number of competitors in their group: between 40 and 44 depending on sessions in the Kiel experiment, and 27 in the Perth experiment.

Participants were told that not all of them would be able to win contracts and that they were therefore competing against each other. To keep things very simple, each participant could put up just one land unit of wheat, the same area for all participants. They were told that if they won a contract, they would be paid the difference between their bid and their opportunity cost.

For both groups, three rounds were held in order to investigate the performance of the auctions with repetition. That is, which of the two auction formats was better able to maintain a good performance as bidders get to “play the game” several times? In rounds two and three, exactly the same setup was used, except that bidders knew of their own result in the previous round(s), and successful bidders had been paid their net gains at the end of each round. For equity reasons without which repetitions could not have been held, opportunity costs were reshuffled between rounds. That is, we ensured that those who had been in the third or fourth cost quartiles were at least once in the first or second quartile. Otherwise, some participants would always have been low-cost bidders while others would always have been high-cost, thereby less likely to be selected. This would have resulted in refusal to participate, thus making the experiment impossible.

*Auction specific setup*

The two auction formats differed mainly with respect to the information given to, and asked of, the bidders. Since auctions are very sensitive to information structure, it was important to perfectly control for this aspect.

BC auction specifics: In the first round, the group playing the BC auction was informed of the available budget for the current session. The budget constraint announced (€3900) was clearly distinguished from the actual payments made at the end of the session.[3] Actual bidder payments were proportional to their gains calculated as own bid minus participation cost. Bidders were then asked to state their bid. In the following two rounds, bidders also knew whether they had previously been successful or not, and if so, what their net gains were. No information regarding other bidders was given, as e.g. the number of winners.

TC auction specifics: To the TC auction group, instead of a budget constraint, the number of contracts to be allocated was announced. This number had to be worked out immediately after the BC auction had been held, because the target was set equal to the number of contracts allocated with the €3900 budget constraint. This was done in order to be able to compare the two auction formats on an equal footing. In the first round, the BC auction yielded 29 contracts. Thus the number 29 was announced to the TC auction group. The information treatment was identical to the BC auction. Importantly, during the first session, the two groups were not allowed to communicate. The TC group entered the experimental venue as the BC group exited by an opposite door. Tutors were present to make sure no communication happened. Participants were then asked to state the amount bid for a contract.

*The Perth replicate*

The Perth experiment was in all points identical to the Kiel experiment, save for the following logistical details. Participants were mostly second-year students, with a few third and fourth years as well as a handful of post-graduates – all in the area of agriculture or natural resource management. They totaled about 53 in number, with a variation of one or two between sessions, split about evenly between the BC and TC groups. To reflect the smaller number of participants in the Perth experiment, the budget constraint was lowered proportionately, compared to the Kiel experiment ($2300).

A slight difference in the Perth experiment was the twist given to the story. Rather than nitrogen leaching into the groundwater, the government agency was buying back from horticulturalists in the Swan catchment (around Perth) a composite good made of nitrogen and phosphorus, and the problem was eutrophication in the Swan river following excess runoff of these two nutrients – a socially and politically sensitive issue in Perth.

## IV. RESULTS AND DISCUSSION

*Organizing the results: performance criteria and dimensions for comparison*

Analyzing auction performance is a multi-dimensional task. More than one performance criterion can be used, and comparisons need to be made along several dimensions. In evaluating auction performance, three criteria are standard: budgetary cost-effectiveness, information rents, and economic efficiency. The first is measured as the payment per kg of nitrogen (N) abated; it measures the value-for-money a government agency achieves with taxpayers' money. The second is measured as the payments made over and above participation costs. The third, economic efficiency, collapses in this case to forgone profits, that is, the participation or opportunity cost (OC) per kg of N abated, which measures the cost to society of achieving a unit of N abatement. This criterion would thus better be characterized as economic cost-effectiveness, to the extent that the benefits of N abatement were not directly considered; however, we shall refer to it as economic efficiency since this is the intended performance criterion.

*The first dimension* of comparison confronts the auction to an *equivalent* fixed-rate payment (FRP). As highlighted in section 2, the latter is not arbitrary. In the BC auction, it is the minimum uniform payment rate (MUP) that would have resulted in the same budgetary expenditure as the auction. In the TC auction, it is the minimum uniform payment that would have been needed to achieve the same outcome as the auction. It is important to understand that the MUP benchmark is defined as the FRP to the lowest-cost participants up to the budget or target constraint. That is, landholders are accepted into the program starting from the lowest opportunity costs (OC) until the budget is exhausted or the target is achieved. The MUP thus represents the lowest possible FRP subject to the budget or target constraint. This provides a least-cost uniform pay rate, a theoretical but 'absolute' benchmark for comparison. Of course, it can only be used with controlled laboratory experiments where individual OC are known with certainty.

In practice, policy makers will not have this information, and the MUP will thus not be a realistic benchmark for policy settings. It is more realistic to assume that policy makers and administrators will have some information about the average OC of participation as an anchoring point or benchmark for choosing the payment rate. In the subsequent analysis, we shall refer to this benchmark as the ‘average cost payment’ benchmark (ACP) as opposed to the more theoretical MUP.

Besides comparing auction performance to the MUP and ACP benchmarks, we will track performance criteria as fixed payment rates are varied systematically, from lowest to highest. This is of interest because all real fixed-payment rates are to some extent arbitrary if the regulator has only very limited information about landholders’ compliance costs. It is therefore informative to see how performance criteria vary as a function of the level of payment. The relative performance of the auction can also be positioned on the spectrum of fixed-rate payments. This is done by dividing the total payment made by the number of successful bidders.

*A second dimension* of comparison confronts the two conservation auction formats, the BC and TC auctions. Although to date mainly BC auctions have been used in public conservation programs, governments may wish to know how each format performs relative to a FRP in this context.

*A third dimension* compares different rounds in a repeated auction. An equivalent FRP program is computed for each round to see how the performance of the auction relative to the FRP evolves over repetitions. This is to study the robustness of auctions to potential bidder learning of the cut-off bids, as was demonstrated by the CRP during the late 1980s.

Finally, *a fourth dimension* involves comparing the Kiel and the Perth experiments. This provides information on the robustness and credibility of the results. If the experiments have been implemented in rigorously similar manner, then results should be similar in both cases; if not, some uncontrolled factor is at work and better controlled experimentation is needed before any conclusions can be drawn from the results.

We shall now examine how auctions perform relative to FRP programs using the three above criteria and the analytical template presented above. The focus of this paper being on the first of the four dimensions, the other three will be considered as modifying factors, capable of impacting on the relative performance of auctions.

*Auctions versus FRP programs (without repetition)*

Table 1 presents the results so as to allow a direct assessment of auction performance relative to our two chosen FRP benchmarks: auction performance appears as 100% (of itself) while the MUP and ACP benchmarks are expressed in terms of the auction. The underlying raw data generated by the experiments is provided in Table A1 of the Appendix. Note that in the BC setting the budget is held constant when comparing the auction to the two FRP benchmarks, while in the TC setting the number of contracts awarded is held constant. The performance criteria appear in the three bottom rows in both the Kiel and the Perth tables. The rows above provide the underlying values that help to interpret the results.

Table 1 about here

Starting with *budgetary cost-effectiveness* as measured by the payment per kg N abated, Table 1 shows that in all cases the auction outperforms fixed-price programs, even the MUP. Relative to the MUP, this advantage ranges from 11 to 32 per cent, that is, one unit of abatement paid at a fixed rate would have cost 11 to 32 per cent more than the auction. Relative to the more policy relevant ACP benchmark, the range is, as one would expect, greater. This performance advantage of the auction also holds in terms of *information rents*, indicated in Table 1 by the ratio of total payments to opportunity costs. Again, the advantage of the auction is greater relative to the ACP than to the MUP. In a one-shot auction setting, discriminatory-price bidding thus achieves a unit of abatement at least cost and minimizes the degree of overcompensation relative to the two FRP benchmarks and indeed, as we shall demonstrate below, relative to all possible FRPs.

In terms of *economic efficiency*, recall that the MUP by definition minimizes the opportunity cost per kg N abated. This is because landholders are accepted into the program starting from the lowest opportunity costs (OC) until the budget is exhausted or the target is achieved. Therefore, the best that an auction could do is to equal the MUP, which is the case in the Perth TC treatment. In the three other treatments, the MUP is up to 18 per cent more efficient than the auction; that is, the cost to society of a unit of N abatement is up to 18% higher. On the other hand, relative to the ACP benchmark, results are more mixed: in the Kiel experiment, the auction turns out to be slightly less efficient than the ACP, while the opposite holds for the Perth replicate. Relative to the ACP, the BC auction attracts a greater number of winners, namely those with higher OC, thus raising the *average* OC per kg of N abated. In the TC treatment, the explanation is less intuitive: the auction, through sufficient bid-shading, creates room for higher-cost participants to get selected. By contrast, in the ACP program, only those participants whose OC is less than the ACP will be awarded a contract. When economic efficiency is the driving policy motivation, the advantage of the auction relative to an equivalent fixed-price program based on [an estimate of] the average OC will be far less obvious than if budgetary cost-effectiveness was the main motivation.

Figure 2 shows the positioning of the Kiel auction in the first round relative to the ACP, the MUP, and the whole range of FRPs from the average payment resulting from the auction up to the payment that would attract the last (highest-cost) bidder into the program. The corresponding graphs for the Perth experiment have been omitted since findings are very similar. The average payment made under the auction is shown in Figure 2 by the vertical line labeled “auction”. It was included on the FRP rates axis in order to visualize its relative positioning according to the three performance criteria, even though it conceals a greater number of winners in the BC setting and a smaller total payment in the TC setting. All FRP rates to the left of the MUP are not sufficiently high to attract a large enough number of participants either to achieve the target (TC setting) or to exhaust the budget (BC setting). Therefore, FRP rates below MUP cannot define an auction-equivalent FRP program. Consequently, if an auction outperforms the MUP, it will outperform any other equivalent FRP to the right of MUP. In Figure 2, both auction formats consistently outperform the MUP in terms of budgetary cost-effectiveness and information rents, and therefore, of course, the ACP or indeed any other FRP. On the other hand, for reasons explained above, the auction at best equals the MUP in terms of economic efficiency.

Figures 2 and 3 about here

If we examine the impact of varying fixed-rate payments on the three performance criteria, several facts stand out. First, higher FRP rates deteriorate budgetary cost-effectiveness, as one might have expected. What may appear as less expected is that both economic efficiency and the extent of information rents do not necessarily increase monotonically with FRP rates. In some cases they do not show any tendency to either decrease or increase. This can be understood by recalling that higher FRP rates attract higher-cost landholders, who also abate an increasing amount of N per hectare. Because OC per hectare and N abatement per hectare increase at similar rates, the ratio of OC to N abated remains roughly unchanged when FRP rates increase. This reflects of course the nature of the underlying production functions (see section 3).

*Factors that can affect how an auction compares to a FRP program*

Table 2 gives the performance of the two FRP benchmarks relative to the equivalent discriminatory-price auction (TC or BC). They measure the ratios, in terms of our three criteria, of MUP and ACP performance relative to the auction which is understood to be set everywhere at 100. A number greater than 100 means that the auction performs better than its equivalent FRP program, and the greater of two numbers (whether above or below 100) means that the auction corresponding to the greater number performs better compared to its equivalent FRP than the other auction does relative to its own FRP.

Table 2 about here

First, does the *format* of an auction affect its relative advantage over a FRP program? In terms of economic efficiency, Table 2 clearly shows that the TC auction consistently outperforms BC relative to both fixed-price benchmarks. This, however, should not come as a surprise: the TC format will, by construction, always be superior to the BC format. This is because the TC constrains the number of winning bidders to be fixed, whereas under the BC format, compared to an equivalent FRP, the number of winners is allowed to increase up to the budget limit. This will result in higher-cost participants to be awarded a contract, thus raising the *average* OC per kg of N abated.

In terms of budgetary cost-effectiveness, the TC format outperforms the BC only relative to the MUP benchmark in both the Kiel experiment and the Perth replicate. Relative to the ACP, results are inconclusive: in the experimental setting, they depend on bidders' cost profiles; in the field, they depend on the regulator's choice of the FRP.

In terms of information rents, results are mixed. Seen from the benchmark angle, TC outperforms BC relative to the MUP in terms of two criteria, economic efficiency and budgetary cost-effectiveness. The ACP benchmark does not yield any consistent story: it will depend on the cost profile of participants – e.g. how far apart the average and the median cost are. From a policy perspective, an ACP is the only practical benchmark, and auction format will matter only if economic efficiency is the driving motivation. This result holds, of course, only in terms of auction performance *relative to* a fixed-price program.

Second, let us consider the effect of *repetition* on auction performance. We are interested in two aspects: the advantage of the auction relative to its fixed-payment benchmark, and the advantage of one auction format relative to the other. If we contrast the outcomes of round 1 and 3 in Table 2 (round 2 mostly having values between rounds 1 and 3), we observe that except in the case of the Perth -BC 3 auction, both auction formats have lost their edge to the MUP. In the third round, the first-round results are mostly overturned. The TC auction has lost its advantage even to the ACP. This confirms and refines the results by Hailu and Schilizzi (2004) who interpret this result in terms of bidder learning. Thus, with repetition, an auction loses its performance advantages over FRP programs; but the effect is only clear-cut in the TC case, where the auction clearly performs least well in terms of equivalent fixed-payment rates. In the BC case, this effect remains ambiguous, if at all present. While the BC auction clearly performs less well in round 3 than in round 1, it maintains its advantage over its FRP benchmarks. This suggests that the auction is more robust to repetition under the BC setting than under the TC setting, a result of potential relevance to policy.

While with repetition the TC loses relative advantage over the BC auction in terms of budgetary cost-effectiveness and information rents, this appears not to be the case when economic efficiency is considered: from Table 2, it appears that economic efficiency maintains the relative advantage of TC over BC, although the difference has been diminishing.

If we now examine payments in absolute rather than relative terms, by comparing corresponding graphs in Figures 2 and 3, we observe that, in both the BC and TC settings, the average auction payment rate increases in all cases: from €133 to €159, or by 20%, in the BC auction, and from €147 to €193, or by 31%, in the TC setting. This confirms the greater robustness of the BC auction under repetition.

Third, Table 2 shows that the relative advantage of both auction types relative to their corresponding FRPs is slightly but systematically greater in the Perth replicate than in the Kiel experiment. This would have been a concern for the robustness of the results had the populations of bidders in both experiments been rigorously identical. Instead, as mentioned in section 3, the two populations differed in their risk attitudes, as measured by a standard certainty-equivalence test.[4] We hypothesize that a risk-aversion adjusted set of bids would reduce the differences between the two replicates and allow a meaningful comparison – a topic we leave for future work.

## V. CONCLUSIONS

*Summary of results*

The purpose of this work was to investigate to what extent discriminatory-price auctions perform better than equivalent fixed-price programs. The comparison was made using three performance criteria: budgetary cost-effectiveness, information rents, and economic efficiency. Given insufficient theoretical guidance from the literature, this was done by means of controlled economic experiments. Two possible auction formats were compared, depending on whether the policy tries to achieve the maximum outcome with a given budget (budget-constrained auction) or minimizes its budgetary outlay for a predetermined outcome level (target-constrained auction). Relative auction performance was submitted to repetition to see if potential bidder learning might affect the results. These were further submitted to replication in two different countries to check for their robustness.

Some clear conclusions emerge from this study. The first is that both target- and budget-constrained auctions perform better than any possible fixed-price program in a one-shot setting, where bidders have had no opportunity to learn from previous results. This holds for all three performance criteria, except when economic efficiency is measured relative to the minimum uniform fixed-payment program (MUP) which, by construction, yields the lowest possible cost profile.

The second conclusion is that repetition erodes the advantage of auctions relative to fixed-price programs, making it easily possible for an auction to be outperformed by an equivalent fixed-rate program. Given that this effect was clearly visible in the third round in both replicates, we may conclude that auctions repeated identically and *ceteris paribus* erode their performance edge rather quickly.

The third issue was whether, in the context of multiple-unit, discriminatory-price conservation auctions, format matters. The third conclusion here is that under the one-shot setting, the two auction formats appear roughly equivalent; but the BC format is clearly more robust to repetition than the TC. Since conservation auctions tend to be repeated over time, the greater robustness of the BC auction is the result of potential relevance to policy.

The first two conclusions seem to be robust, in that both Kiel and Perth replicates yield comparable outcomes, although the auction's advantages comes out slightly greater in the Perth replicate than in the Kiel experiment. We attribute this difference to different behavioral profiles of the two bidder populations.

*Policy implications*

The recent surge of interest in conservation auctions has been driven by evaluation results from pilots carried out across Australia since 2001. Stoneham et al. (2003) forcefully demonstrated, using data from the BushTender pilots in Victoria, the superiority of competitive bidding as a contract allocation mechanism. They found that the amount of biodiversity benefits acquired through the first round of BushTender auctions would have cost about seven times as much if a fixed-price program had been used instead. The results from the present study suggest that the gains from auctions relative to an equivalent fixed-price program are not nearly as high. In a one-shot auction, gains are more likely to be in the range of 10 to 60 per cent than 200 to 700 per cent. With repetition, gains are quickly eroded to the extent that the auction may be outperformed by a fixed-price program, as Hailu and Schilizzi (2004) have already highlighted. Our performance figures compare well to the 33 to

36 per cent cost-effectiveness gains reported for the Scottish Challenge Funds (CJC Consultants, 2004), although these figures were not derived in comparison with equivalent fixed prices.

It is important to note, however, that the magnitude of these numbers depends upon the nature of the environmental problem at hand. In our case, production functions were used to derive, for each individual landholder, opportunity costs and simulate reduction in fertilizer use and nutrient leaching. Different coefficients or functional forms would have resulted in different bid levels, abatement benefits, and thus different auction performance. It is thus conceivable, though highly unlikely, that the physical and economic structure underlying the BushTender pilot might be such that the very high cost-effectiveness gains reported by Stoneham et al. (2003) might have been possible.

Our results confirm the experience gained from the US Conservation Reserve Program: when bidders have the opportunity to learn from preceding bidding rounds, they will use that information to update their bids and reap higher rents – at the detriment of auction performance. The implication for the policy maker is that auctions will in general perform better than equivalent fixed-payment programs only in one-shot settings. If, however, the auction is to be repeated several times, which would indeed be the case with most conservation programs, then one may hypothesize that changing one or more parameters of the auction would mitigate the erosion of the auction's advantage; for example, by announcing different explicit reserve prices or changing the budget or the target level. The extent to which this would be true, however, is yet to be researched.

The choice of auction format, BC or TC, does not seem to matter very much in the one-shot setting, unless economic efficiency is the driving policy motivation. In this case, it was shown that the TC format would, by construction, perform better than an equivalent fixed-price program. Policy makers, however, usually place more weight on budgetary cost-effectiveness and information rents than on economic efficiency. Our findings suggest that, with repetition, the TC loses its relative advantage over the BC auction in terms of budgetary cost-effectiveness and information rents. This makes the BC the more appropriate format for multiple-signup conservation programs. These results again highlight the importance of experimental studies for informing the design of conservation auctions in the field.

*Limitations and further research*

The confrontation of our experimental study with ex-post empirical evaluations of field trials has highlighted the extreme importance, indeed the absolute necessity, of controlled laboratory experiments for measuring the performance of auctions relative to equivalent fixed-price programs. The challenge facing authors like Stoneham et al. (2003) is that they have attempted an impossible task: to measure the performance of a discriminatory-price auction without knowledge of the bidders' underlying opportunity costs. It should be clear from the present study that this cannot be done. This raises the question of whether ex-ante auction experiments, carried out in controlled laboratory conditions, might be able to help with such ex-post evaluations. This seems to be as yet an unresearched problem.

One of the goals of this study was to check the reliability of the experimental results by showing that between the two replicates, carried out in two different countries, there were no systematic differences. Instead, slight though systematic differences were found, which were traced back to differences in risk attitudes between bidder populations. This highlighted the fact that the null hypothesis, whereby no differences between the replicates should be observed, relied on the assumption that all bidders in both populations were risk-neutral (or at least had the same risk attitudes), a standard assumption in the auction theory literature. To allow a meaningful comparison between the replicates, bids would need to be adjusted for different risk attitudes. This is a topic for another study which, although important from a theoretical perspective, remains marginal for the purposes of the present paper, and will therefore be left for future work.

This study has focused on the performance of BC and TC auctions relative to equivalent fixed-price programs; the results cannot be extrapolated to how each auction compares, in absolute terms, relative to each other. This study has highlighted the fact that they obey two rather different rationales, reflecting different information structures for bidders. More work is needed to fully understand the theoretical and the policy implications of this difference. Research is also needed to explore how sensitive the preference between the two auction formats might be for such things as the degree of heterogeneity of bidders' opportunity costs, cost efficiency of production, or scale of operation.

Caution is called for in extrapolating the results of this study given that it is likely that they will to some extent depend upon the underlying production functions and cost structures. Further research is warranted to explore this dependence in a systematic manner.

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NOTES

[1] This can be seen by observing that area KBC is smaller than area AEK.

[2] The experimental protocol may be obtained from the authors upon request.

[3] This budget constraint of 3900€ was in "nominal" lab euros, which reflected the production functions underlying the costs imposed by reduced nitrogen applications. This was clearly distinguished from the limited funds available for each session of the experiment (300€). Salience was preserved through the fixed proportionality rate between gains in nominal lab euros and payments in hard currency.

[4] The Kiel population of students was found to be slightly risk-taking (CE = 107), whereas the Perth population of students was found to be risk-averse (CE = 88); a perfectly risk-neutral population would have a CE of 100.

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TABLE 1

BC AND TC AUCTION PERFORMANCE RELATIVE TO THE TWO FRP BENCHMARKS, 1ST ROUND (SEE TABLE A1 IN APPENDIX FOR UNDERLYING ABSOLUTE VALUES)

| **The Kiel experiment** | **Kiel BC 1** (Budget = €3900) | | | **Kiel TC 1** (Target = 29 participants) | | |
|---|---|---|---|---|---|---|
| | Auction | MUP | ACP | Auction | MUP | ACP |
| Applicants (or bidders) | 100 | 59 | 70 | 100 | 67 | 70 |
| Contracts awarded | 100 | 90 | 72 | 100 | 100 | 100 |
| Fixed pay rate (equivalent) | 100 | 108 | 139 | 100 | 124 | 129 |
| Total payment | 100 | 97 | 101 | 100 | 124 | 129 |
| Total opportunity cost | 100 | 72 | 72 | 100 | 91 | 95 |
| Total N abated | 100 | 87 | 77 | 100 | 96 | 98 |
| Budgetary cost-effectiveness = Payment / kg N abated | **100** | **111** | **131** | **100** | **129** | **131** |
| Information rent rate = Total payment / opp cost | **100** | **135** | **140** | **100** | **136** | **136** |
| Economic efficiency(*) = Opp cost / kg N abated | **100** | **82** | **94** | **100** | **94** | **97** |

| **The Perth replicate** | **Perth BC 1** (Budget = \$2300) | | | **Perth TC 1** (Target = 19 participants) | | |
|---|---|---|---|---|---|---|
| | Auction | MUP | ACP | Auction | MUP | ACP |
| Applicants (or bidders) | 100 | 59 | 74 | 100 | 73 | 81 |
| Contracts awarded | 100 | 84 | 63 | 100 | 100 | 100 |
| Fixed pay rate (equivalent) | 100 | 114 | 152 | 100 | 116 | 126 |
| Total payment | 100 | 97 | 101 | 100 | 116 | 126 |
| Total opportunity cost | 100 | 64 | 65 | 100 | 90 | 98 |
| Total N abated | 100 | 75 | 64 | 100 | 88 | 92 |
| Budgetary cost-effectiveness = Payment / kg N abated | **100** | **129** | **158** | **100** | **132** | **138** |
| Information rent rate = Total payment / opp cost | **100** | **151** | **157** | **100** | **129** | **130** |
| Economic efficiency(*) = Opp cost / kg N abated | **100** | **86** | **101** | **100** | **100** | **106** |

(*) In this case, collapsed to 'economic cost-effectiveness' (see text).
BC1 and TC1 : budget- and target-constrained auctions, first round
MUP : Minimum Uniform Payment rate (absolute benchmark)
ACP : Average Cost Payment rate
kg N : kilograms of nitrogen (per hectare)

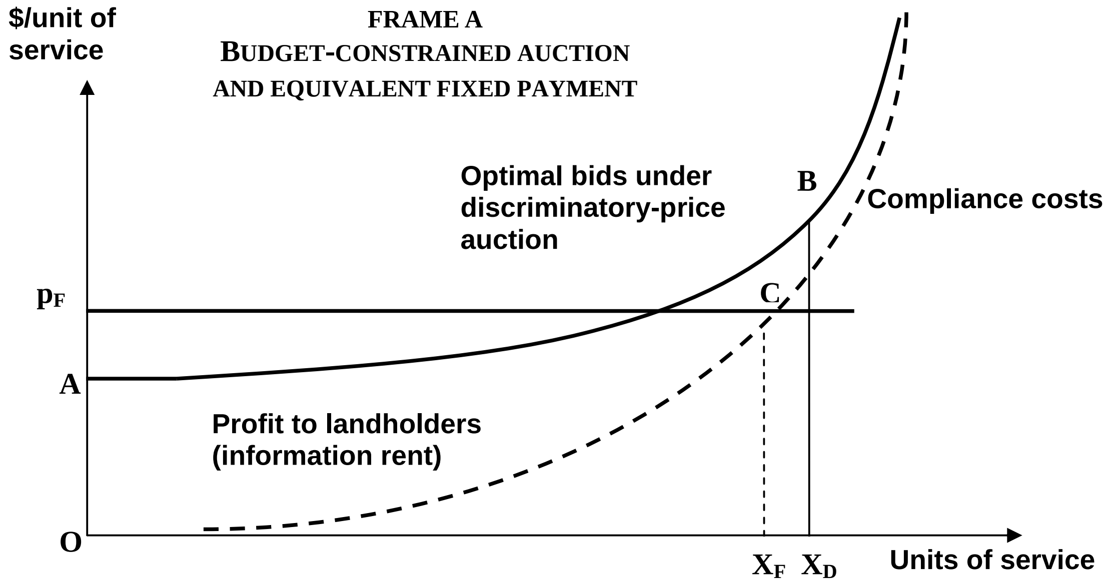
TABLE 2

AUCTION PERFORMANCE RELATIVE TO MUP AND ACP FOR DIFFERENT CRITERIA (AUCTION = 100)

| **Relative auction performance** | **Kiel experiment** | | **Perth replicate** | | **Auction type and round** |
|---|---|---|---|---|---|
| | MUP | ACP | MUP | ACP | |
| Payment / kg N abated | 111 | *131* | 129 | **158** | BC 1 |
| Total paymt / Opp Cost | 135 | **140** | **151** | **157** | |
| Opp Cost / kg N abated | 82 | 94 | 86 | 101 | |
| Payment / kg N abated | 129 | *131* | 132 | **138** | TC 1 |
| Total paymt / Opp Cost | 136 | **136** | **129** | **130** | |
| Opp Cost / kg N abated | 94 | 97 | 100 | 106 | |
| Payment / kg N abated | *98* | **116** | **106** | **133** | BC 3 |
| Total paymt / Opp Cost | **107** | **115** | **114** | **124** | |
| Opp Cost / kg N abated | 91 | **101** | 93 | **107** | |
| Payment / kg N abated | *98* | **99** | **99** | **99** | TC 3 |
| Total paymt / Opp Cost | **100** | **104** | **104** | **104** | |
| Opp Cost / kg N abated | 98 | **96** | 95 | **95** | |

MUP: Minimum Uniform Payment rate (absolute benchmark)
ACP: Average Cost Payment rate
BC and TC: budget- and target-constrained auctions, rounds 1 and 3

**In bold: values where BC > TC**
In normal: values where BC < TC
*In italic: values where BC = TC*



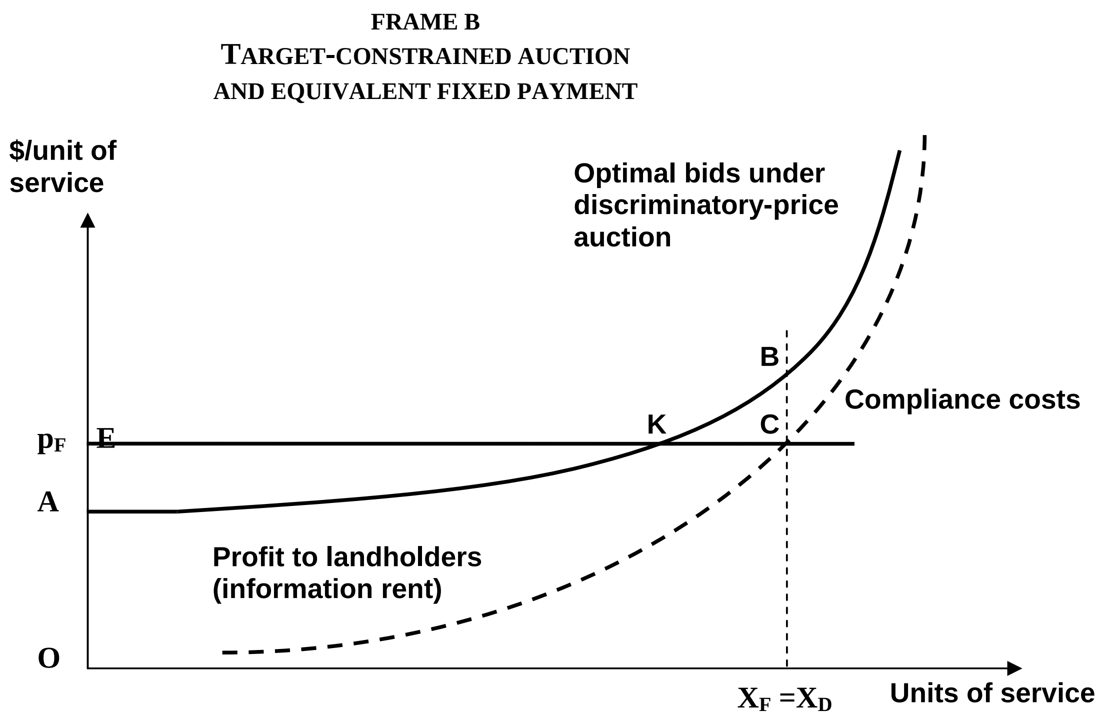




FIGURE 1

A CONCEPTUAL FRAMEWORK FOR ASSESSING THE PERFORMANCE OF A *BUDGET-CONSTRAINED* (ABOVE) AND A *TARGET-CONSTRAINED* (BELOW) AUCTION VIS-À-VIS AN EQUIVALENT FIXED-PRICE SCHEME

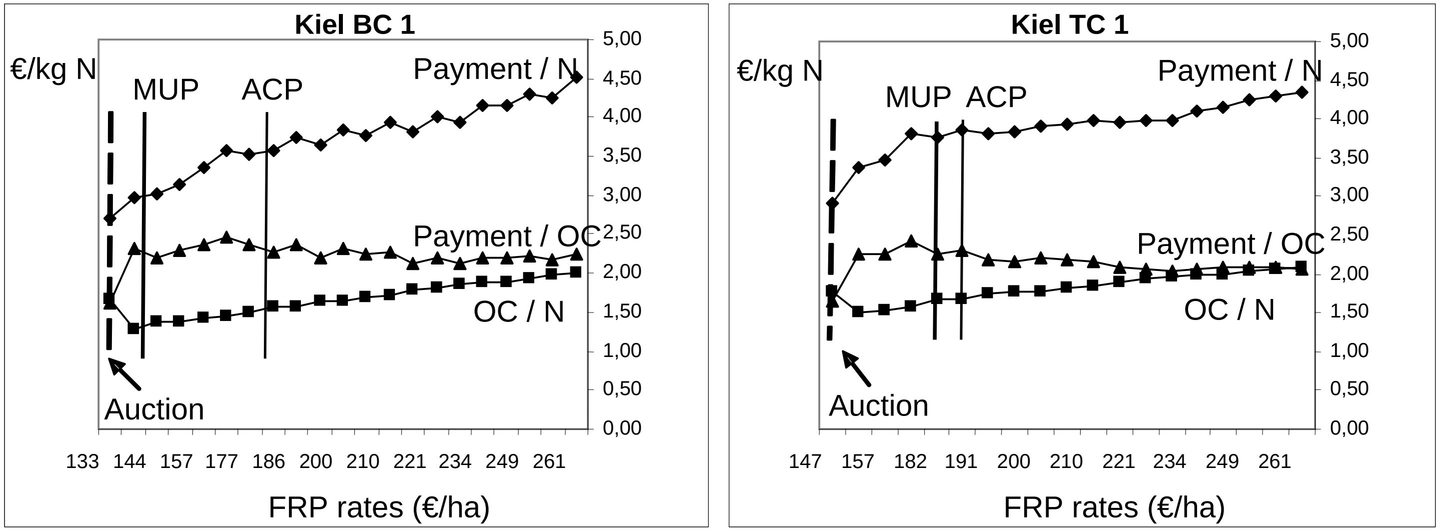



FIGURE 2

POSITIONING OF THE AUCTION AND THE TWO BENCHMARKS ON THE SPECTRUM OF FRP RATES, ROUND 1

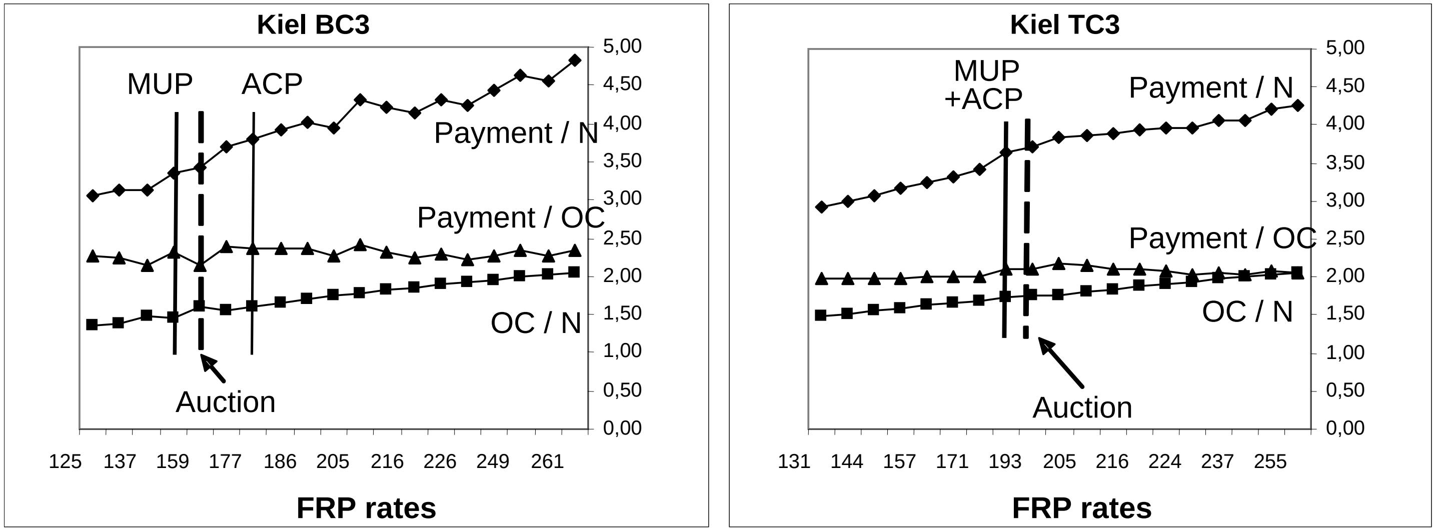



FIGURE 3

POSITIONING OF THE AUCTION AND THE TWO BENCHMARKS ON THE SPECTRUM OF FRP RATES, ROUND 3

## APPENDIX

TABLE A1

PERFORMANCE OF BC AND TC AUCTIONS AND OF THE TWO FRP BENCHMARKS, 1ST ROUND

| **The Kiel experiment** | **Kiel BC 1** (Budget = €3900) | | | **Kiel TC 1** (Target = 29 participants) | | |
|---|---|---|---|---|---|---|
| | Auction | MUP | ACP | Auction | MUP | ACP |
| Applicants (or bidders) | 44 | 26 | 31 | 43 | 29 | 30 |
| Contracts awarded | 29 | 26 | 21 | 29 | 29 | 29 |
| Fixed pay rate (equivalent), $/ha | 133 | 144 | 185 | 147 | 182 | 189 |
| Total payment, $ | 3861 | 3737 | 3900 | 4262 | 5269 | 5481 |
| Total opportunity cost, $ | 2380 | 1704 | 1722 | 2573 | 2333 | 2435 |
| Total N abated, kg | 1422 | 1241 | 1092 | 1459 | 1402 | 1430 |
| Budgetary cost-effectiveness = Payment / kg N abated, $/kg | **2.72** | **3.01** | **3.57** | **2.92** | **3.76** | **3.83** |
| Information rent rate = Total payment / opp cost, $/$ | **1.62** | **2.19** | **2.27** | **1.66** | **2.26** | **2.25** |
| Economic efficiency(*) = Opp cost /kg N abated, $/kg | **1.67** | **1.37** | **1.58** | **1.76** | **1.66** | **1.70** |

| **The Perth replicate** | **Perth BC 1** (Budget = $2300) | | | **Perth TC 1** (Target = 19 participants) | | |
|---|---|---|---|---|---|---|
| | Auction | MUP | ACP | Auction | MUP | ACP |
| Applicants (or bidders) | 27 | 16 | 20 | 26 | 19 | 21 |
| Contracts awarded | 19 | 16 | 12 | 19 | 19 | 19 |
| Fixed pay rate (equivalent), €/ha | 120 | 137 | 183 | 175 | 203 | 221 |
| Total payment, € | 2274 | 2197 | 2300 | 3320 | 3857 | 4198 |
| Total opportunity cost, € | 1544 | 991 | 998 | 2404 | 2162 | 2346 |
| Total N abated, kg | 915 | 684 | 587 | 1229 | 1080 | 1128 |
| Budgetary cost-effectiveness =Payment /kg N abated, €/kg | **2.49** | **3.21** | **3.92** | **2.70** | **3.57** | **3.72** |
| Information rent rate =Total payment / opp cost, €/€ | **1.47** | **2.22** | **2.31** | **1.38** | **1.78** | **1.79** |
| Economic efficiency(*) =Opp cost /kg N abated, €/kg | **1.69** | **1.45** | **1.70** | **2.00** | **2.00** | **2.08** |

(*) In this case, collapsed to 'economic cost-effectiveness' (see text).
FRP: Fixed Rate Payment
BC1 and TC1 : budget- and target-constrained auctions, first round
MUP : Minimum Uniform Payment rate (absolute benchmark)
ACP : Average Cost Payment rate
kg N : kilograms of nitrogen (per hectare)