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AUCTIONS AS A MECHANISM FOR ALLOCATING CONSERVATION CONTRACTS AMONG FARMERS

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ABSTRACT

AUCTIONS AS A MECHANISM FOR ALLOCATING CONSERVATION CONTRACTS AMONG FARMERS
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Auction theory is employed to quantify the potential efficiency gains that can be achieved by offering conservation and supply control contracts to farmers on the basis of competitive bidding instead of fixed-rate contracts. A model for optimal bidding decisions, which captures the specific features of auction markets for conservation contracts, has been developed and applied to 100 model farms that differ in the cost of adopting a low-input technology. The results indicate that the implementation of a bidding environment, compared to a scheme of fixed-rate contracts, can yield significant savings in government outlays per unit of environmental improvement (and surplus reduction). In general, whatever system is used (either offer system or auction scheme), the government can improve programme performance by gathering information on the size and distribution of switch-over costs. The greater the information asymmetry, however, on switch-over costs between individual farmers and the government, the larger the benefits in programme cost-effectiveness that can be achieved by implementing auctions.

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CONTENTS

PREFACE

This study analyses the potential efficiency gains that can be attained by offering conservation contracts to farmers on the basis of competitive bidding compared to fixed-rate contracts. The study is original in that it contains a first attempt to apply auction theory to the case of agricultural conservation contracts.

The study is a co-production of Ir. C.P.C.M. van der Hamsvoort of the Socio-Economics Division, Agricultural Economics Research Institute (LEI-DLO), the Netherlands and Dr. U. Latacz-Lohmann of the Department of Agricultural Economics at Wye College, University of London, United Kingdom. Part of the research was carried out when the latter author was a visiting scholar at the Economic Research Service of the U.S. Department of Agriculture, in Washington, D.C., funded through grant La 838/1-1 of the German Research Foundation (*Deutsche Forschungsgemeinschaft*), Bonn, Germany. Both authors share senior authorship.

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SUMMARY

During the past decade, many European countries have implemented an increasing number of conservation programmes that offer farmers some incentive payments for the voluntary adoption of well-defined environmentally benign farming practices. Among the well-known programmes are the British Management Agreements, offered in designated areas of environmental sensitivity; the Dutch *Relatienota* Programmes; the German Contractual Nature Conservation Schemes; the EC Low Input Agriculture Programme (1989-1992) and its successor programme, implemented under the umbrella of the Accompanying Measures of the 1992 Common Agricultural Policy Reform. The last two schemes mentioned are aimed not only at environmental protection but also at reducing commodity surpluses.

Most of these programmes are offered on the basis of fixed-conditions, fixed-rate contracts. The payment rates are normally derived from the presumed average cost of adopting the conservation technology in question. It is in the very nature of the problem that for some farmers, the payment rates on the basis of average cost exceed the amount needed to encourage participation, while, for the others, this amount is less than the profit foregone, and therefore unattractive. There is evidence that those farmers who strongly rely on intensive and polluting technologies do not participate. On the other hand, farmers with an initially low level of farming intensity preferably enter into conservation agreements. Undoubtedly, this results in a low level of programme cost-effectiveness in terms of environmental improvements (and surplus reduction) per unit of incentive payment.

Similar conservation programmes in the United States are offered on the basis of competitive bidding. Farmers who wish to participate submit bids to the government, stating the amount of payment for which they are willing to accept the restrictions imposed by the programme. Only bids that lie below an unknown exclusion level, i.e. the bid cap, are accepted.

In this report auction theory is employed to government purchases of environmental services (and surplus reduction) via conservation agreements. The aim of the report is to quantify the potential efficiency gains that can be achieved by offering conservation contracts to farmers on the basis of competitive bidding rather than as fixed-rate agreements. After a brief theoretical treatment of auction markets, a model for optimal bidding decisions is developed, which captures the specific features of auction markets for conservation contracts. The optimal bid is the one which maximizes the expected rent of participation. The optimal bid of a risk-neutral decision maker is a function of the cost of adopting the conservation technology and the individual beliefs about the bid cap. A risk-averse decision maker additionally takes into account

differences in the variability of profits between the conventional and the conservation technology.

The efficiency gains of implementing a competitive bidding scheme are quantified by applying the bidding model to 100 model farms that differ in the cost of switching towards a low-input technology in the production of small grains. Each of these farms is characterized by a production function that gives the technical relationship between nitrogen inputs and the output of grain. The production function approach allows us to quantify for each of the model farms the economic effects (profit foregone), the environmental effects (nitrogen balance surplus) as well as the supply control effects (output reduction) of participation in the programme. Participation and the corresponding impacts on aggregate output and aggregate nitrogen emissions are simulated both for a competitive bidding scheme and a scheme of fixed-rate contracts. The results show that the implementation of a bidding scheme can yield substantial savings in government outlays per unit of emission reduction. The more asymmetric the information is between farmers and the government on the costs of adopting the target technology and the environmental benefits associated with participation, the higher the benefits of implementing an auction. The farmers' informational advantage is normally transformed into an economic rent earned above the payment necessary to encourage participation. By ensuring competition in the bidding process, however, farmers have to balance net payoffs and the acceptance probability. A higher bid increases net payoff, but reduces the probability of winning, and vice versa. An auction in that respect can be considered a mechanism that constitutes an incentive for the farmers to (partly) reveal their true preferences in their bids and, consequently mitigate the problem of information asymmetry.

Furthermore, two issues of effective programme administration are discussed. The first one deals with strategic bidding behaviour in multiple-signup auctions, where farmers have proved to learn the maximum acceptable payment rates and bid almost exactly at those rates. On the basis of the bidding model, a strategy for the programme administrator to accommodate such strategic bidding behaviour is discussed. The second issue deals with the design and implementation of bid acceptance schemes that directly target programme objectives. The benefits that can be achieved by a bid ranking mechanism are quantified by a run of the bidding model. Finally, some conclusions are drawn on the usefulness of auction theory in practical auction design.

1. INTRODUCTION

1.1 Background and definition of the problem

Theory and practice provide various ways for allocating assets or resources. Those include both non-economic possibilities (e.g., lotteries) and economic ones such as posted prices, negotiations and auctions (see Shubik (1970) for a more extended discussion). Posted prices are suitable to be used in cases where the seller knows what price to post and has the advantage of probably having the lowest transaction costs among the mentioned economic alternatives (Rothkopf and Harstad, 1994). For many items and services, however, there are asymmetries of information on the market and, consequently, there is ignorance of what price to set. In those cases negotiations or auctions are an alternative and effective way of price formation, as they enable the participants to deal with uncertainty about the value of the object being sold or purchased (McAfee and McMillan, 1987). In fact a significant proportion of government purchases from the private sector is allocated on the basis of competitive bidding (e.g., the building of railways or roads). An important reason for that is that bidding is perceived to be fair, which is politically important, making a transfer publicly legitimate. Moreover, by holding a public auction, the public authority avoids being confronted with questions about the choice of the negotiating partners or the fixed price that will arise when using one of the other allocating mechanisms (Rothkopf and Harstad, 1994).

This study considers governmental purchases of environmental services provided by farmers through participation in conservation schemes. Following the arguments mentioned before, auctions would be the most preferred mechanism for allocating the conservation contracts for at least two reasons 1). First, the 'commodity' being traded, the provision of environmental services, has no standard value (Baneth, 1994). Second, there is a clear presence of information asymmetry, i.e. the farmers know better than anyone else what kind of conservation actions they intend to carry out and the size of the profit foregone by applying the conservation contract. Auctions in that respect constitute a mechanism that in essence is able to have farmers reveal their true preferences.

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1) Experiences in the UK with the allocation of Management Agreements (introduced as part of the 1981 Wildlife and Countryside Act (WLCA)) on the basis of *negotiations* have shown to cause efficiency problems. In the individual bargaining process, farmers proved to be able to transform their information advantage about their own costs and production plans into an economic rent earned above the payment necessary to induce compliance (Anonymous, 1993).

Despite this conclusion, in practice most of the conservation programmes are offered on the basis of fixed-condition, fixed-rate contracts. Many programmes, such as the 'EU Low Input Agriculture Programme' or the 'Market Relief and Cultural Landscape Conservation Programme' in Baden-Württemberg (Germany) aim not only at environmental protection but also at the relief of surplus markets. Other programmes, such as the 'Environmentally Sensitive Area (ESA) Scheme' in the UK and a similar scheme implemented in the Netherlands (in the so-called 'Relatienota' areas), only aim at the conservation of nature and landscape amenities 1). Relief of surplus markets can, however, be an important side effect (Ministerie van Landbouw, Natuurbeheer en Visserij, 1993; Potter, 1991). The payments offered are normally derived from the presumed average cost of adopting some well-defined environmentally benign farming practices, and they are equal for all farmers accepting a similar management prescription 2). It is in the very nature of the problem that for some farmers the payment rates exceed what is necessary to encourage participation, while for others it is less than the profit foregone, and therefore unattractive (Colman, 1989). There is evidence that particularly those farmers who strongly rely on intensive and potentially polluting technologies do not participate, while farmers with an initially low level of farming intensity preferably enter into conservation agreements. Undoubtedly, this results in a low level of programme cost-effectiveness in terms of the environmental improvements (and surplus reduction) per unit of government outlays.

The basic principle of 'equal payment for equal commitment' ensures the (politically preferred?) equal treatment of all participating farmers indeed. Nevertheless, it insinuates the involvement of a number of disadvantages, which may substantially lower the performance of conservation programmes.

The 'U.S. Conservation Reserve Programme (CRP)' aimed at reducing soil erosion and commodity surpluses by idling environmentally sensitive land, and the 'U.S. Wetlands Conservation Reserve Programme (WRP)' are - to the best of our knowledge - the only conservation programmes offered on the basis of competitive bidding. Farmers who wish to participate, submit bids to the government authority in charge of the programme in which they state the amount of payment for which they are willing to take the land out of production and establish a vegetative cover. Only bids below a previously unknown exclusion level, the bid cap, are accepted. The bid caps are differentiated according to soil productivity and the environmental sensitivity of the land, thus taking into

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1) And in some cases in the UK at keeping farmers in business in less-favoured areas.

2) Payments in the ESA scheme in the UK, for instance, range from only EP 10 per hectare for a low level management prescription for extensive sheep and cattle grazing in the North Peak ESA to EP 300 per hectare for the 'tier 2' management prescription of the Brecklands ESA (Colman, 1991). In the Netherlands on top of a subdivision into management prescription, payments also differ according to the type of soil to which the agreement applies: clay, peat or sand.

account both the individual cost and the presumed environmental benefits of participation.

Based on the previous analysis the definition of the problem is formulated as follows:

> 'What is the potential of efficiency gains that can be attained by offering conservation contracts to farmers on the basis of competitive bidding compared to fixed-rate contracts?'

1.2 Aim of the study, methodology and outline of the report

Both in the literature and in practice, the possible role of auctions and auction theory in assigning conservation contracts is rarely discussed. Therefore the aim of this study is to stimulate and contribute to this discussion by analysing the farmer's bidding behaviour and providing an estimate of the benefits of auctions in assigning agricultural conservation contracts.

The study starts off with a brief essay on what theory tells about optimal auction design in case of conservation contracts. In chapter 3 a model for optimal bidding decisions is developed that captures the specific features of auction markets for conservation programmes. In the next chapter the model is applied to 100 model farms that differ in the cost of adopting towards a low-input technology in the production of small grains. Participation and the corresponding impacts on aggregate emission and output reduction are simulated both for a competitive bidding scheme and an offer system of fixed-rate contracts. Subsequently, chapter 5 analyses to what extent the government can enhance programme performance by manipulating control variables. Finally, the report ends with some concluding remarks.

2. AUCTION THEORY AND CONSERVATION CONTRACTING

2.1 Four basic auction types

What is an auction? 'An auction is a market institution with an explicit set of rules determining resource allocation and prices on the basis of bids from market participants' (McAfee and McMillan, 1987:701). Classifying auctions based on the rules they exert, four basic auction types can be distinguished for a unique item being bought or sold: English, First-price sealed bid, Second-price sealed bid, and Dutch, although many variations upon the basic forms are used (Baneth, 1994). In the *English* 1) *auction*, the price of a good to be sold, is successively raised until only one bidder remains. The winning bidder's payoff is his valuation of the good minus his own (highest) bid. The English auction is often used for selling antiques and artwork. The *Dutch or descending-bid auction* is the reverse of the English auction. Now the seller announces an initial bid which he successively lowers until one bidder accepts the bid. The bidder's strategy is influenced by both his own valuation of the good and his beliefs about his competitors' valuations. The Dutch auction is used, for instance, for selling flowers in the Netherlands. In the *First-price sealed bid auction*, which is often used for government procurement contracts, each potential buyer submits one bid and the highest bidder wins. The basic difference between this auction type and the English auction is that in the latter each participant can observe his rivals' bids, and accordingly can revise his own bid. In the former auction type, on the other hand, each participant submits only one bid in ignorance of his rivals' bids. The bidder's strategy in a First-price sealed bid auction is guided by the same features as in the Dutch auction, while the winning bidder's payoff is his value minus his bid. The *Second-price sealed bid auction or Vickrey auction*, finally, exerts the same auction rules as the First-price sealed bid auction except that the winning bidder who offers the highest price, only pays the second highest bid. This auction type has been developed and introduced in theory by Vickrey (1961), but is seldom used in practice.

Which of the four auction types should be chosen in case of conservation contracts?

Auction design can be considered a principal-agent problem in the sense that the principal aims at setting up auction rules in a way that provides the highest benefits to himself. In the case of conservation contracting, the government, as purchaser of environmental services, acts as the principal and, therefore, organizes the auction. The government's objective is to maximize the environmental benefits, given some budget limitation. The farmers, as poten-

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1) Also called the oral, open or ascending-bid auction.

tial suppliers of environmental services, react to the bidding environment set up by the principal. Their objective is to maximize expected net revenue or expected utility. This is reflected in the farmers' bids. From the government's point of view, the type of auction to be chosen should be one that constitutes an incentive for the farmers to reveal their true preferences in their bids.

2.2 The Benchmark model and its assumptions

Theory shows that under a set of basic assumptions each auction form yields on average the same revenue to the auctioneer. This is known as the Revenue-Equivalence Theorem (Myerson, 1981; Riley and Samuelson, 1981; Vickrey, 1961). The assumptions are that (McAfee and McMillan, 1987) 1):

1. the bidders are risk-neutral;
2. the bidders have independent private values;
3. there is symmetry among bidders;
4. payment is a function of bids alone;
5. there are zero costs to bid construction and implementation.

This model is referred to in literature as the Benchmark model. Relaxation of the various assumptions violates the Revenue Equivalence Theorem and consequently leads to other conclusions about the optimal auction form. Most of the analytical literature on auctions deals with the Benchmark model or related issues. Milgrom (1989) states that although this makes data collection, model construction and solving the optimisation problem easy, it may often 'fail to portray the auction environment accurately' (Milgrom, 1989:4). Rothkopf and Harstad (1994) in a more recent article underline Milgrom's argument by refering to the fact that most of literature analyses 'single isolated auctions' that sometimes lack realism, but add that 'auction models can sometimes serve as useful building blocks or starting points for analyses that take account of the effects of other transactions' (Rothkopf and Harstad, 1994:369). This study intends to give in, at least partly, to both arguments in at least two ways. Although the analysis starts with the Benchmark model, in the remainder of this section some basic assumptions will be relaxed, making the model more realistic for the specific case of allocating conservation contracts with consequences for the optimal auction design. Moreover, as said in the introduction, section five presents some recommendations of how to effectively implement bidding systems, taking into account the assumptions made in the model and the auction environment in practice by using the experiences gained with the CRP in the U.S.

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1) In some game theory models of single auctions two additional assumptions are made (Rothkopf and Harstad, 1994):
   1. there is a single, isolated auction involving a fixed set of bidders;
   2. the rules of the auction are commonly known, firm and credible.

2.3 Relaxing the assumptions

Risk neutrality

With respect to the assumption of risk-neutral bidders, empirical analysis does not arrive at a unanimous judgement. Although farmers are generally assumed to be risk-averse, studies assessing farmers' conservation attitudes produce ambiguous results. Lynne, Shonkwiler, and Rola (1988), for instance, show that there is some degree of risk aversion involved in the conservation attitude and, consequently, conservation effort by farmers, mainly related to the income effect. Work of Gasson and Potter (1988) and Fraser (1991), on the other hand, concludes that risk aversion with respect to conservation is a phenomenon that is only marginally present among the farmers. Baneth (1994) somewhat relaxes the results from the last two studies by saying that they have been carried out at a time of relative agricultural price stability, which may induce that farmers' risk aversion was probably underestimated. This argument, however, does not explain the difference in outcome with the study of Lynne, Shonkwiler and Rola, which was carried out in the same period.

Assuming risk aversion has implications for the auction form to choose. The theoretical literature shows that with risk-averse bidders, the first-price sealed bid auction produces larger expected revenues to the auctioneer than the English or second-price sealed bid auction (Riley and Samuelson, 1981). In case of conservation programmes risk aversion translates to a higher level of programme performance in terms of the ratio between environmental improvements and the cost to the government. The reason behind this expectancy is that the conservation premium as a non-stochastic income component will decrease the farmers' income uncertainty, which will induce them to marginally lower their bids (as compared to the risk-neutral bidder) in order to increase the probability of acceptance. Although a first-price sealed bid auction is the best auction form to be chosen, it is not the *optimal* auction design as it fails to fully exploit the bidders' risk aversion. A solution to this problem could be to impose additional risk on the bidder either by penalizing undesired and subsidizing desired bidding behaviour 1) or by concealing the number of competing bidders 2).

Independent private values

The second assumption of independent private values is one of two extremes. The 'independent private values model' assumes that each bidder knows precisely how highly he or she values the item or, in case of bidding for

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1) Matthews (1983) for instance proposed a bidding fee that, in a conservation programme, is an increasing function of the bid.

2) See footnote nr. 5, which shows that it is a standard assumption in the Benchmark model that each bidder knows the exact number of bidders he is competing with.

conservation contracts, how high the production costs or profits foregone are. Moreover, the individual bidder does not know the valuation of the item by the competing bidders but perceives those valuations as being drawn from some probability function. Learning about the competitors' valuations will not cause the bidder to change the own valuation, although he might, for strategic reasons, change the bid. This model applies for instance to an auction for an antique with no resale, but also for government-contract bidding (McAfee and McMillan, 1987). The other extreme is the 'common values model' in which the item being auctioned has an objective true value. The bidders' perceptions of this value are independent draws from a probability distribution that is known to all participants in the auction. An example of the common value model is an auction for antique with resale in which the buyers will make a guess about the value of the antique on the resale market. Many items auctioned in practice, however, contain features of both extremes. For instance, the purchasers of antique for resale may have different resale possibilities so that the ultimate real value of the item depends on the buyer who wins. In such a case bidders' valuations are correlated or affiliated. Milgrom and Weber (1982) have developed a more general auction model that allows valuations be to correlated and that contains both the independent private values model and the common values model as extreme cases. Bearing this in mind, it is reasonable to maintain the independent private values assumption for conservation contract auctions. Each farmer is assumed to know his own production costs in terms of profit foregone when participating in the conservation programme that, besides some other factors, determines his bid. This information can be considered independent private information. Experiences with the U.S. CRP programme have learned that a common value element can arise when the conservation contracts are not sold in one auction but in different sequential auctions (Reichelderfer and Boggess, 1988). Farmers then can analyse the results of the preceding rounds and can update (often increase) their bids.

Symmetry among bidders

The requirement of symmetry among bidders means that all bidders draw their valuations from the same distribution function. For conservation programmes this should, however, not necessarily be the case. Farmers on different locations may have a different quality of land, resulting in different achievements of environmental quality. For the conservation programme this may imply that although bids may be equal in monetary terms, the resulting provision of environmental services may differ. This case is known as an asymmetric bidding situation, as different farmers draw their valuations from different probability functions. Theory tells that in the case of asymmetric bidders, the optimal auction system for the government agency generally is the one in which the item being purchased is assigned to the lowest bidder (Myerson, 1981). In case of conservation contracts, however, such an optimal auction design is discriminatory in the sense that it favours the lower bidders with possibly a low ratio of environmental output per monetary unit of bid against higher bidders with a higher ratio. Besides possible political objections such a system therefore has the practical objection of not achieving the targets of the programme. Practical solutions to this problem are discrimination of bids (Anonymous, 1993), the establishment of eligibility criteria with respect to which farmers are actually allowed to participate 1) (Reichelderfer and Boggess, 1988) or the distinction, a priori, of homogeneous classes of bidders based on natural circumstances (Baneth, 1994; Latacz-Lohmann, 1993).

Payment is only a function of bids

The Benchmark model further assumes that payments can only be a function of bids. Sometimes, however, it is in the seller's or buyer's interest to make payments conditional on some additional information about the winners' valuation of the item. McAfee and McMillan (1987) exemplify this with an auction of oil rights to government-owned land. After the assignment of the rights the government can observe the actual amount of oil extracted, which provides her with additional information about the winning bidder's true value of the oil right. The payment by the winning bidder may now equal his or her bid plus a royalty payment based on the amount of oil extracted, although also other bidding mechanisms are possible. A similar system may be applied in case of conservation contracts by linking the payment level to the monitoring. The winning bidders receive part of their bid when the contracts are assigned and the remainder depending on the achieved results at the end of the contract period.

Zero costs to bid construction and implementation

The final assumption deals with the costs involved in bid construction and implementation. Although in the Benchmark model they are assumed to be zero, the costs associated with bid construction and submission may not be negligible in the bidding process. In case of conservation contracting, for instance, farmers have to acquire information about the expected profits foregone under the conservation scheme. The costs involved in bid preparation can be considered sunk costs once the bid has been submitted (Rothkopf and Harstad, 1994). Moreover, those costs imply a loss to the farmer if the bid is rejected and a reduction in the accruing economic rent if the bid is accepted (Anonymous, 1993). Bid preparation costs being too high will therefore diminish the number of bidders and probably violate the efficiency potential of the auction. To counteract this potential problem when assigning conservation contracts it is important that the auctioned contracts are simple and understandable to the farmers. Moreover, it is generally in the purchasing government agency's interest to provide as much information as possible about the contracts auctioned.

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1) A solution used in the CRP.

2.4 Reserve prices and multiple similar contracts

Finally two more issues will be discussed: the use of reserve prices and variation in purchasing constraints. With respect to the former the question can be raised whether the government agency should impose a reserve price or in case of conservation contracts set a bid cap above which no bids are accepted. Theory says it should as it provides farmers with an incentive to reveal their bids honestly that will consequently lower the expected costs for the purchasing government agency. Therefore, although the Revenue Equivalence stated that under the Benchmark model all auction forms yield on average the same revenue to the government agency, theory adds that any of these auction forms only is the optimal auction mechanism if it is supplemented by an optimally set reserve price (Myerson, 1981; Riley and Samuelson, 1981) 1). A reserve price, however, only proves to be effective when bidding competition is weak (McMillan, 1994), which may be the case when the number of bidders is small or when there is collusion among bidders.

The last issue deals with the number of conservation contracts purchased by the government agency. The theory described until now applies to a *unique* item being auctioned. A conservation programme, however, generally offers *multiple similar* contracts. To what extent does this change the conclusions drawn until now? For multiple similar contracts either a discriminatory first-price sealed bid or a uniform-price auction can be used. In the first case, the *n* lowest bidders are rewarded, receiving the payment stated in their bids. In the uniform-price auction the *n* successful bidders receive a payment at the amount of the lowest unsuccessful bid. The uniform-price auction consequently, corresponds to the second-price sealed bid auction in the single unit case, and in determining the optimal auction form, the conclusions set out for a single-item auction, also apply for the multiple-unit auction considered here (McAfee and McMilllan, 1987).

In case of multiple contracts with no budget constraint, optimal auction design additionally requires the use of a reserve price in order to increase bidding competition.

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1) In auction theory one generally assumes that bids are a function of bidders' valuation of the item being sold or purchased. The optimal reserve price as set by the auctioneer in all of the auction forms under the Benchmark model now equals the valuation as held by bidders that earns a payment equal to the auctioneer's valuation of the item.

3. A MODEL OF PARTICIPATION AND OPTIMAL BIDDING BEHAVIOUR

3.1 The general bidding model

A necessary condition for farmers to participate in a conservation scheme is that the expected utility of income in case of participation is at least equal to or higher than in case of non-participation. Let us assume that the farmers eligible for the programme have private information about the profits of farming, both under the conventional and the conservation technology, denoted by Π_0 and Π_1, respectively 1). Under a fixed-rate offer system with the fixed rate denoted by $\bar{p}$, farmers will participate if:

$$U(\Pi_1+\bar{p})-U(\Pi_0)>0 \tag{1}$$

where $U(\cdot)$ is a monotonically increasing, twice differentiable von Neumann-Morgenstern utility function. $U(\Pi_0)$ will in the following be called the reservation utility. Whereas with a fixed-rate payment farmers only need to decide whether or not to participate, under a bidding system also the amount of the bid is at the farmers' discretion.

Before proceeding with the farmer's decision rule in a bidding environment, let us first assume that the governmental authority that administers the conservation programme announces to set a reserve price or bid cap β. All individual bids below β will be accepted, while bids above the bid cap are rejected. The farmer will now tender a bid b if his expected utility in the case of participation exceeds his reservation utility:

$$U(\Pi_1+b)\cdot P(b\leq\beta)+U(\Pi_0)\cdot(1-P(b\leq\beta))>U(\Pi_0) \tag{2}$$

where P stands for probability. The bidders neither know the bid cap, nor the other bidders' switch-over costs and bid prices. It is then plausible to assume that each bidder forms individual expectations about β. These expectations can be characterized by its density function $f(b)$ and distribution function $F(b)$. The probability that a bid will be accepted, can then be written as:

$$P(b\leq\beta)=\int_b^{\beta} f(b)db=1-F(b) \tag{3}$$

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1) We shall use the expressions profit foregone, switch-over costs, costs of participation, and profit differential as synonyms to verbalize the expression (Π_0 - Π_1).

where $\bar{\beta}$ denotes the upper limit of the bidder's expectations about the bid cap, i.e. the maximum expected bid cap. Substituting (3) into (2) yields:

$$U(\Pi_1+b)\cdot(1-F(b))+U(\Pi_0)\cdot F(b)>U(\Pi_0) \tag{4}$$

A common characteristic of all bidding situations is the balance between net payoffs and the acceptance probability. A higher bid increases the net payoff, but reduces the probability of winning, and vice versa. The farmer therefore faces the problem of determining the optimal bid, which is the one that maximizes the expected utility (on the left of the relation sign) over and above the reservation utility (on the right of the relation sign). In the following two sections the optimal-bid formulas will be derived for both risk-neutral and risk-averse bidders, as risk attitude studies about farmers' conservation behaviour do not provide unambiguous arguments for a well-founded choice (see previous chapter).

For ease of analysis, both Benchmark assumptions that there are no costs in bid preparation and implementation and that payment is only a function of the bid, are maintained 1).

3.2 The risk-neutral decision maker

For a risk-neutral decision maker, who simply maximizes expected profits, expression (4) can be rewritten as:

$$(\Pi_1+b-\Pi_0)\cdot(1-F(b))>0 \tag{5}$$

which denotes the expected income *gain* through participation in the conservation scheme. The optimal bid of a *risk-neutral* decision maker, b^*_{rn}, that maximizes the expected net payoffs, can now be derived by maximizing (5) through the choice of b. This yields:

$$b^*_{rn}=\Pi_0-\Pi_1+\frac{1-F(b)}{f(b)} \tag{6}$$

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1) The former assumption is, however, not as unrealistic as it seems. From expression (4) it is clear that each farmer has to acquire information about the expected profit foregone under the conservation scheme. The same costs are, however, reasonably borne by farmers who have to decide whether or not to join a fixed-rate conservation scheme. Bearing the aim of this article in mind, negligence of bid preparation costs will not necessarily violate the results of the analysis.

In order to be able to calculate a number for b^*_{rn}, assumptions must be made about the type of distribution considered. For reasons of simplicity, it is assumed that the bidders' expectations about the bid cap are uniformly distributed in the range $[\underline{\beta},\bar{\beta}]$, where $\underline{\beta}$ and $\bar{\beta}$ represent the minimum and maximum expected bid cap, respectively. Although assuming a triangle distribution would be more realistic, this would increase the mathematical burden unreasonably. The density and distribution functions of a rectangular distribution are given as follows (adapted from Law and Kelton, 1991):

$$f(b)=\begin{cases} 0 & \text{if } b<\underline{\beta} \\ \dfrac{1}{\bar{\beta}-\underline{\beta}} & \text{if } \underline{\beta}\leq b\leq\bar{\beta} \\ 0 & \text{if } b>\bar{\beta} \end{cases} \tag{7a}$$

$$F(b)=\begin{cases} 0 & \text{if } b<\underline{\beta} \\ \dfrac{b-\underline{\beta}}{\bar{\beta}-\underline{\beta}} & \text{if } \underline{\beta}\leq b\leq\bar{\beta} \\ 1 & \text{if } b>\bar{\beta} \end{cases} \tag{7b}$$

In analyzing optimal bidding behaviour, it is important to note that it does not make economic sense to submit a bid lower than the minimum expected bid cap $\underline{\beta}$. Furthermore, a bid will be submitted only if the (optimal) bid price at least covers the cost of adopting the target technology. Taking these arguments into account and substituting (7) into (6), the optimal-bid formula of a risk-neutral decision maker can then be written as

$$b^*_{rn}=\max\left\{\frac{\Pi_0-\Pi_1+\bar{\beta}}{2},\underline{\beta}\right\} \qquad s.t. \quad b^*_{rn}>\Pi_0-\Pi_1 \tag{8}$$

Two things are important to note from expression (8):

1. the optimal bidding strategy of a risk-neutral decision maker is a linearly increasing function of the bidder's switch-over cost and the maximum expected bid cap. The optimal bid is simply half of the profit foregone plus half of the maximum expected bid cap;
2. a positive bid of ½ $\bar{\beta}$ (or at least $\underline{\beta}$) will be submitted by farmers for whom the adoption of the target technology does not involve any cost. Therefore, a free-rider problem, encountered under the fixed-rate contract scheme, is expected to exist also under a competitive bidding scheme.

3.3 The risk-averse decision maker

For a risk-averse decision maker it is important that the conservation payment is a non-stochastic income component. Moreover, in his decision whether or not to participate in the programme he will also take account of possible changes in the variation of his income from market production when adopting the conservation technology. Those aspects affect the risk-averse farmer's utility as introduced in equation (2). Since utility as such is, however, not tangible, it is replaced in the following mathematical exposition by the certainty equivalent *(CE)*:

$$CE_1 \cdot (1-F(b)) + CE_0 \cdot F(b) > CE_0 \tag{9}$$

Since the certainty equivalent is defined as the difference between expected income and a risk premium *(RP)*, (9) can be rewritten as:

$$(\Pi_1 + b - RP_1(b)) \cdot (1-F(b)) + (\Pi_0 - RP_0) \cdot F(b) > \Pi_0 - RP_0 \tag{10}$$

where the risk premium $RP(\cdot)$ is a function of the expected value $([\Pi_1+b]$ and Π_0 for RP_1 and RP_0, respectively), and the standard deviation (σ) of income (see appendix 1 for an elaboration of the formulas). After rearranging terms:

$$[(\Pi_1 + b - RP_1(b)) - (\Pi_0 - RP_0)] \cdot (1-F(b)) > 0 \tag{11}$$

This expression denotes, analogous to (5), the expected gain in certainty equivalent through participation in the conservation scheme. Maximizing (11) with respect to b yields the optimal-bid formula of the risk-averse decision maker. Again, take into account that no bids will be submitted below the minimum expected bid cap. Moreover, the optimal bid will be submitted only if it ensures a gain in certainty equivalent. Then,

$$b^*_{ra} = \max \left\{ \Pi_0 - \Pi_1 - (RP_0 - RP_1(b)) + \underbrace{(1-RP_1'(b))}_{factor<1} \cdot \underbrace{\frac{1-F(b)}{f(b)}}_{premium}, \beta \right\} \tag{12}$$

$$s.t. \quad CE_1(b^*_{ra}) > CE_0$$

From (12) is clear that the optimal bid comprises the profit foregone minus the difference in risk premiums plus a premium multiplied by a factor less than one. The greater the risk aversion, the smaller the factor and, thus, the lower the optimal bid price. The analogy to the bidding strategy of risk-neutral bidders is clear by setting RP_0 and RP_1 equal to zero. Then expression (12) is reduced to the optimal-bid formula of risk-neutral decision makers as given in (6) and (8). From (8) and (12) it is expected, as indicated in chapter 2, that risk-averse farmers will normally tender lower bids than risk-neutral farmers, unless the variability of profits under the conservation technology (affecting RP_1) is significantly higher than under the conservation technology. This may, for example, be the case when the conservation scheme requires farmers to refrain from applying pesticides.

In order to calculate a number for b^*_{ra}, assumptions on the type of distribution and the type of utility function must be made. The latter is needed to calculate the risk premiums. In the interest of clarity, the mathematical treatment of this matter has been deferred to the appendix. There the optimal bidding strategy for risk-averse decision makers is derived under the assumption of uniformly distributed expectations about the bid cap and a utility function of the type $U(Y) = lnY$.

4. MODEL APPLICATION TO A HYPOTHETICAL EXTENSIFICATION PROGRAMME

4.1 Introduction

In this chapter, the bidding model developed in the previous chapter, is applied to a hypothetical extensification programme characterized by only one restriction: a maximum input of 80 kg of nitrogen per hectare. The programme is aimed at the reduction of both nitrogen emissions and the production of surplus commodities. It is offered to 100 model farms of each 100 ha that differ in the cost of adopting the low-nitrogen technology in the production of small grains 1). Each of the farms is characterized by a production function that describes the technical relationship between nitrogen input and the output of grain. The production function approach allows us to quantify for each of the model farms the economic implications (profits foregone), the environmental effects (nitrogen emission reduction) as well as the supply control effects (output reduction) of participation in the programme. Programme performance is simulated for different variants of an auction system and the results are compared to the outcomes that would be achieved under an offer system of fixed-rate contracts.

4.2 The farm-level model

For each of the model farms a production function of the type $y(n) = a+b \cdot n+c \cdot n^2$ is assumed, where y and n denote yields of grain per hectare and nitrogen application per hectare, respectively; and a, b, and c are the coefficients of the production function. The farms differ in soil quality and other natural and climatic factors. These factors are reflected in different values of the technological parameters a, b, and c, thus, resulting in different levels of nitrogen use and different yields. Those parameters have been chosen in approximation to empirically estimated production function coefficients, like those given in Schindler (1990) and Claupein (1994). Assuming a product price of p and a nitrogen per-unit price of r, for each of the model farms the optimal nitrogen intensity, n^*, the corresponding yield, $y(n^*)$, and profit, $\Pi(n^*) = \Pi_0$ is

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1) Each farm is assumed to grow only small grains.

calculated, where profit is defined as revenues minus the cost of nitrogen fertilization $(p \cdot y(n^*) - r \cdot n^*)$. 1)

Individual nitrogen balances (NB), indicating the environmental impacts of the agricultural production process, are subsequently calculated as difference between the optimal nitrogen input, n^*, and the nitrogen export with the corresponding crop yields: $NB = n^* - \gamma \cdot y(n^*)$, where γ denotes the amount of nitrogen extracted per unit of crop yield.

Table 4.1 Characteristics of selected model farms under conventional and low-nitrogen technology

Characteristics		Model farm number				
		1	25	50	75	100
Production	a	24.9	32.4	38.3	42.4	44.6
Function	b	0.249	0.332	0.393	0.427	0.436
Coefficients	c	-0.00141	-0.0013	-0.0012	-0.0011	-0.001
Conventional technology:						
n^*	(kg/hectare) a)	75	113	150	182	207
$y(n^*)$	(mt/hectare)	3.57	4.34	7.07	8.48	9.38
$\Pi_0=\Pi(n^*)$	(ECU/ha)	327	489	647	775	855
$NB(n^*)$	(kg/hectare) b)	10.5	17.0	22.4	28.9	38.3
Target technology:						
$\tilde{n} \leq 80$	(kg/hectare)	75	80	80	80	80
$y(\tilde{n})$	(mt/hectare)	3.57	5.07	6.26	6.97	7.33
$\Pi_1=\Pi(\tilde{n})$	(ECU/ha)	327	475	590	665	701
$NB(\tilde{n})$	(kg/hectare) b)	10.5	-11.2	-31.9	-45.5	-51.9
Differences:						
Yield	(mt/ha)	0	-0.27	-0.79	-1.47	-2.05
Nitrogen bal.	(kg/ha) c)	0	-17.0	-22.4	-28.9	-38.3
Profit	(ECU/ha)	0	-14	-57	-110	-154

a) At p = ECU 100 per mt grain and r = ECU 0.4 per kg nitrogen; b) At γ = 18 kg nitrogen per metric ton (mt) yield (Source: Hydro Agri Dülmen, 1993); c) Only reductions of nitrogen *emissions* are considered environmental improvements. If under the low-input technology the nitrogen balance is negative, only the initial nitrogen balance surplus over and above zero, not the entire difference between $NB(n^*)$ and (negative) $NB(\tilde{n})$, is taken into account.

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1) This is a simplifying assumption. In fact, it would be more realistic to take into account interdependencies between variable inputs in the sense that a reduction in nitrogen intensity is likely to induce a decrease in the use of complementary inputs like insecticides, fungicides or growth regulators, and an increase in the use of substitutive inputs like green or animal manure. Assumptions about the size of these changes would, however, be completely arbitrary.

The economic, environmental, and supply control effects of switching towards the low-nitrogen technology are now simulated by entering the target nitrogen intensity, $\tilde{n}$, into the production function model. Assuming realistic prices of nitrogen and grain and a plausible extraction factor γ, the results both for the conventional and the low-input technology are illustrated in table 4.1 for a few model farms.

The higher the initial (optimal) nitrogen intensity has been, the larger the profit foregone. This implies that participation in the conservation scheme is offered at increasing marginal cost. A graphical depiction of the marginal cost curve (the switch-over cost curve) is given in the upper charts of figure 4.1 and 4.2. Note that participation does not involve any cost if the target technology is already in place (like in the case of model farm # 1). It is clear that in those cases there is also no marginal contribution to the achievement of the programme goals.

4.3 Assumptions and scenarios

The production function model is linked up with the bidding model through the profit differential. Recall from expressions (6), (8), and (12) that although the profit foregone is one of the major determinants of the optimal bid, the optimal-bid formulas can only be applied when assumptions are made on the farmer's expectations about the bid cap. The bidders' expectations are assumed to be uniformly distributed in a range of plus/minus 40% of the presumed average profit foregone of all eligible farmers with positive switch-over costs 1). In the calculations made, the average cost is ECU 67 per hectare. Consequently, the range of expectations is bordered by $\underline{\beta}$ = ECU 40.2 and $\overline{\beta}$ = ECU 93.8 per hectare. Moreover, it is assumed that each bidder faces the same density and distribution function, implying that all bidders have the same expectations about the bid cap. This corresponds to applying the assumption of symmetry among bidders.

Quantification of the risk-averse farmers' optimal bids (according to expression (12)) additionally requires assumptions on the variability of profits, both under the conventional and the low-nitrogen technology, in order to calculate the risk premiums. It is assumed that the variation coefficient of profits (excluding conservation incentive payments) is 0.25 for either technology 2).

The aforementioned assumptions are reflected in the optimal bids. Programme performance, however, depends not only on the farmers' bids but also on various issues related to auction design and the rules exerted, such as eligibility criteria, bid selection rules, and the use of bid pools. As theory is ambigu-

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1) We shall vary this assumption in chapter 5.

2) The variation coefficient is defined as the ratio of the standard deviation to the mean. Recall this paper considers a nitrogen de-intensification programme without any restrictions on other factor inputs. Therefore, it is assumed that profit variability does not change. If also the use of pesticides were restricted, participation would likely increase profit variability.

ous about optimal auction design programme performance is simulated for different variants or scenarios.

It is important to note that for all variants it is assumed that farmers are required to enroll their acreage into the programme on an all-or-nothing basis, i.e. the number of hectares is not a decision variable. Although some nature conservation programmes (e.g., in the Netherlands) allow farmers to choose which tracts of their farms to put under conservation contract, extensification programmes such as the EC Low Input Agriculture Programme require farmers to de-intensify their entire farm.

The different variants chosen are:

1. *Flat-rate offer system (reference):*
   a flat, pre-announced payment, $\bar{p}$, is offered to all farmers who agree to implement the target technology on their farms. The payment rate is fixed by the government at the presumed average profit foregone of all eligible farmers with positive switch-over costs. All farmers who sign up for the programme will be accepted. Most of the conservation programmes in European countries are based on this type of payment scheme. From the point of view of the producers, participation is worthwhile if $\Pi_1+\bar{p}>\Pi_0$ for risk-neutral decision makers, and if $\Pi_1+\bar{p}-RP_1(\bar{p})>\Pi_0-RP_0$ or, equivalently, $CE_1 > CE_0$, for risk-averse farmers. This payment scheme will serve as reference against which the following schemes will be compared.

2. *Simple auction system (uniform bid cap):*
   according to the theory in chapter 2 the optimal auction for multiple contracts under budget limitation in a risk-averse environment is a discriminatory first-price sealed bid auction. Farmers submit sealed bids, prompting the amount of payment needed for participation. The government announces that a uniform bid cap will be set after the closing date for bid submission. In order to guide the farmers in preparing their bids, the government notifies them that the (ex-ante) bid cap is oriented at the presumed average profit foregone, and that only bids below this level will be accepted. Although the bid cap has no function as an exclusion mechanism as such, its announcement is psychologically important to provide farmers with the incentive to bid honestly.
   Because theory is less clear about the optimal auction design in case of unlimited budget, within this variant two scenarios are considered:

   2a. *No budget limitation:*
   in contrast to the announcement, *all* bids are accepted, which corresponds to variant 1 where all farmers who sign up for the programme are accepted. The difference between this variant and variant 1 is that in the latter farmers are paid a pre-announced and equal payment, while in the former farmers receive their bids submitted;

2b. *Budget limitation:*
the budget is restricted to the amount of variant 1 (reference). The government accepts bids, starting with the lowest bid, until the budget is exhausted. Therewith, the ex-post bid cap is set as a residual at the level of the highest successful bid.

Although the previous two variants do not expressly take account of asymmetry among bidders, in chapter two it was argued that its negligence can result in both political and practical objections because of diminishing programme performance. In the following two variants the asymmetry issue is analysed by distinguishing homogeneous classes of bidders based on natural circumstances. It is assumed that the government has information on switch-over costs sufficient to cluster all eligible farmers into three pools (*j*) of equal size: farms with low, average, and high profits foregone. Again it is assumed that the bidders' expectations about the maximum acceptable bid level are uniformly distributed in the range of minus 40 to plus 40% of the presumed average switch-over cost of the pool and that all farmers within one pool face the same density and distribution function. By doing this, we relax the symmetry assumption of the Benchmark model only between the pools, but stick to it within the pools. The different variants chosen are:

3. *Offer system with differentiated payment rates:*
a pool-specific, pre-announced payment, $\overline{p}_j$, $j = 1, 2, 3$, is offered to farmers who agree to sign a conservation contract. Similar to variant 1, the payment rate for group *j* is fixed by the government at the presumed average profit foregone of all group *j* farmers with positive switch-over costs. All farmers who sign up for the programme will be accepted.

4. *Bid pool auction system (differentiated bid caps):*
similar to variant 2, farmers tender sealed bids to the government. Each bid received is assigned to a bid pool. Like in variant 3, there are three pools of different switch-over cost. The government announces that pool-specific bid caps will be set after the closing date for bid submission. Every farmer knows to which bidding pool his farm is assigned. Again, two sub-scenarios are considered:

4a. *No budget limitation:*
in contrast to the announcement, *all* bids are accepted.

4b. *Budget limitation:*
the budget is restricted to the amount of variant 1 (reference). The government accepts, for each bid pool, bids, starting with the lowest one, within the available budget. This again implies that the ex-post bid cap is only a residual.

4.4 Results

Figure 4.1 confronts the optimal bids under the simple auction scheme against a flat-rate payment fixed at the average of the switch-over cost as estimated by the government. In figure 4.2 the same is depicted for an offer system with differentiated payment rates and the corresponding bid pool auction scheme. Optimal bids and payment rates must be seen in relation to the switch-over cost curve that is also depicted in figure 4.1 and 4.2. The quantitative results of the model calculations are listed in table 4.2 for risk-neutral decision makers and in table 4.3 for risk-averse decision makers, respectively. The columns indicate the various payment schemes and the rows indicate the variables that measure the programme performance in relation to the flat-rate offer system which is set to 100.

Implementation of the bidding schemes increases programme performance significantly. A major reason for this is that replacing an offer system by an auction scheme reduces the windfalls (vertical distance between payments and costs in figure 4.1 and 4.2) accruing to farmers who enroll land with lower-than-average switch-over cost, while, at the same time, some producers with higher-than-average cost are encouraged to participate. Under all auction scheme variants the relative increase in absolute goal achievement (amounts of emission and output reduction: the shaded areas in figure 4.1 and 4.2 and rows B and C in table 4.2 and 4.3) and in switch-over cost lies above the relative increase in the number of participants. Since, at the same time, farmers enrolling low-cost land tender bids lower than the amount they would receive under a flat-rate offer system, the level of programme cost-effectiveness, measured as absolute goal achievement per unit of programme outlays (rows G and H), rises significantly. Replacing the flat-rate scheme (1) by a simple bidding system (2b) yields an additional 14% of emission reduction and an additional 25 to 26% of commodity surplus reduction with the same amount of government outlays. Moreover, net income transfers reduce by about 16%. The programme cost-effectiveness improves by 16 and 27-28% for the emission- and output reduction, respectively.

The advantages of switching to a simple auction scheme are even larger if the government budget is unlimited (variant 2a). Compared to the offer system, programme cost-effectiveness with respect to output reduction increases by 47%, while net income transfers reduce by 29 (risk neutrality) and 32% (risk aversion), respectively.

The largest improvements in programme performance can, however, be achieved by differentiating payment rates and bid caps according to the presumed regional or farm type specific switch-over cost (variants 3, 4a, 4b). The largest absolute goal achievement is accomplished by a bid pool auction scheme without budget constraints (variant 4a). Although, for instance, in the risk-neutral case the number of participating farmers increases by only 59%, total emission and output reduction increases by 131 and 307% respectively, with a budget increase of 98%. The benefits of differentiating bid caps (which is shown in figure 4.2) stem from the fact that the discrete adjustment of the maximum acceptable payment level to the switch-over cost curve allows high-

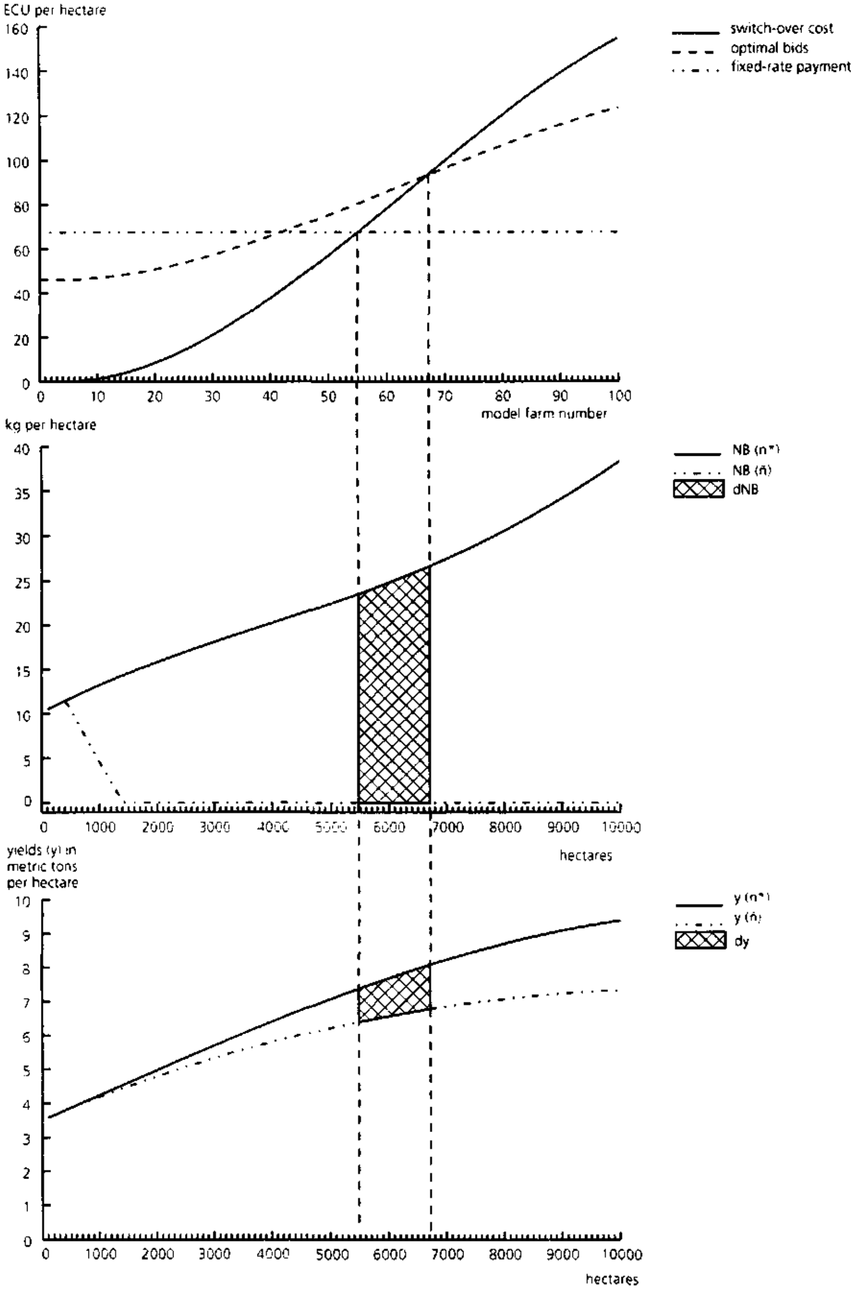

Figure 4.1 Economic, environmental, and supply control effects of programme participation for risk-neutral farmers: simple bidding scheme (variant 2a) versus fixed-rate offer system (variant 1)

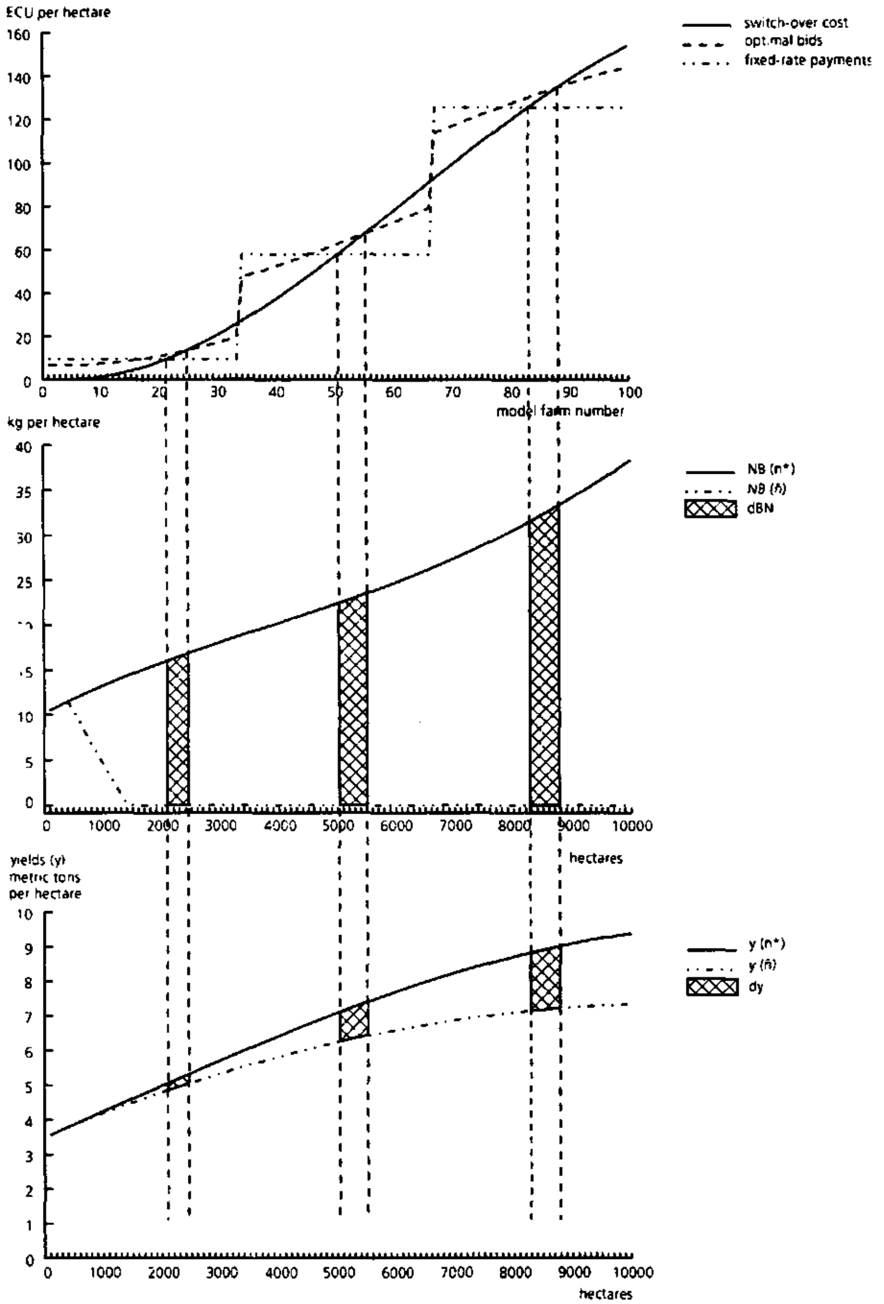

Figure 4.2 Economic, environmental, and supply control effects of programme participation for risk-neutral farmers: bid pool auction (variant 4a) versus differentiated fixed-rate payment (variant 3)

Table 4.2 *Simulated performance of the extensification programme for risk-neutral decision makers under different payment schemes (flat-rate offer system = 100)*

Performance measures	Variants					
	1	2a	2b	3	4a	4b
	flat-rate offer system	simple auction scheme	simple auction, budget	offer system, pools	bid pool auction scheme	bid pool auction, budget
A. Number of participants	100	124	109	98	159	117
B. Total emission reduction	100	139	114	117	231	138
C. Total output reduction	100	173	126	180	407	199
D. Total programme outlays	100	118	98	88	198	100
E. Total switch-over costs	100	185	129	203	475	220
F. Net income transfer a)	100	71	84	32	29	38
G. Emission reduction per unit of programme outlays (B/D)	100	117	116	134	116	138
				(100)	*(105)*	*(107)*
H. Output reduction per unit of programme outlays (C/D)	100	147	128	205	205	200
				(100)	(109)	(108)

a) Total programme outlays minus total switch-over costs, i.e., overcompensation of switch-over costs.

Table 4.3 *Simulated performance of the extensification programme for risk-averse decision makers under different payment schemes (flat-rate offer system = 100)*

Performance measures	Variants					
	1	2a	2b	3	4a	4b
	flat-rate offer system	simple auction scheme	simple auction, budget	offer system, pools	bid pool auction scheme	bid pool auction, budget
A. Number of participants	100	125	109	107	157	116
B. Total emission reduction	100	141	114	132	224	136
C. Total output reduction	100	176	125	204	381	192
D. Total programme outlays	100	120	98	101	191	98
E. Total switch-over costs	100	188	128	230	439	210
F. Net income transfer a)	100	68	83	27	26	35
G. Emission reduction per unit of programme outlays (B/D)	100	118	116	131	117	139
				(100)	*(105)*	*(112)*
H. Output reduction per unit of programme outlays (C/D)	100	147	127	201	199	195
				(100)	*(109)*	*(107)*

a) Total programme outlays minus total switch-over costs, i.e., overcompensation of switch-over costs.

cost farmers, who rely more than others on polluting farming practices, to participate.

The largest improvement in programme cost-effectiveness is achieved in variant 4b, i.e. an auction scheme with regionalized bid caps and a limited budget. With the same government outlays as in the reference variant, emission-reduction and output reduction per unit of government outlays increases by 38 and 100% in the risk-neutral case and by 39 and 95% in the risk-averse case, respectively.

4.5 Auctions and information asymmetry

Notwithstanding the improvements that can be achieved by differentiating payment rates and bid caps, it requires reliable information that is costly to obtain. It stands to reason that the more information is available and, thus, the more precisely bid caps and payment rates can be set, the better the programme will perform. In the extreme, when the government has perfect information about the switch-over cost curve, each farmer could be offered a payment to the amount of his or her profit foregone plus an incremental amount to encourage participation. It is clear that, in this case, the implementation of a bidding scheme does not yield any benefits. Conversely, the benefits of implementing a bidding scheme are higher, the less information about switch-over costs is available to the government, i.e., the larger the information gap between farmers and the government. The *italic* numbers in table 4.2 and 4.3 give evidence of this: the efficiency gains of replacing a three-pool offer system (variant 3 - implying some information) by a bid pool auction scheme (4a and 4b) are substantially lower than the gains that can be achieved by switching from the flat-rate offer system (variant 1 - implying very limited information) towards a simple auction scheme (2a and 2b).

The matter of information asymmetry can also be examined from another angle: first, note that the rent of participation, denoted net income transfer in table 4.2 and 4.3, is in all variants below the level of the reference variant. The rent of participation can be regarded as returns to private information on the individual farmer's switch-over cost earned above the payment needed to encourage participation. The more information the government acquires, i.e., the smaller the information gap, the less the farmers will be able to extract high information rents because the government can, to a certain extent, identify and discriminate applicants with 'unreasonably' high bids.

In this respect, it is important to note that the implementation of a bidding environment reduces information asymmetry inherently, as the bidding process reveals, to a certain extent, the individual bidders' switch-over costs. Since the optimal bid is, among others, a linear function of the profit foregone, a high bid signals high switch-over costs and vice versa. This cost-revelation mechanism makes auctions a valuable tool for the government to cope with information asymmetry.

5. MANIPULATING CONTROL VARIABLES TO ENHANCE PROGRAMME PERFORMANCE

5.1 Introduction

The previous chapter has shown that substantial gains in programme cost-effectiveness can be elicited from implementing an auction market for conservation contracts. The size of these benefits can be influenced by manipulating key control variables to directly target objectives. In this chapter, major control variables available to the government are identified and the impacts of its variations on programme performance are analysed.

5.2 Enhancing bid competition in multiple-signup auctions

Bid competition depends for the most part on the farmers' expectations about the maximum acceptable payment rate. Given multiple signups, observed decisions in one period are likely to influence the bidders' expectation in the next period. The earlier mentioned U.S. CRP, gives evidence of this so-called Bayesian learning. During the first four signups, the mean value of the bids increased (Osborn et al., 1990), while the distribution of the bids declined (Reichelderfer and Boggess, 1988), implying that the farmers had learned the bid caps. By the 9th signup, more than 80% of all bids were almost exactly equal to the bid caps (Osborn, personal communication).

In the language of our bidding model, such learning narrows the range $[\underline{\beta},\overline{\beta}]$ of expectations about the maximum acceptable bid level. According to the optimal-bid formulas (8) and (12), this encourages farmers wishing to enroll low-cost land to bid at least $\underline{\beta}$, while high-cost farmers are discouraged from tendering bids, because $\overline{\beta}$ is less than the cost of adopting the target technology. A decline in bid competition, thus, decreases programme performance. In the extreme, when the bidders know the bid cap with certainty, i.e., $\underline{\beta}$ equals $\overline{\beta}$, the bidding scheme degrades to a fixed-rate offer system.

On the other hand, a very wide range $[\underline{\beta},\overline{\beta}]$ of expectations, which may occur in the first signup, encourages the farmers to tender 'unreasonably' high bids. This is immediately clear from the optimal-bid formulas (8) and (12). As a consequence, programme performance decreases, especially when total programme outlays are limited. Low programme performance at both a narrow and a wide range of bid cap expectations implies that there is an 'optimal' range $[\underline{\beta},\overline{\beta}]$ that provides maximum bid competition.

Figure 5.1 and 5.2 analyse, based on the data of the previous section, the impact of the range of bid cap expectations on selected performance measures. Figure 5.1 does this for a simple auction scheme without budget limitation (variant 2a) and figure 5.2 for one with budget constraint (variant 2b). All performance measures are depicted in relation to the flat-rate offer system for which the numbers are set to 100.[1] The range $[\underline{\beta},\overline{\beta}]$ of expectations is expressed by a factor $c = [0,1]$ in combination with the average cost (AC) of adopting the target technology such that: $\underline{\beta}=AC\cdot(1-c);\overline{\beta}=AC\cdot(1+c)$. In the previous chapter c was assumed to be 0.4, bordering the range of expectations by $\underline{\beta} = 40.2$ and $\overline{\beta} = 93.8$.

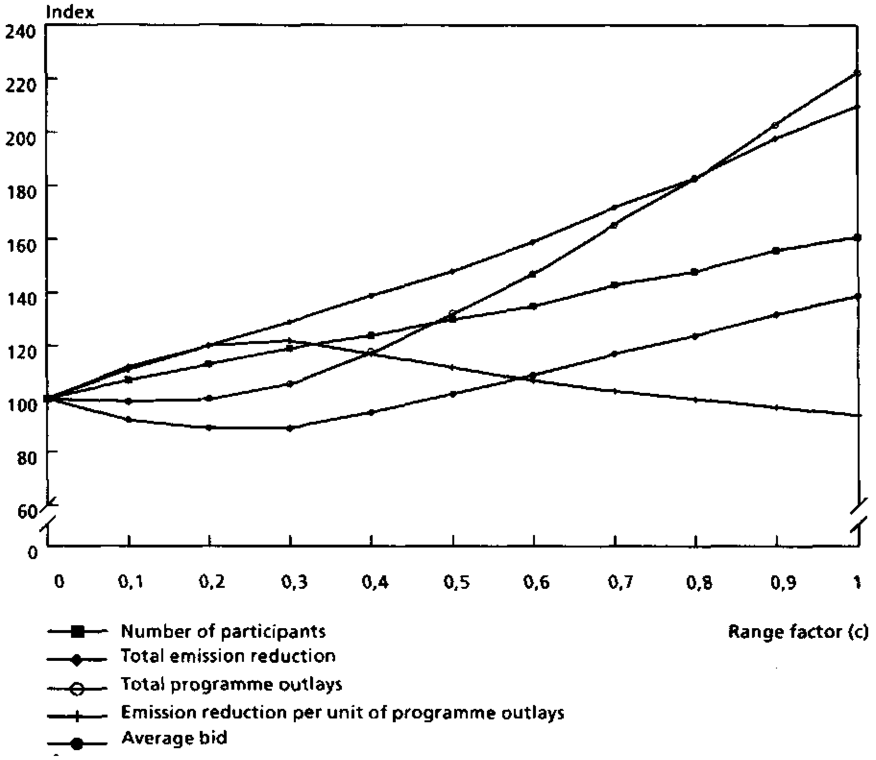

Figure 5.1 *The impact of the range of bid cap expectations on programme performance (offer system = 100) for a simple auction scheme without budget limitation (variant 2a)*

Figure 5.1 shows that an increase in the range of expectations encourages enrolment, because a wider range gives leeway to tender (high) bids for land with higher-than-average switch-over cost. Consequently, the environmental performance of the programme in terms of total emission reduction increases. Total programme outlays first decrease slightly due to increased bid competi-

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[1] Recall that an offer system is equivalent to a bidding system with known bid cap.

tion, but soon begin to rise and exceed the level of the offer system. The disproportionate increase in outlays at high levels of *c* is caused both by the growing number of farmers enrolling high-cost land and the increase in the (optimal) bids of farmers wishing to enroll lower-than-average cost land. This is reflected in the average-bid curve which cuts the reference level at $c \approx 0.5$. As a consequence, programme cost-effectiveness (emission reduction per unit of outlays) first increases, reaches its maximum at $c \approx 0.3$, then decreases and falls below the reference level at $c \approx 0.7$. A very wide spread of bid cap expectations, thus, may lead to outcomes worse than under an offer system.

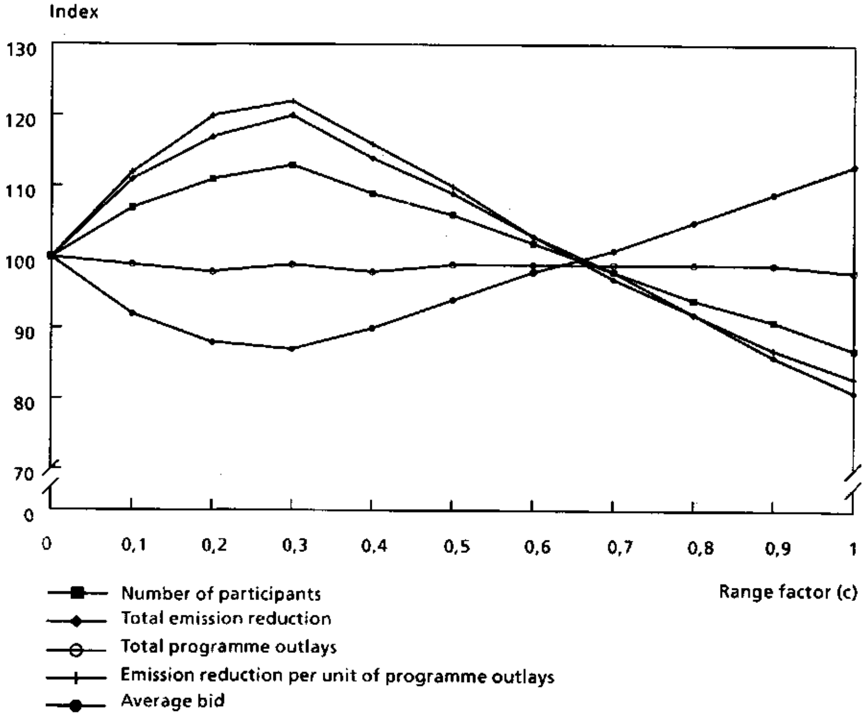

Figure 5.2 The impact of the range of bid cap expectations on programme performance (offer system = 100) for a simple auction scheme with limited budget (variant 2 b)

If total programme outlays are limited to the amount required for the flat-rate offer system, the impact of the range of bid cap expectations on programme performance becomes more stringent (figure 5.2). Like above, all measures of performance improve with an increase in the range of expectations when the initial range is narrow. In contrast to a system without budget limitation, all performance measures deteriorate significantly if c exceeds a critical value of approximately 0.3, and programme outcomes fall below the level of the offer system if c lies above 0.65. This decline in performance is caused by increasing (optimal) bid prices in combination with a fixed budget. The higher the bids, the less producers can be accepted within the overall budget. Note from figure 5.3 that the performance measures fall below the 100% mark at the point where the average bid exceeds this mark.

In summary, it may be said that both a very narrow and a very wide range of bid cap expectations is undesirable with respect to programme performance. Wide-spread expectations are more risky in the sense that programme outcomes may fall below the level that is attained with an offer system.

These relationships call for the programme administrator to manipulate bidders' expectations in a way that provides maximum bid competition. On the one hand this requires keeping farmers in the dark about the maximum acceptable payment rates. On the other hand, the farmers should be given some guide in forming their expectations, because too much uncertainty (i.e. a very wide range of expectations) may deteriorate programme performance. A way to influence the farmers' expectations in the desired direction could be to simply pre-announce the range in which the bid cap will be set. The actual bid cap can then be fixed either by the programme administrator or at random, as long as it is within the pre-announced range. In our example the range that provides maximum bid competition would have to be announced at average profit foregone plus/minus 30% of this value. Such pre-announcing can be regarded as a strategy to accommodate and prevent strategic behaviour of the bidders.

There is another benefit associated with a pre-announcement strategy. If the programme administrator knows both the amount of the bids and the values of $\underline{\beta}$ and $\overline{\beta}$ underlying those bids, the bidders' actual cost of adopting the target technology can be elicited by solving the optimal-bid formula (8) for $(\Pi_0 - \Pi_1)$. For bidder *i*,

$$\Pi_{0i} - \Pi_{1i} = 2 \cdot b_i - \overline{\beta} \tag{14}$$

Two things are important to note from this expression:

1. the calculation can be carried out only if $\overline{\beta}$ is publicly known;
2. it provides the government with a way to reduce the information gap without having to acquire costly information on farmers' switch-over costs.

The drawbacks of a pre-announcement strategy in a multiple-signup auction stem from the need to enforce what has been announced: the ex-post bid cap has to be within the pre-announced range and to be actually enforced, i.e. it has to be effectuated as an exclusion level. Moreover, over multiple signups the ex-post bid cap has to be varied within the *whole* pre-announced range. If the government fails to do so, the system will lose credibility, encouraging farmers to bid strategically again (based on own expectations rather than the pre-announced ones), making the potential advantages of the pre-announcement strategy largely vanish. These requirements restrict the administrator's possibilities to set the maximum acceptable payment rates according to objective needs like a budget limitation or an enrolment target.

5.3 Designing efficient bid acceptance procedures

It has been assumed so far that the government accepts bids, starting with the lowest bid price, within the overall budget. This implies the assumption that the government's objective is to maximize enrolment with a limited amount of public money. Under a wider perspective, the government's objective should be characterized as to maximize environmental benefits (and/or supply control), given a fixed amount of money 1). This requires the government to recognize each farmer's contribution to the achievement of the objectives pursued by the programme.

If some information is available which allows the programme administrator to roughly estimate the prospective environmental (and supply control) effects of enrolling each farmers' land, all bids received could be ranked according to the ratio of 'impacts' to public cost of enrolling the land. Most of the information needed could be gathered as part of the bidding process. The bidders could be required to supply data, for example, on the actual level of farming intensity, yields, and other characteristics of their technology. This information could be supplemented by data about the environmental sensitivity of the land, such as soil type, some soil leachability measure, location of the land in a designated area of environmental sensitivity, proximity to water bodies, etc. Those data will become available at decreasing cost with the progressive implementation of Geographic Information Systems. Certainly, those data are only proxies of the actual environmental effects of farming activities. Therefore, bid acceptance decisions will inevitably have to be met in an environment of imperfect information.

In the United States, a bid selection process which directly targets programme objectives was developed for the Conservation Reserve Programme (CRP) after the General Accounting Office had heavily criticized the old bid acceptance method which was aimed at minimizing public cost of enrolment subject to an enrolment target (U.S. General Accounting Office, 1989). Bids are now ranked for acceptance based on the ratio of an environmental benefit index (EBI) to the Government cost of the contract. The EBI is a parcel-specific estimate of the potential contribution to each of the seven programme goals that the land would provide if enrolled (USDA-ERS, 1994). Since the bid acceptance process must be completed within 60 days, the EBI relies on a few readily available data (Osborn, personal communication).

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1) Note that this is a strict public-finance view. Ideally, the government should pursue economic efficiency rather than procurement efficiency. This, however, requires information on the monetary value of the environmental benefits of adopting the conservation technology. Since this information is usually not available at reasonable cost, this study continues to focus on procurement efficiency.

The model developed in this report was employed to estimate the effects of a bid acceptance system that ranks all bids received according to the ratio of nitrogen reduction $(n_{1*} - \tilde{n})$ to the individual farmer's (optimal bid) b_{i*}, hereafter called cost-effectiveness acceptance mechanism. Undoubtedly, it would have been better to directly target emissions. In practice, however, non-point source emissions from agriculture like those considered here, are hard to observe or measure. Therefore, it is realistic to target an observable proxy which is assumed to be closely correlated with emissions. In the Netherlands, for example, farmers are required by law to keep records on the quantities of fertilizers and pesticides purchased and applied. This information could be used for bid ranking in the acceptance process.

The results of the model simulation are presented in table 5.1 for the case of risk-neutral bidders 1). Like above, programme performance is measured relative to the flat-rate offer system. The table shows that the implementation of an auction scheme with a cost-effectiveness acceptance mechanism enhances programme performance significantly. Although the number of participants is almost constant in all variants considered, aggregate emissions and total output are reduced by 29 and 71% under the simple auction scheme and by

Table 5.1 *Simulated performance of the extensification programme for risk-neutral decision makers, with bid acceptance based on the ratio of nitrogen reduction to the amount of the bid (flat-rate offer system = 100).*

Performance measures	Variants				
	1	2b		4b	
	flat-rate offer system	simple auction scheme; cost effectiveness ranking a)		bid pool auction scheme; cost-effectiveness ranking a)	
A. Number of participants	100	98	(109)	102	(117)
B. Total emission reduction	100	129	(114)	143	(138)
C. Total output reduction	100	171	(126)	217	(199)
D. Total programme outlays	100	100	(98)	100	(100)
E. Total switch-over costs	100	184	(129)	246	(220)
F. Net income transfer b)	100	57	(84)	25	(38)
G. Emission reduction per unit of programme outlays (B/D)	100	130	(116)	143	(138)
H. Output reduction per unit of programme outlays (C/D)	100	171	(128)	217	(200)

a) The numbers in parentheses refer to table 4.2 (bid acceptance based on the amount of the bid only); b) Total programme outlays minus total switch-over costs, i.e., overcompensation of switch-over costs.

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1) The results for risk-averse bidders do not differ significantly from those presented here.

43 and 117 under the bid pool auction scheme, respectively. Since these improvements are achieved with (approximately) the same amount of outlays, programme cost-effectiveness with respect to both goals (row G and H) increases by the same degree.

To isolate the effects of the cost-effectiveness selection mechanism, the performance measures are compared with those of table 4.2 (in parentheses), where bid acceptance is based only on the amount of the bids, regardless of the individual bidders' potential contribution to the programme goals. Although the number of participants is lower under the cost-effectiveness acceptance procedure, all other performance measures lie significantly above the ones for the corresponding auction schemes without cost-effectiveness ranking. This is because under the targeted bid selection system mainly farmers with higher than average switch-over costs and higher than average emission loadings are accepted for participation, while the reverse is true for the untargeted bid selection.

Note from table 5.1 that the benefits of implementing a cost-effectiveness selection mechanism are higher under the simple auction scheme than under the bid pool auction. This is again a matter of information asymmetry. In a simple auction, implying limited information about farm-level relationships, the marginal value of the information about the individual farmers' fertilizer use as provided with their bids, is high, translating into high gains in programme performance. In a bid pool auction, implying some farm-level information, the value of the additional information is lower, resulting in a lower increase in the performance measures.

6. CONCLUDING REMARKS

The presented results indicate that the implementation of an auction scheme for agricultural conservation contracts, instead of a fixed-rate offer system, can yield substantial gains in programme cost-effectiveness. The benefits of auctions are greater the larger the information asymmetry on switchover costs between individual farmers and the government. The main contribution of this article is that it makes auction theory applicable to conservation contracting. Moreover, the theoretical concepts developed are supported with some insights into the quantitative implications of implementing an auction for conservation contracts. Nevertheless, some simplifying assumptions had to be made, both with respect to issues related to the conservation programme and to auction theory. Starting with the former, for ease of analysis it was assumed, for instance, that farmers only grow grains and can enroll their land only on an all-or-nothing basis. Moreover, the conservation programme considered consists of one restriction only, while in practice most conservation programmes impose a package of restrictions. It is expected, however, that those assumptions do not necessarily violate the conclusions drawn so far. The potential gains achievable by implementing an auction, namely, mainly hinge on the extent to which information asymmetry between farmers and the government is present, regardless of the complexity of the conservation contracts considered. The latter becomes relevant only if it increases the costs involved in bid preparation to such an extent that it stops farmers from submitting bids.

With respect to auction theory, some of the Benchmark assumptions are relaxed in order to portray the auction environment of conservation contracts as accurately as possible. Nevertheless, some problems inherent to auction theory in general remain. For instance, the assumption of independent private values requires that farmers know precisely their profits foregone. In practice, however, there is often a common element of uncertainty among farmers about the consequences of adopting the conservation technology, resulting in affiliated values instead of independent private values. In this case theory is ambiguous about the choice of the optimal auction form. Theory also leaves us with ambiguity if more than one Benchmark assumption is relaxed simultaneously. Moreover, the previous analysis considered an auction in isolation of the environment in which it takes place, which may have unexpected implications. For instance, farmers have proved to be reluctant to participate in conservation programmes because they distrust the government to allow them to remove the realized amenities after the contract has expired. This may have unforeseeable implications for the willingness to participate and bidding behaviour.

Bearing this in mind, how useful is auction theory to assist practical auction design? Looking at its direct application by decision makers, one can conclude that the use of auction theory for practical auction design is very limited. To the best of our knowledge, there is only one very recent example in which auction theory is extensively used for practical auction design: the selling of spectrum rights in the U.S. (Anonymous, 1994; McMillan, 1994). Although theory in this case has turned out to have limits, its predecessor, the 1990 New Zealand spectrum auction, came up with embarrassing results which could have been avoided easily by consulting auction theory. Because of its shortcomings, the theory, however, cannot provide us with a cut-and-dried solution, although it can play an important role in communicating and thinking about auction design and bidding behaviour. Besides, it may avoid possible pitfalls that could otherwise occur. Nevertheless, as each auction situation is in fact unique, judgment and guesswork will be needed to merge the various partial theories, to weigh the government's objectives, to estimate the relative sizes of the different effects, etc. (McMillan, 1994). In the area of conservation contracting the aforementioned arguments can be eloquently illustrated by taking the case of the CRP programme. It demonstrated the presence of Bayesian learning after multiple signups, making the potential gains achievable by using an auction largely vanish. Moreover, evidence suggests that the implementation of the CRP in 1986 was suboptimal and that substantial increases in programme cost-effectiveness could have been achieved if the government would have identified the control variables and the impact of variations in it on programme performance (Reichelderfer and Boggess, 1988). The analysis in this article supplies sufficient clues to assume that auction theory, if consulted, would have been able to predict both pitfalls in advance.

This article gives an initial impetus to the use of auction theory in optimal auction design for conservation contracting. More research is needed in order to make auction theory better applicable to the specific features of conservation contracts. The challenge for researchers is to communicate auction theory and its potential advantages in an accessible way to decision makers. Policy makers are encouraged to smoothen the path for implementing auctions in conservation contracting and to leave behind political objections that so far have been unduly impeding their application.

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APPENDIX

Appendix 1 Derivation of the optimal-bid formula of a risk-averse decision maker

Assumptions:

1. The decision maker has a utility function of the form *U(Y) = ln Y*, where *Y* is the income from market production and, in case of participation, the conservation payment;
2. The bidder's expectations about the bid cap are uniformly distributed in the range $[\beta,\overline{\beta}]$.

The risk premium is a function of the income level and the income variability and can be expressed by using the Arrow-Pratt absolute risk aversion coefficient as follows (for a detailed discussion see Laffont, 1989):

$$RP=-\frac{1}{2}\sigma^2\frac{U''(Y)}{U'(Y)} \tag{A1}$$

where σ^2 is the variance of income. Applying the utility function *U(Y) = ln Y* leads to

$$RP_0=\frac{1}{2}\sigma_0^2\frac{1}{\Pi_0} \quad \text{and} \quad RP_1(b)=\frac{1}{2}\sigma_1^2\frac{1}{\Pi_1+b} \tag{A2}$$

(non-participation) *(participation)*

Substituting the formula for $RP_1(b)$ and the functional form (7) of the distribution function into the optimal-bid formula (12) leads to:

$$b=\Pi_0+RP_0-\Pi_1+\frac{1}{2}\sigma_1^2\frac{1}{\Pi_1+b}+(1+\frac{1}{2}\sigma_1^2\frac{1}{(\Pi_1+b)^2}\cdot(\overline{\beta}-b)) \tag{A3}$$

The optimal bid is found by solving equation (A3) consistently for *b*, which is, in fact, a mathematically somewhat complicated venture. By multiplication and rearrangement of terms in (A3), in the first step, a cubic equation is obtained of the form:

(A4)

$$b^3+cb^2+gb+h=0$$

with

$$c=\frac{5\Pi_1-\Pi_0+RP_0-\overline{\beta}}{2}$$

$$g=\Pi_1(2\Pi_1-\Pi_0+RP_0-\overline{\beta})$$

$$h=\frac{\Pi_1(\Pi_1^2-\Pi_1\overline{\beta}-\Pi_1\Pi_0+\Pi_1RP_0-0.5\sigma_1^2)}{2}-0.25\sigma_1^2\overline{\beta}$$

Now Cardan's Solution for cubic equations can be applied (for details see, for example, Korn and Korn, 1968) by transforming equation (A4) to the 'reduced' form:

$$x^3 + px + q = 0 \qquad p = -\frac{c^2}{3} + g \qquad q = 2\left(\frac{c}{3}\right)^3 - \frac{cg}{3} + h \tag{A5}$$

through the substitution $b = x - \frac{c}{3}$. The roots x_1, x_2, and x_3 of the 'reduced' cubic equation (A5) are:

$$x_1 = A + B \qquad x_{2,3} = -\frac{A+B}{2} \pm \frac{A-B}{2}\sqrt{3}$$

with

$$A = \sqrt[3]{-\frac{q}{2} + \sqrt{\left(\frac{p}{3}\right)^3 + \left(\frac{q}{2}\right)^2}} \qquad B = \sqrt[3]{-\frac{q}{2} - \sqrt{\left(\frac{p}{3}\right)^3 + \left(\frac{q}{2}\right)^2}} \tag{A6}$$

The optimal-bid formula of a risk-averse decision maker under the assumptions set out above then is:

$$b^{*}_{ra} = \max\left\{ x - \frac{c}{3},\ \underline{\beta} \right\} \qquad s.t.\quad b^{*}_{ra} > CE_0 - CE_1 \tag{A7}$$

Among the three solutions that (A7) yields the one with $b^{*}_{ra} \in [\underline{\beta}, \overline{\beta}]$ is the optimal bid. Therewith the optimal bid of a risk-averse decision-maker is a function of $(\Pi_0,\ \Pi_1,\ \overline{\beta},\ \underline{\beta},\ \sigma_0^2,\ \sigma_1^2)$.