UNIVERSITY OF COPENHAGEN

**Københavns Universitet**

# Auction mechanisms for setting aside forest for biodiversity

Thorsen, Bo Jellesmark; Strange, Niels; Jacobsen, Jette Bredahl; Termansen, Mette; Lundhede, Thomas

*Publication date:*
2018

*Document version*
Publisher's PDF, also known as Version of record

*Citation for published version (APA):*
Thorsen, B. J., Strange, N., Jacobsen, J. B., Termansen, M., & Lundhede, T. (2018). *Auction mechanisms for setting aside forest for biodiversity*. Department of Food and Resource Economics, University of Copenhagen. IFRO Report No. 267

Download date: 07. Oct. 2026

DEPARTMENT OF FOOD AND RESOURCE ECONOMICS
UNIVERSITY OF COPENHAGEN

IFRO Report

# Auction mechanisms for setting aside forest for biodiversity

*Bo Jellesmark Thorsen*
*Niels Strange*
*Jette Bredahl Jacobsen*
*Mette Termansen*
*Thomas Hedemark Lundhede*

**267**

**IFRO Report 267**

Auction mechanisms for setting aside forest for biodiversity

Authors: Bo Jellesmark Thorsen, Niels Strange, Jette Bredahl Jacobsen, Mette Termansen, Thomas Hedemark Lundhede

Scientific quality control: Suzanne Vedel

Published April 2018

ISBN: 978-87-92591-89-0

This report is prepared for The Danish Environmental Protection Agency.

You can find the IFRO Report series here: http://ifro.ku.dk/publikationer/ifro_serier/rapporter/

Department of Food and Resource Economics (IFRO)
University of Copenhagen
Rolighedsvej 25
DK 1958 Frederiksberg
www.ifro.ku.dk/english

# Table of Contents


**DANSK SAMMENDRAG (DANISH SUMMARY) ..... 3**

**SUMMARY ..... 5**

**1. INTRODUCTION ..... 7**

**2. THE ORIGIN OF PROCUREMENT AUCTIONS THEORY ..... 8**

**2.2 Basic features ..... 9**

**3. PROCUREMENT MECHANISMS IN ENVIRONMENTAL SCHEMES FOR AGRICULTURAL AND FOREST LAND ..... 14**

**3.1 Insights from full-scale cases and field experiments ..... 14**

3.1.2 Field experiments with first rejected price reverse auctions ..... 15

3.1.3 Field experiment with discriminative payment ..... 15

**3.2 Insights from Stated Preference and lab experiments ..... 17**

3.2.1 Menu of contract applications ..... 17

3.2.2 Reverse auctions in stated preference surveys and lab experiments ..... 19

**4. KEY ASSUMPTIONS AND COMMON CHALLENGES CONTRASTED WITH THE CASE OF PROCUREMENT OF UNTOUCHED FOREST ..... 21**

**4.1 Some key assumptions ..... 21**

4.1.1. The selling agents ..... 21

4.1.2 The goods asked for ..... 22

4.1.3 The principal ..... 22

**4.2 Some common challenges ..... 23**

4.2.1 Market size and cost heterogeneity ..... 23

4.2.2 One-off auctions, repeated auctions, post-offer negotiations and learning ..... 24

4.2.3 Announcing budgets and pricing mechanisms ..... 26

4.2.4 Factoring in environmental quality variation and spatial aspects ..... 27

4.2.5 Intermediaries and other agents ..... 29

4.2.6 Issues post-contracting ..... 30

**5. BIODIVERSITY AND ENVIRONMENTAL TARGETING ..... 31**

**5.1 Auctions, goals and targets ..... 31**

**5.2. Biodiversity data ..... 33**

## 6. CONSIDERATIONS OF THE PROS AND CONS OF ALTERNATIVE DESIGNS IN A DANISH FOREST CONTEXT ..... 35

**6.1 Alternative designs ..... 35**

**6.2 Data ..... 36**

**6.3 Results ..... 37**

**6.4 Conclusions from the simulations and the implications for the design ..... 40**

## 7. BARRIERS FOR PARTICIPATION ..... 41

**7.1. Stage 1: Alignment ..... 41**

**7.2 Stage 2: Opportunity and engagement ..... 42**

**7.3 Stage 3: Contracting and post-participation ..... 44**

## 8. REFERENCES ..... 45

# Dansk Sammendrag (Danish Summary)

Den danske regering har opstillet specifikke mål for bevarelsen af biodiversiteten i Danmark. Et af disse mål er henlæggelse af urørt skov, som indebærer, at skovdriften i form af hugst skal ophøre. I 2017 oprettedes en tilskudsordning, der skulle kompensere skovejere for tabt indkomst i forbindelse med henlæggesen af skov som urørt. I private skove kan dette også foregå gennem opkøb af hugstrettigheder. Disse kan opkøbes gennem en såkaldt 'omvendt' auktion, en licitation, som er en auktionsform, der forsøger at skabe de lavest mulige tilbud i en situation, hvor der er én køber (her staten) og mange udbydere (her de private skovejere). Dette er i modsætning til en normal auktion, hvor man har én sælger og mange købere, der byder, og således søger at opnå den højeste pris for den auktionerede vare. Prisen, som en privat skovejer vil kræve for at sælge sine hugstrettigheder, vil afspejle ejerens underliggende omkostningsfunktion, som primært er påvirket af den indkomst, skovejeren mister, men også af for eksempel de herlighedsværdier, ejeren selv værdsætter, og deres fremtidige handlemuligheder. Disse informationer er kun kendt af skovejeren, og denne informationsasymmetri vil uundgåeligt lede til en såkaldt 'informationsrente', som udtrykker muligheden for, at skovejeren kan profitere på sin egen viden. Forskellige auktionsdesign adresserer muligheden for at nedbringe informationsrenten, og denne rapport beskriver nogle af disse auktionsdesign.

Et af de centrale designs kaldes Vickrey-auktionen (*second price auctions*), hvilket ofte i omvendte auktioner, licitationer, benævnes som en 'første afviste pris' auktion (*first rejected price*). Ved denne auktionsform bliver alle tilbud rangeret efter pris, og der tilbydes købskontrakter fra den billigste ende, indtil køberens budget er opbrugt. Alle udbydere bliver betalt den samme pris, og svarende til tilbudsprisen fra den første afviste udbyder. Dette design kan opstilles, så det sikrer, at tilbudsgivere ærligt fortæller den mindste pris, de er villig til at sælge til. Men denne ærlighed kommer blandt andet, fordi den ensartede betaling indebærer til tider betydelige informationsrenter for de mest omkostningseffektive.

Et alternativ er den såkaldte prisdiskriminerende auktion (*discriminatory price auction*), hvor de udvalgte udbydere betales den pris, de hver især har forlangt. De udbydere, der ved, at de kan tilbyde en konkurrencedygtig pris relativt til deres kvalitet for eksempel, har således et incitament til at tilbyde varen til en højere pris end den laveste pris, de er villig til at acceptere, og således høste

informationsrente. Alligevel kan designet være mere omkostningseffektivt samlet set, hvis blot ejernes overbud ikke overstiger den pris, der ville være resultatet af en 'første afviste pris'-auktion.

For danske skovejere er træarten, boniteten og den stående vedmasse de væsentligste kilder til variation i den mistede produktionsindtægt ved udlæg af urørt skov. Samtidig er disse parametre tæt knyttet til de beskyttelsesmæssige karakteristika, som man ønsker at opnå ved urørt skov. Dette forhold indikerer, at man bør benytte en form for vægtning eller segmentering af udbyderene i auktionen. Hvis alle skovtyper omfattes i én enkelt auktion, vil resultatet kunne blive, at der kun indkøbes hugstrettigheder fra billige elle- eller askeskove og/eller skove på dårlig bonitet. Endvidere vil stor variation i omkostningerne betyde, at de udbydere, der kan tilbyde en lav, konkurrencedygtig pris, vil høste informationsrente, hvis ikke auktionsdesignet tager højde for disse systematiske variationer i omkostninger.

Andre kvalitetsparametre, for eksempel forskellige biodiversitetsmål, som beskrevet rapporten, kan være vigtige for det miljømæssige udbytte og dermed omkostningseffektivitet. Nogle af disse parametre vil være kendte på forhånd af køber, andre vil være ukendte. Især håndteringen af den rumlige afhængighed af de miljømæssige værdier er vanskelig. Rapporten beskriver en såkaldt '*yard stick*'-algoritme, som er resultatet af forskning i efficiente indkøb af goder med mange forskellige karakteristika, og rapporten beskriver, hvordan denne algoritme kan benyttes i auktioner, hvor indkøber kun har lidt eller måske ingen information tilgængelig om godet ex ante. Algoritmen kan også anvendes til at reducere nogle af incitamenterne til at give tilbud med priser over den sande minimumspris.

Rapporten illustrerer også, ved hjælp af eksisterende data over den rumlige fordeling af skovejere, indikatorer for biodiversitet og venteværdier af modne bevoksninger, hvordan forskellige hovedantagelser kan påvirke resultatet af en omvendt auktion. Endelig beskriver rapporten forskellige forhold, der kan påvirke deltagelsen i en auktion, og hvordan disse kan imødegås.

# Summary

The Danish government has set specific goals for setting aside forest land for biodiversity purposes in the form of untouched forests, where no production forestry operations can be undertaken. Part of these goals will be fulfilled on public and state owned forest land, and parts will be fulfilled on private lands. Setting aside forest land as untouched with the restriction that no further harvest can take place implies the loss of future income from forestry net of related forest operation costs and in 2017 a support grant scheme was designed and implemented to compensate forest owners for their forgone income. In private owned forests the government can terminate normal forestry operations by purchasing the right of harvesting from the forest owner. These rights can be offered to the government on a basis, which resembles a reversed auction. A reverse auction seeks to generate the lowest possible offers of purchasing price for an auctioned good in a situation where there is one buyer (in this case the government) and many sellers (forest owners) in contrast to a 'normal' auction that seeks to reveal the highest selling bid for an auctioned good in a situation where there are many buyers and only one seller.

The price a forest owner will ask for selling harvesting rights is driven by the forest owner's cost function of conserving forest land, notably the forgone income, but also amenity values or option values will influence their reservation price. This information is private to the forest owner, and such an asymmetry of information will inevitably lead to paying what is termed information rents. A key feature of (reverse) auction design is to address the issue of asymmetric information, through inducing competition among (sellers) buyers.

The report reviews different auction formats. One of these is the so-called second price auction mechanism, which in procurement auctions is often called the 'first rejected price' mechanism. Here, all offers are ranked and contracts signed from the cheapest end until the desired quantity is obtained or the budget exhausted. All the suppliers are paid a uniform price equal to the offer of the first rejected supplier. The design ensures sellers will state their true minimum price, but this comes at the cost of paying information rents. An alternative design is the discriminatory price auction. In a discriminatory price auction the selected participants are paid the price they state in their offers. This auction design may encourage agents to pursue information rents by offering their product at a higher price than their minimum reservation price, especially if the agents believe they are competitive in terms of cost to quality. However, if the overbidding still results in prices below

what would be the ‘first rejected’ uniform price, the design is overall competitive even if true costs are not revealed.

For Danish forest owners, a substantial part of the overall variation in costs relates to tree species, standing volume and site quality, which suggest that segmentation and weighting could be considered in designing a reverse auction, either ex ante or in the selection algorithm ex post. If all forest types are handled in one auction, with no weighting or segmentation, most of the contracted forest land will likely be low cost alder or ash type of forest and/or on poor soil. Furthermore, cost variation could result in rather high information rents for forest owners offering low cost forest types, if the auction design does not take these systematic differences into account.

But other quality parameters, e.g. various biodiversity measures as described further in the report, may be considered important for the quality and value of the environmental outcome. Some of these will be known to the buyer and some will be unknown. Especially, the handling of spatial co-dependence of environmental values of land offered is difficult to handle. The report examines research in efficient multi-attribute procurement that has addressed the potential for applying pricing methods that can resolve procurement auctions with as little a priori information collection as possible, yet still handle the fact that cost information is private to suppliers adequately. Specifically, the use of data envelopment analysis for yard stick pricing in procurement auctions is being studied.

The report also illustrates the influence of some of the key considerations for a cost-effective design, using existing data of the spatial distribution of forest owners, biodiversity indicators and the capital value of mature forests to analyse four possible designs. Finally, it is essential for reverse auctions to reach an adequate level of participation from landowners in order to obtain the desired environmental effect and to secure competition. Consequently, the report concludes by examining potential barriers for participation.

# 1. Introduction

The Danish government has set specific goals for biodiversity conservation in forests. Part of these goals will be fulfilled on public and state owned forest land, and parts will be fulfilled on private lands (Miljø- og Fødevareministeriet 2016). This report focuses on the private land. An efficient way to achieve these goals is setting aside forest land in the form of untouched forests, which implies that harvesting of timber can no longer be undertaken (Petersen et al., 2016). Setting aside forest land as untouched with the restriction that no further harvest can take place implies the loss of future income from forestry net of related forest operation costs. For the forests on private land, the government can compensate forest owners for their forgone income. A support grant scheme was designed and implemented in 2017 to compensate private landowners for their foregone income and other costs of setting aside forest land as untouched (Miljø- og Fødevareministeriet 2017). But, other factors than forgone income might influence the forest owner's cost function of conserving forest land, for example amenity values or option values. Information about forgone income and other influential factors are, however, private to the landowner, and this asymmetry of information will inevitably lead to the agency paying information rents. One way to reveal this is by looking at the problem of compensating forest owners for foregone income as an issue of buying the right of harvesting from the landowner – potentially through an auction. The literature on auction theory suggests different ways to reduce this information rent and increase efficiency when implementing grant schemes.

# 2. The origin of procurement auctions theory

The literature on the use of reverse auctions for procurement problems is large and diverse, due to the diversity in practical contexts of procurement implementations. Basically, an auction seeks to reveal the highest selling bid for the auctioned good in a situation where there are many buyers and one seller. The reverse auction seeks to generate the lowest possible offers of purchasing price for the auctioned good in a situation where there is one buyer (in our case the government) and many sellers (forest owners). In this report, we consistently use the term 'offer' as indicating the wanted price from contractors in a reverse procurement auction. In some parts of the literature the word 'tender' is used synonymously with 'offer'.

At the root of the literature is the quest for methods to secure cost efficient procurement outcomes ensuring that the production of each specific type and quantity of goods is allocated to the producers that can supply the goods in demand at the lowest aggregate cost.

The seminal paper by Vickrey (1961) set the benchmark for how to approach the design of auctions and evaluate their outcomes, upon which also the design of reverse auctions in procurement cases builds. A key feature of auction design is to address the issue of asymmetric information. Specifically, in the case of procurement auctions, the general case is that from the buyer's point of view, there is private information about the production costs of the seller. The primary function of the auction is therefore to reveal enough information from sellers to reduce potential rents from such information. The revelation mechanism is an auction design, which places sellers in a competition situation where their optimal strategy is to submit offers that are as truthful as possible. Such a mechanism is called an incentive compatible mechanism.

Vickrey (1961) proposed the so-called second price auction mechanism. He shows that under standard assumptions and for a homogenous divisible product, a second price auction mechanism will secure Pareto-optimal outcomes. Simply put, all bids for a good is ranked and the bidder offering the most is allowed to buy the good, but is only asked to pay the second highest bid. This means, in the context of a normal auction, that the good is sold to the buyers valuing the good the most, and that for all bidders, truth telling is a weakly dominant strategy: Submitting a bid below your willingness to pay implies running a risk of bidding just below the highest bid, which in turn means missing out on a gain.

In procurement auctions this form of auction is often called the ‘first rejected price’ mechanism, and here the most cost-effective producers are contracted. The simple mechanism requires the buyer to outline the price setting mechanism prior to any offers being placed. The pricing mechanism is that all offers are ranked and contracts signed from the cheapest end until the desired quantity is obtained or the budget exhausted. All the suppliers are paid a uniform price equal to the offer of the first rejected supplier. It can be proven that for a sufficiently large number of suppliers, the best strategy for any supplier is to report truthfully on their cost and hence make offers according to their forgone benefits. It can also be shown that neither buyer nor suppliers need spend resources on guessing the cost functions of others or the benefit function of the buyer. In the following we provide an in-depth explanation of the basic features of the reversed auction.

## 2.2 Basic features

The core feature and promise of the use of reverse auctions and similar instruments is the use of competition among agents for a profit, in terms of an informational rent, to improve coordination. We will use Figure 2.1 to illustrate these concepts.

We illustrate the potential difference between the current support scheme, where forest owners are compensated based on a model of the present value of their specific forest production potential, and a first rejected price type reverse auction. Thus, in the current support scheme, the compensation paid is external to the assessment of the forest owner and the forest owners’ own preferences, including potential private amenity values or other aspects. Of course, the forest owners’ decision to sign up is not external to their perceptions of costs and possible payments.

In Figure 2.1, the bars represent five examples of forest owners coming forward and receiving payments per hectare as indicated by the height of the bar for an area indicated by the width of the bar. Thus, the bar area represents the payment made. We return to the reason for the different colours below.

The smooth curve in Figure 2.1 represents a sorting of all the relevant forest land held by forest owners according to the forest owners’ own perception of the costs to them of setting the forest

aside as untouched. Thus, this takes into account possible private benefits (or additional costs) from this action, enjoyed by the forest owners. In a first rejected price auction, where forest owners know they will receive the same payment as everyone else, provided their offer is below the price, the rational forest owner will state their true costs as their offer. Turning in an offer understating their true cost increases the probability of being selected, but only if the final price is below their true cost – and hence understating their cost implies only a risk of a loss. Overstating the cost does not affect the final price they will get, and hence their profit, but it does reduce the probability of being selected. Thus, overstating reduces expected returns.

There are two reasons why a first rejected price auction will enhance efficiency relative to the current scheme.

The first is coordination. Note that there are forest owners with fairly low perceived costs, who have not come forward and thus do not appear in Figure 2.1. That may be because the current scheme will only just compensate their costs, or perhaps pay below their true costs if they have a forest of low production value, but have other cost concerns. If a budget corresponding to the area under the yellow or blue dashed lines is available, then forest owners revealing true perceived costs below those lines will have an incentive to enter, because they will all be paid the price indicated by the dashed line. That means they earn an information rent equal to the distance between the dashed line and their part of the curve. If forest owners are rational, all – not only some – of those with low true opportunity costs will come forward. That means that we do not allocate any funds to buy forest from the forest owners behind the two highest bars. They are competed out of the artificial market.

The second reason why efficiency may be improved is that it relies on forest owners' own perceived costs and not an external estimate; that means private benefits from the action are taken into account. We see from the relationship between the bars and the curve that the two red bars illustrate cases where the forest owners perceive the costs to be lower than the external estimates – they earn a very high information rent. Under the auction, they will be paid a lower information rent – if they are even selected. On the other hand, the three blue bars indicate cost estimates closer to the true cost, in which case information rent is not paid at all.

The yellow dashed line approximately indicates a market where the same forest land area (x-axis) is bought under the auction as in the case where we buy the forest land area indicated by x-axis width of the bars. Thus, we see that under an auction we can contract the same land area at a much lower budget (area under the yellow dashed line), when compared with the current compensation scheme (area of bars); simply because forest owners willing to offer up expensive forest land are not contracted. The blue line shows the case, where we use a budget equal to that of the sum of the bars, but in an auction setup. The result is that more land is contracted, for the same budget.

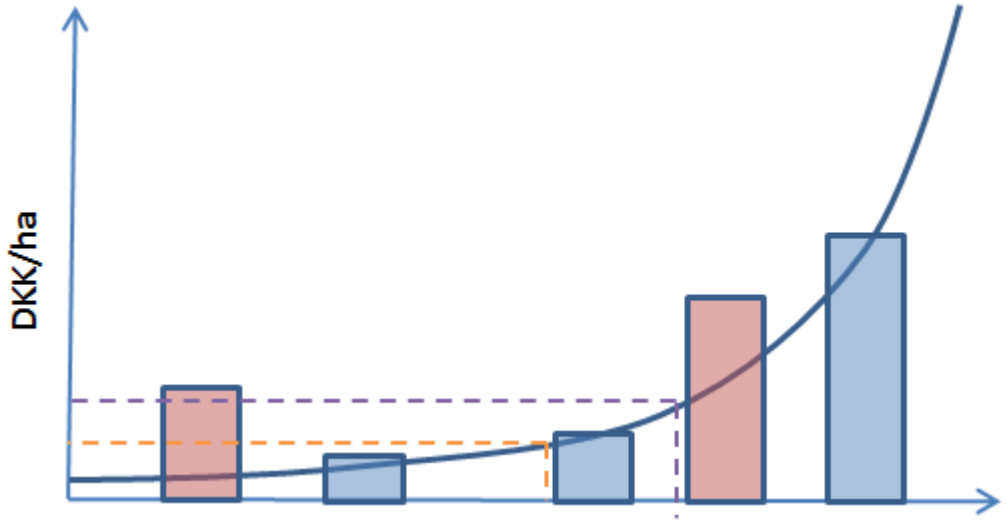


**Figure 2.1** Illustrating potential gain in efficiency from competition in terms of coordination improvement subject to payment of information rent; relative to current compensation schemes where owners are compensated according to an external cost estimate. The curve illustrates owners' land areas sorted according to owners' own perception of costs. Bars represent examples of forest land being compensated according to external cost estimates. The height of the bars indicates payments per hectare for an area indicated by the width of the bar and thus the bar area represents the total payment made. The two red bars illustrate cases where the forest owners perceive the costs to be lower than the external estimates offered to them. Area under dashed flat lines illustrates the same amount bought (yellow line) or the same budget used (blue line) for the price indicated by the line.

An often applied alternative to the first rejected price auction, where all selected participants are paid the same price, is the discriminatory price auction, where selected participants are paid the price they state. This auction design will encourage agents to offer a product at a higher price compared to, in particular, agents who believe they are low cost and competitive, attempting to secure information rents. Nevertheless, if the offered price is not too high, it may still be a more

efficient scheme as illustrated in Figure 2.2, where the information rent transfer to owners is reduced by the amount A.

Numerous papers since Vickrey (1961) have developed models and designs for contexts where the basic premises differ. To mention just a few: cases where the buyers are procuring products with multiple attributes in iterative learning and offer processes (Parks and Kalagnanam 2005), where single sourcing or multiple suppliers are used, with or without fixed quantity tenders (Dasgupta and Spulber 1989) as well as equilibrium effects of procurements systems on e.g. suppliers' investments in cost reduction measures (Arozamena and Cantillon 2004). Numerous variants have been studied empirically in lab experiments (Kwasnica and Sherstyuk 2013), in stated preference surveys and in field experiments as we turn to below.

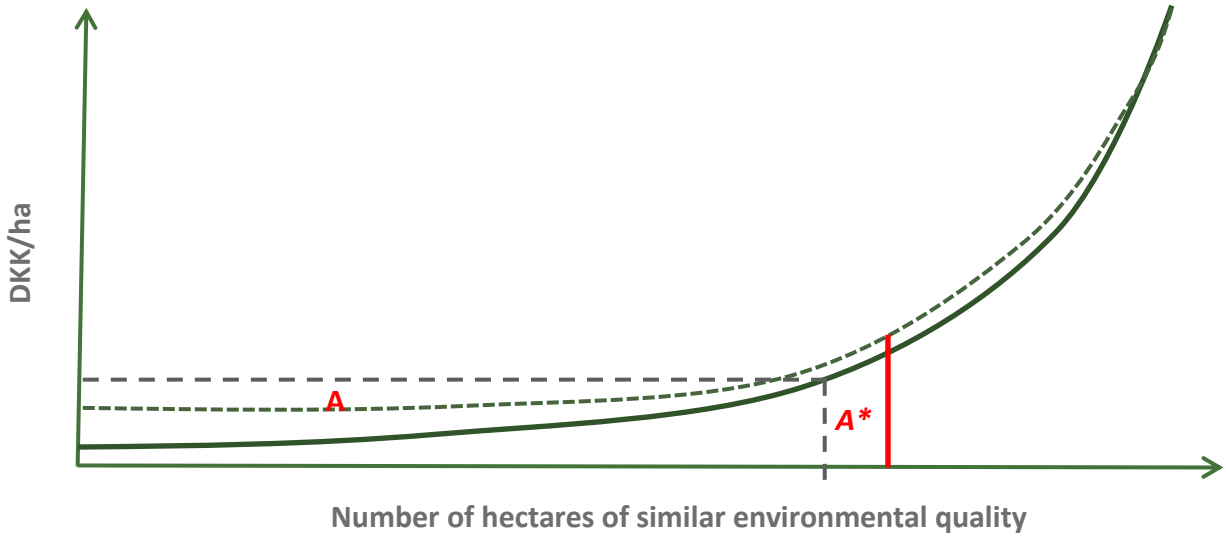


**Figure 2.2** An illustration of the discriminatory pricing auction relative to the first rejected price auction. Under the latter, forest owners will bid their true cost (full line curve) and those selected under the budget will receive a price corresponding to the horizontal dashed line. In a discriminatory price auction, forest owners will overstate cost in their offer, because they are paid their offer. Thus their offers could be the dashed curve. The effect is to reduce information rents by the area *A* between the horizontal line and the bid curve. This can be used to buy the additional area indicated by *A**.

Latacz-Lohmann and Hamswort (1997, 1998) analysed various aspects of introducing procurement auctions into agri-environmental schemes and discussed the possible short-comings of the second price auction when the products procured are not homogenous and may differ in quality. They suggested that some form of discriminatory pricing may be better, if legally and ethically possible, and reduce rents even if offers would not be entirely truthful. Ferraro (2008) provides an overview

of the key challenges for most reverse auction applications in the field of ecosystem services, and we draw forward those most relevant for the current setting in the sections below along with additional challenges. It is noteworthy that in most of these later works, a basic premise remains that to obtain information about the true cost to producers and hence at least partially truthful offers, procurement auction designs must account for asymmetric information regarding costs, and this typically involves some form of rent for the low-cost agents.

# 3. Procurement mechanisms in environmental schemes for agricultural and forest land

## 3.1 Insights from full-scale cases and field experiments

Connor et al. (2008) analyse the Australian Catchment Care program, which applies a sealed bid[1] discriminant price auction for procurement of conservation efforts. Landowners submit offers along with conservation actions they propose, chosen from a closed set of options. Landowners are given information as to what parameters will be considered when assessing the environmental value of their proposal, but are not informed about the actual and rather complex assessment of this. As Connor et al. (2008) points out, keeping this information private to the agency could reduce successful rent seeking. They also show that the auction is equally good to negotiated discriminatory contracts entered with full information and somewhat better than uniformly priced negotiated contracts. This may suggest that not many private amenity values are present on the landowners side and that the cost structure can be assessed fairly well, which contrasts to Danish and Finnish findings (Juutinen and Ollikainen 2010; Vedel et al. 2015a). Otherwise this case has interesting similarities to the Danish untouched forest case.

Binney and Whiteoak (2010) present a review of the Tasmanian Forest Conservation Fund, which also implemented conservation measures using a competitive tender, reverse auction with discriminative offers (here discriminative means that each seller will be paid the price they offered, if accepted), information on conservation index, and in this case with several rounds. They observed a significant cost efficiency of the competitive approach though efficiency was reduced over rounds, possibly as the most cost effective sites were contracted in earlier rounds, but agent learning may also have played a role.

Jacobsen (2004) reports on the performance and result of a Danish experiment buying back nitrogen quotas from landowners using a reverse auction framework. The auction used a discriminatory pricing setup. Offers were received from both forestry properties (where quotas were likely in surplus from former Christmas tree plantations) and from various farm types. There was a huge

[1] Consistent with our terminology, it is a sealed offer, but the literature refers to it as ‘bid’, so this term will be used.

variation in offers from 7 DKK/kg N to 85 DKK/kg N. Nevertheless, authorities decided to pay all offers the requested price, resulting in a lower than possible efficiency and some agents capturing substantial rents.

#### 3.1.2 Field experiments with first rejected price reverse auctions

Jack et al. (2009) applied a single round, sealed bid, first rejected price auction of payment contracts to elicit cost information for a conservation payment program targeting soil erosion on coffee farms in Indonesia. Soil erosion generates downstream ecological and economic costs in these areas. Notably, the first rejected price auction design was chosen in this case due to poverty alleviation considerations, that is, information rent transfers served a second objective as an income equity measure. The potential distortions from this kind of secondary objectives in such schemes have been discussed by Delacote et al. (2014).

Pant (2015) presents the result of what is essentially a first rejected price auction among Nepalese farmers aimed at reducing the practice of burning rice straw post-harvest. The study engaged with 317 farmers across 18 villages each placing individual offers and all contracted farmers received the same uniform unit price. Jindal et al. (2013) report the results of a pilot Payment for Ecosystem Services scheme in Tanzania's Uluguru Mountains, applying a first rejected price reverse auction. They present an analysis of the performance to inform later larger scale roll-outs.

#### 3.1.3 Field experiment with discriminative payment

There is laboratory evidence that discriminative payments can be superior to uniform price auctions under suitable conditions (Cason and Gangadharan 2005), and several field experiments have pursued these.

Eigenraam et al. (2005) present the result of a pilot of a program called the EcoTender, targeting the enhanced supply of a number of different ecosystem services. The pilot was designed as a first price, discriminatory sealed offer auction with a single round. The participating landowners were informed about the aggregate environmental scores of their land, as well as the parts of that score, along with the overall distribution of scores from all the *potential* offers. The fact that it was potential offers, which is likely a much larger pool than actual offers, in combination with the

'single round' feature, may explain why this information had little effect on the offers given and hence information rents.

Juutinen and Ollikainen (2010) analyse the Finish Trade in Nature Value (TNV) program, the first, and still one of fairly few, full-scale experiments with reverse auctions in European forest policy. They use data from actual TNV contracts from the years 2003 and 2004 to simulate and analyse the outcome of a discriminatory first-price auction design, in which the government makes a separate contract with each landowner. They show that under certain conditions about ecological ranking, the buyers' benefit function and the information available to those making offers, information rent can be substantial. In their simulations, these rents depend massively on the value assigned to the biodiversity score and its weight relative to the offer, and rents make up most of the payment and vastly exceed actual estimated opportunity costs. This is because the actual individual offer is the anchor for the negotiation and the forest owners can assess post-offer if their biodiversity/offer ratio is competitive. Juutinen and Ollikainen (2010) correctly point out that it is crucial to decide how precise the measure defining biodiversity quality should enter the compensation schedule. The more exact the measures are defined, the higher average biodiversity values, but the cost being significant losses in terms of hectares covered and potentially therefore much lower aggregate biodiversity conservation impact.

Khalumba et al. (2014) report the results of a mixed method experiment in Western Kenya. They combined procurement auctions for forest enrichment contracts with (outcome) performance-based payments among participatory forestry communities. They compared the outcomes with a baseline scenario currently used by the Kenyan Forest Service. They found that the procurement auctions were the most cost-effective, and further that the outcome based measures post-contract provided additional incentives to care for the planted seedlings and hence better outcomes. They further compared the gains to transactions cost (e.g. the costs related to preparation and submission of an offer), which is rarely done, and found that gains clearly exceeded the transactions costs. The field experiment did, however, target a fairly small number of communities and participants.

Narloch et al. (2017) analysed two pilot schemes for payment for ecosystem services that were implemented as procurement auctions (conservation tenders) asking farmers to coordinate and offer as groups in a discriminatory price one-off auctions to win a tender. Winners were identified based

on a cost-benefit assessment undisclosed to those making offers. Payments where both cash and collective premiums like machinery. The study found that such auctions could effectively induce coordination among agents, thus placing part of that cost among agents rather than at the agency.

## 3.2 Insights from Stated Preference and lab experiments

There is an abundant literature assessing the willingness of landowners (farmers or forest owners) to enter contracts specifying costly management actions on their land targeting some form of environmental improvement. What we focus on in this section is how the different experiments set up the participation and payment mechanisms for the landowners, and what can be said regarding to what extent the designs encourage truthful opportunity cost reflections.

### 3.2.1 Menu of contract applications

A significant number of the studies apply setups that resemble a so-called menu of contracts. A menu of contracts is a set of different contract alternatives each with an attached payment related to it. Good examples of such are the Danish schemes for afforestation and for biodiversity measures, where landowners might opt for different contract versions implying different levels of restrictions and demands on their actions, and each resulting in different, often pre-specified, compensation payments. Thus, in these cases forest owners are often left to assume that if they qualify for a scheme, they can also expect to land a contract, though budget restrictions may of course affect that in practice. More importantly, landowners do not have to specify offers as the payments are predetermined. The landowners only have to decide if and which scheme they will opt for. Under such circumstances, the menu of contracts needs to be designed to account for asymmetric information to ensure that each landowner picks the contract scheme most suited to his or her cost and production setup (Anthon et al. 2007).

Examples of stated preference studies that can be perceived as menu of contract studies are;

- Vaissière et al. (2017) on willingness to accept biodiversity offset contracts with compensation paid from a fund based on payments from land developers. They applied a choice experiment setting with variable contract compositions.

- Broch and Vedel (2012) analysed the willingness to enter afforestation contracts in a choice experiment setting. Danish landowners were asked to pick between various contracts, with varying design features, and each with variable contract specific compensation payments. Though not an auction, the results demonstrated significant variation in stated willingness to accept, and hence likely opportunity costs of landowners. They also demonstrated aggregate compensation claims not too far from actual payments in existing schemes.

- A contingent valuation study on agri-environmental schemes contracts by Dupraz et al. (2003) also found that stated willingness to accept was quite close to comparable actual payments from existing schemes suggesting that hypothetic bias is modest when the setup and cost levels are well known.

- Vedel et al. (2015a) present the results of a choice experiment asking Danish forest owners to pick several alternatives among several sets of contracts rewarding them (with lower property taxes) for setting aside forest as untouched, increasing recreational access options and preserving single trees for natural death and decay. The results again show stated willingness to accept measures that are easily within reasonable capital cost measures as e.g. found in Jacobsen et al. (2013). Furthermore, Vedel et al. (2015a) showed that forest owners, who stated they already allowed access for the public or had set aside forest as untouched, also had a considerable lower compensation claim. See Figure 3.1 based on that paper, which shows the large variation in Danish forest owners stated compensation claims for setting aside 5 per cent of their current forest property as untouched. A relatively large fraction of owners has expressed low compensation claims. Data is extrapolated to national scale; however, it is based on observations from forest owners who own 12.5 per cent of the total private forest area.

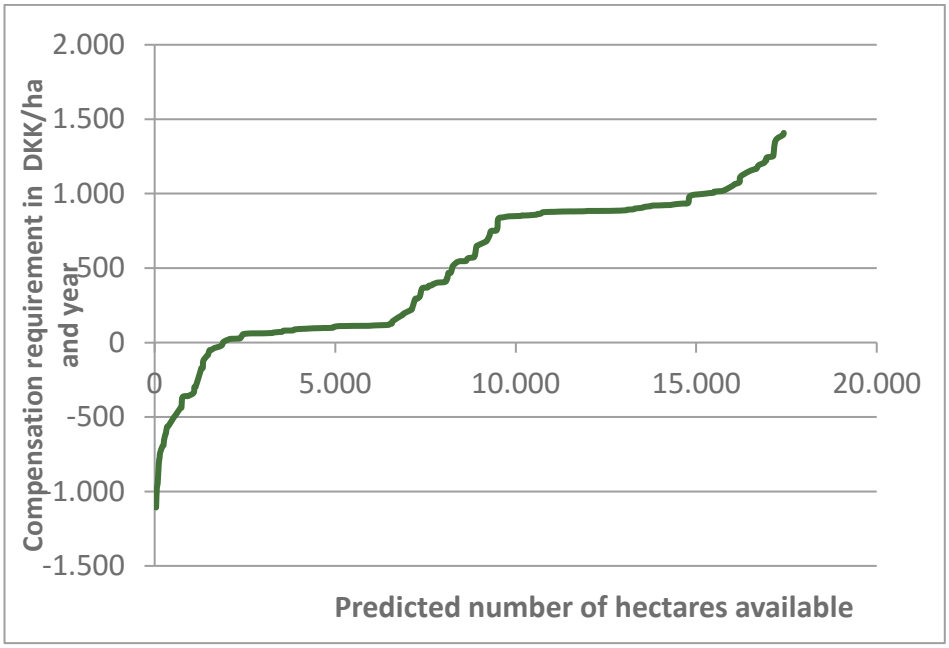


**Figure 3.1** The simulated supply for various levels of compensation offers for setting aside untouched forest in Denmark. Based on Vedel et al. (2015a).

A different variant of procurement mechanisms was investigated by Bush et al. (2013) who applied contingent valuation in asking households for willingness to accept compensation contracts for reduced access to national park areas. They framed this as a provision point mechanism scheme, where a certain minimum of total contracts was required for any households to obtain a contract. This effectively reduced compensation claims, even if no actual coordination was called for. While this is not a competition situation, it is a case where inflating your claim increases the overall risk of no one getting a contract. This could be a relevant point to consider in cases where auctions or other instruments are designed to e.g. encourage forest owners to cooperate to put up offers either in a competition with other teams, or setting them up to offer individually without collaboration and information exchange, but against a similar mechanism.

#### 3.2.2 Reverse auctions in stated preference surveys and lab experiments

Schilizzi and Latacz-Lohmann (2007) undertake a lab experiment evaluation of various conservation auction designs, and with specific focus on the difference between single and multi-round discriminatory price auctions. They also implement a treatment regarding the framing of the auction, where in one auction, participants were told there was a limited budget to compete for, in

the second treatment, they were told there was a specific target to be contracted. The two auctions appeared similar in efficiency in one-shot setting, but the budget framing appears more robust in results over repeated rounds.

Reeson et al. (2011) undertake a lab experiment focused on testing the options for enhanced coordination at landscape levels in multiple round procurement auctions. They evaluate designs where the number of rounds are either known or unknown and where a lock-in is either required or not. They find that when the number of bidding rounds is unknown a priori to agents, the cost effectiveness is improved. There is also an effect of requiring lock-in, which is implemented as a rule prohibiting raising prices across rounds. They do not evaluate against the single round alternative.

Iftekhar and Tisdell (2014) belong to a larger group of lab experiment studies concerned with how to encourage coordination among landowners when environmental services are best delivered over larger tracts of land across landowners (e.g. Parkhurst et al. 2002; Wätzold and Drechsler 2005). However, rather than the bonus grant scheme typically set up for that literature, they let groups of landowners offer against each other in a series of repeated open bidding auctions with communication. The sequential structure implies learning, which similar to standard non-coordinated auctions increases rents in particular as the landowners were able to assess the relative value of their project. It also increases coordination, however, and hence the environmental value of the projects proposed, and cost-efficiency as such increases over at least the initial part of the bidding sequences. This is contrary to non-coordinated auctions.

Bakkegaard et al. (2017) implemented a contingent valuation type procurement auction instrument among small holders in Amazon. The instrument targeted reduced logging of primary rain forest on land held by rural households. The auction instrument was designed as a first rejected price auction (a reverse second price auction). This proved to be substantially more cost-effective than a simple discriminatory price procurement format, simply asking for the required compensation but without the competitive aspect of an auction.

# 4. Key assumptions and common challenges contrasted with the case of procurement of untouched forest

In this section, we list and discuss a number of the key assumptions underlying the theory and practice of using reverse auction type instruments in e.g. environmental regulation systems. We outline the basic features of the way various forms of reverse auctions function, ideally, and use this to describe key concepts and potential benefits. Based on this, we address a number of challenges for implementation in practice as revealed by the literature on existing schemes as well as field and lab experiments. In all sub-parts, we discuss how each issue may be viewed and thought of, as well as inform about the potential design and implementation of the reverse auction type instrument for the procurement of forest land for biodiversity protection in Denmark.

## 4.1 Some key assumptions

The key assumptions concern three elements; the selling agents, the good asked for, and the principal asking for and buying the good.

### 4.1.1. The selling agents

Forest owners, as rational agents, are assumed to know their net private costs of setting aside a specific part of their forest as untouched. Note that the net includes taking into account possible private benefits they may expect to gain from this action, e.g. amenity values, and including possible spillovers to other parts of their property or activities (Juutinen et al. 2013; Vedel et al. 2015a). These assumptions are in all likelihood well satisfied for forest owners, in general. It is not generally necessary for the selling agent to know all aspects of the quality of the environmental good they are delivering; just the quality aspects that the good is requested to possess to be eligible for the market or that can be described and varied along with price in their actual offer. In the current context, forest owners e.g. may know they possess an eligible forest area – and if the design allows or asks for it – offer it at a specific price and quality in terms of volume left or treatment of ditches and drains.

Finally, it should be stressed that agents, and hence forest owners, are also assumed to be price-takers on relevant markets, including the artificial market created in the reverse auction. This

implies that they are unable to coordinate and collude with other agents to affect the resulting prices (across agents) of the goods to be delivered in the reverse auction in any meaningful way. This assumption cannot be seen separately from the design of the auction and notably the delineation of the market and the resulting potential number of suppliers. Below, we discuss this aspect in relation to the case of paying forest owners for setting aside forest land for untouched forest. It relates to issues like geographical or other quality targeting, which may reduce the number of competitive suppliers in ways that hand them instruments to identify likely competitors and collude.

#### 4.1.2 The goods asked for

Some assumptions about the good typically also need to be fulfilled for an instrument to perform well, but which assumptions depend to some extent on the design of the instrument. For first rejected price auctions, where all participants are paid the same amount for the good delivered, a homogenous good is preferable. Below, we discuss this aspect in relation to e.g. segmenting of markets according to tree species. For discriminatory pricing schemes, where the payment to each participant is (a function of) their own offer, homogeneity requirements can be more lax within the same competing pool, provided quality variation is taken into account in selecting offers and setting payments (Latacz-Lohman and Haamsvoort 1997).

#### 4.1.3 The principal

The principal paying for, buying, and holding the contracts for the environmental good is usually also assumed to fulfil some assumptions. First and foremost, the principal is assumed to know their objective function and hence be able to formulate a clear preference function across relevant dimensions. This will allow them to select the optimal set of offers from the offers received, taking into account relevant quality attributes and costs as determined by the auction pricing mechanism. The principal is also often assumed to have a finite budget or a finite environmental measure target, which works to enhance competition, just like the principal may also set some maximum prices. Because benefits are rarely measured in welfare economic terms, none of the studies in the literature or schemes implemented in field experiments or full scale have targeted welfare maximization in the design and contracting targets. In a few cases, this latter feature has resulted in outcomes, which seem in contrast with welfare maximization, e.g. the former Danish experiment with a reverse auction for N-quotas among landowners (Jacobsen 2004). In the literature, one issue discussed

based on both full-scale schemes and various experiments, is to what extent the overall performance may benefit from the principal trying to be explicit a priori about their preferences, typically using some form of weighting scheme across several criteria and supplying this information embedded in the auction procedure.

## 4.2 Some common challenges

In this section, we briefly address some of the common challenges identified in the literature that we find relevant to consider also for the case of an untouched forest instrument.

### 4.2.1 Market size and cost heterogeneity

As stressed several times in the literature, e.g. Latacz-Lohmann and Schilizzi (2005), the use of reverse auction type instruments should only be considered in cases where a number of suppliers are likely to participate, and where this number is sufficiently high to ensure competition. This has implications for design, because e.g. targeting or segmentation may reduce the pool of potential suppliers and thereby may reduce competition. At the same time, the less information available about cost heterogeneity among suppliers, the larger the overall potential from the auction instrument. In the case of untouched forest, model based estimates of opportunity costs combined with site visits underpinning the current scheme do provide some information about costs across suppliers. However, there is no way to infer other elements, including possible private benefit, which could be substantial for some owners (Vedel et al. 2015a).

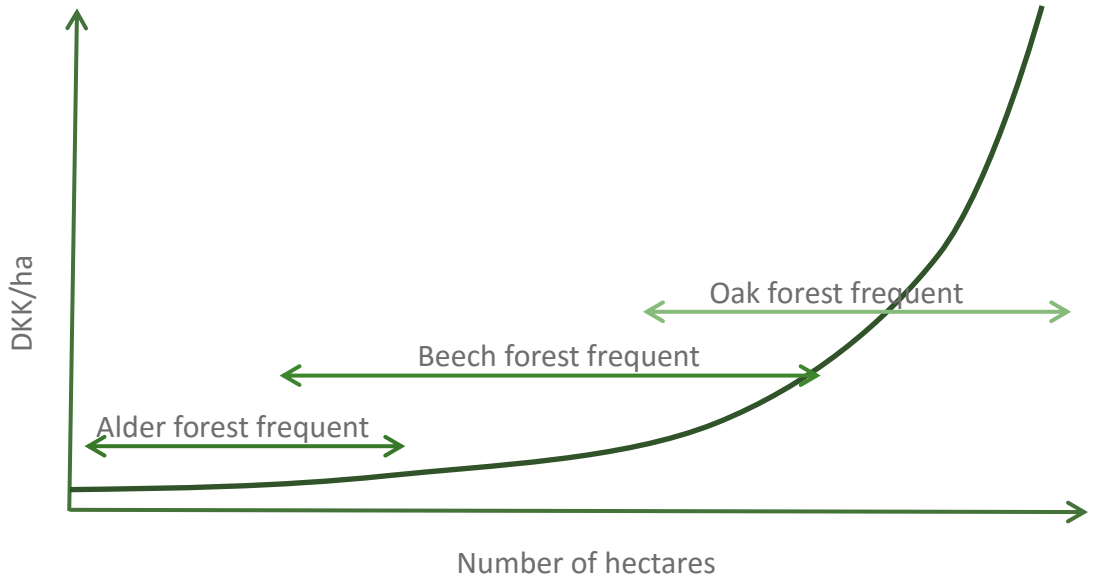


**Figure 4.1** An illustration of how forest owners perceived costs of setting aside forest as untouched (curved line) may relate to what type of forest they have.

In the Danish untouched forest case, these generic challenges have relevance for the potential segmentation of the market into different auctions. The production model based estimates of forest owners' opportunity costs reveal that a substantial part of the overall variation in costs relate to tree species, standing volume, and site quality. In Figure 4.1 this is loosely sketched. These differences suggest that segmentation and weighting should be considered for two reasons: First of all, if all these forest types are handled in one auction, with no weighting, then most of the forest land contracted will likely be low-cost alder or ash type forest and/or on poor soil conditions. This may be counter to preferences of society. Second, whether handled in a discriminatory or first-rejected price auction, the cost variation is likely to result in rather high information rents for forest owners offering low-cost forest types. Separating the forest types into different auctions, with each type competing only with itself, will eliminate these problems. It will of course imply fewer suppliers in each auction, but if no other restrictions or targeting is implemented, this segmentation in itself should not reduce competition unduly. We discuss issues related to further targeting below.

#### 4.2.2 One-off auctions, repeated auctions, post-offer negotiations and learning

There are several discussions in the literature building on experiences from full-scale schemes and experiments related to the role of auction frequency and post-auction negotiations for efficiency. We draw forward some of relevance for the Danish untouched forest case.

It is well-documented that in repeated reverse auctions, where the landowners frequently enter in new offers for contract renewal on the same land or for new contracts on additional land, offer patterns over time tend to increase for low-cost agents as they learn about the buyer's preferences and willingness to pay for the environmental goods they offer (Rolfe et al. 2009; Latacz-Lohmann and Schilizzi 2005). This increases information rents and reduces efficiency of the instrument. This observation is an argument for making such reverse auctions one-off and for making contracts permanent or at least long-term, which would fit the Danish untouched forest case well.

In some schemes, e.g. the Finnish case (see e.g. Juutinen et al. 2013), it has been practice to follow-up the offer from the landowner with e.g. a site visit and subsequent negotiations on the price, and perhaps additional measures. The costs and benefits of this can be hard to predict. If the suppliers think they have a good chance of being selected and may come under pressure to reduce prices, they have an incentive to increase the initial offer. If the initial offer is not binding, due to subsequent negotiation, they may also decrease their offer to increase the chance of being selected for negotiations, then increase offers during negotiations and walk away if not enough rents are made. Neither of these behaviours is beneficial for efficiency, but they do imply additional transaction costs for both parties. The potential benefit for the buyer side, therefore, is the option to ask for project modification that increases the environmental quality of the good delivered at suitably low costs – or decrease the offer asked at no or suitably low reductions in environmental quality. In the Danish case, where setting aside the forest is a main and straightforward measure, it may be this latter option that has value, e.g. if removing part of the wood value can be done at little or no harm to environmental goals but used to reduce the offer.

Despite the one-off and permanent type of contracts expected under the Danish untouched forest scheme, the fact that the scheme is expected to be repeated over the coming years may imply some learning and effects on future offers. This may happen for landowners who submit new offers over several years or happen across landowners as new landowners decide to enter offers in later rounds. This is likely to put efficiency under pressure as the option to wait and postpone the offering has value, if learning can happen. This holds even without strategic motives, if dynamic cost uncertainty exists. As pointed out by Thorsen (1999), one-off offers are likely to be cheaper under such uncertainty.

Finally, the scheme that ran in 2017 may have some impact on the performance of the coming reverse auction outcomes. First, as evident from Figure 4.1 above, forest owners who have a larger private benefit from setting aside forest as untouched are likely to find the current scheme attractive. Provided their private benefits are large and their production value opportunity costs are too, the current scheme could be more attractive than the auction. If they have low production value based opportunity costs, they may have seen larger benefits in waiting for the reverse auction to be implemented.

#### 4.2.3 Announcing budgets and pricing mechanisms

To provide an incentive for suppliers to place offers, a reverse auction framing has to explicitly describe how offers are converted to pricing of contract. Latacz-Lohmann and Haamsvoort (1997) point out that apart from such a price setting rule or algorithm, either a budget constraint and/or a reserve price that is a maximum acceptable price, should in general be published to ensure participants perceive they compete for a limited amount of funding. They also cite evidence that a reserve price is less effective whereas e.g. truthful budget constraint information is useful. This is likely due to reserve prices essentially working as a targeting anchor for participants. It may also be useful to state, if possible, that the buyer is under no obligation to spend the budget on received proposals if they are found to be of insufficient relevance or too expensive. One may also consider estimates of the full potential market volume to be worthwhile information to publish along with the auction procedures, to inform potential participants about the competition level.

In the Danish case, the existence of a budget constraint for the 2018 round of the auction forms a natural basis for a message about the limited budget. If accompanied by a message about absence of buying obligations and perhaps an undisclosed price limit, these should be effective in framing the auction as a true competition.

It can also be important for ex post efficiency that the buyer has decided upon a budget constraint and/or maximum price ceilings. Without it, information rents paid over the entire auction can be prohibitively expensive, as was the case in the earlier case of N-quota reverse auctions evaluated by Jacobsen (2004).

#### 4.2.4 Factoring in environmental quality variation and spatial aspects

Reverse auctions for conservation and other types of environmental contracts are often a complex type of multi-attribute procurement. Society, and hence the buyer, may consider a number of attributes of an area and/or a land management action important for the quality and value of the environmental outcome. In principal, all environmental goods offered for contracting may differ from each other on any number of quality parameters.

The effect is that the buyer may worry about how to obtain the best aggregate environmental outcome for the budget across any number of attributes. For this reason, several examples can be found of schemes and experiments testing the use of indices or rankings or other ways of ranking the offered contracts prior to selecting which offers to accept (see the above review, and also e.g. Latacz-Lohmann and Schilizzi (2005)). Such approaches may e.g. condense environmental attributes into a single score, e.g. using some linear weighting scheme, representing the overall environmental performance of the supplied lands. Offers are then selected for the conservation programs on the basis of their "score/cost" ratio under the given budget constraint.

While these aspects are undoubtedly important for efficiency, they also raise challenges. Some qualities, e.g. spatial aspects like proximity to other protected areas or other areas offered in the auction are hard if not impossible to handle meaningfully using simple linear weights, often specified a priori. Furthermore, acquiring the necessary information may be costly and its application uncertain or subject to challenges ex post.

In some existing experiments and schemes, some of the information used in the ranking procedure has been made available for the suppliers prior to making their offer. This is also not without difficulty and may have several effects. On the positive side, it increases the potential transparency and may work to draw forward more land of relevance. On the other hand, it raises the transaction costs of participation, which may reduce participation overall. Furthermore, landowners with environmentally attractive land may realize this and use the information as a basis for extracting higher rents and increase their offer – in turn reducing efficiency.

For these reasons, it is a matter of scientific and practical debate what and how much prior information to give potential suppliers about the different aspects of environmental quality and how

they are taken into account in the selection of offers. Examples exist where this is described in broader terms and e.g. landowners are only informed about the score of land in their region and the overall distributions of scores across all relevant land areas. Such aggregate information is both fairly precise and yet also formulated in a way to discourage strategic behaviour, but it can be costly to produce and may be contested on technical grounds.

The handling of spatial co-dependence of environmental values of land offered is particular difficult to handle. Proximity to existing protected land may be an asset, which can be assessed ex post as well as by the supplier before providing an offer. However, it may also be of value if new land areas offered for conservation are spatially linked or close to each other. This requires either ex ante coordination among landowners or some ex post selection criteria, which by definition cannot be assessed before. Ex ante coordination may be handled by letting landowners submit coordinate offers for e.g. contiguous areas, along with independent offers for those same areas. That will allow the buyer to select the land from all landowners, paying a potential premium for them to offer contagious areas, or only some of the land in non-contiguous configurations. This of course increases transactions costs and may also limit competition and encourage unwanted coordination of the individual offers.

More generally, in multi-attribute procurement cases like the Danish untouched forest scheme, it is difficult and costly to formulate even reasonably accurate objective functions for the buyer in mathematically tractable ways that allow simple constructs like indices and scores to carry sound meaning when used ex post to prioritize and select what offers to accept. In fact, because the scores are often simplified linear constructs based on incomplete ex ante knowledge, they can result in rankings and decisions that ex post are obviously wrong and potentially costly (Hougaard et al. 2016). Research in efficient multi-attribute procurement has addressed the potential for applying pricing methods that can resolve procurement auctions with as little a priori information collection as possible, yet still handle the fact that cost information is private to suppliers adequately. Specifically, the use of data envelopment analysis for yard stick pricing (see below) in procurement auctions is being studied (Bogetoft and Nielsen 2008), and current research efforts are addressing the potential for applying this to public procurements schemes much like the Danish untouched forest scheme (Hougaard et al. 2016; Nielsen et al. 2017b). The ambition is to have if not first-best optimal outcomes then at least very good approximations that can be obtained without costly

information collection efforts of both suppliers and the buyer, while still retaining truth-telling as a useful strategy for the suppliers and applying pricing rules that leaves suppliers no worse off than their stated offers ex post. The approach implies that suppliers provide their offers (combinations of prices and some information about the qualities of the offer). Offers are then described in terms of these as well as potentially additional attributes, where information is readily available, for example various biodiversity measures as will be described below in Chapter 5. A yardstick-based algorithm then calculates a set of efficiency corrected yardstick offers, one for each offer, where each offer is measured up against a yardstick defined by the most efficient span of all closely related offers. The buyer then ex post selects the combination of offers that the buyer finds are optimal, given the yardstick prices. In this way, the buyer need not formulate preference a priori in condensed form, but can satisfy preferences overall across the entire set of offers ex post. The selected suppliers are offered the maximum of their stated offer and the calculated, efficiency corrected yardstick price, and this feature implies that truth-telling remains a dominant strategy for them when formulating offers.

#### 4.2.5 Intermediaries and other agents

Landowners, whether farmers or forest owners, may often rely on intermediaries, e.g. extension service agents, consultants or professional management companies, for much of the administrative work, for decision support, for obtaining information about rules, regulations and market information and many other aspects. The presence and behaviour of such agents may influence the performance of reverse auctions in different ways.

A potential positive effect of these agents is that they provide an information effect and enhance transparency. Aggregating across landowners, they are able to harvest economies of scale, enabling them to cover costs of information search and analysis, e.g. about new instruments and their potentials, and disseminate these in a targeted and adapted manner to the different landowners. Fulfilling this role, such agents work to enhance information uptake, possibly increasing participation rates and hence market size and competition in the reverse auctions. This works to enhance efficiency of the instruments.

A potential negative effect of these agents may arise if they not only inform the forest owners, but also support their cost assessments and perhaps submit offers. This could result in unwanted and

untruthful homogenization of offers across landowners, and it could be conducive to collusion and coordination of offers. This may happen even in the absence of strategic behaviour, but simply as the result of agents decreasing own costs of entering offers or being concerned about issues of perceived fairness across customers, both concerns may be a reason for submitting too similar offers that do not reflect actual variation in opportunity costs.

Both of these aspects need to be considered in the case of untouched forest in Denmark. The Danish forest sector has numerous agents that can be activated in various ways to enhance information up-take and hence market size. At the same time, procedures to counter offer homogenization and coordination through these agents might need to be developed.

#### 4.2.6 Issues post-contracting

In many contracting cases, there is a need to describe and implement a structure able to handle moral hazards. Moral hazards arise when the supplier has an incentive to shirk or somehow violate the terms of the contract. This can be hard and costly for the buyer to monitor and to detect, and when detected, it may be impossible to re-establish the environmental good contracted, effectively implying a loss for the buyer. To discourage such behaviour on the supplier side, contracts need to include a description of the consequences for the supplier, typically involving actions like confiscation of any gains, repayment of original payments, possibly including accumulated interest and perhaps a fine in addition. The buyer may also describe rules for the frequency of control visits, documentation requirements or other features that introduce control and monitoring. While such contract aspects are generally necessary, they may of course also come at a cost in terms of higher offers being asked for due to the negative effect monitoring has on landowners utility (Vedel et al. 2015b).

# 5. Biodiversity and environmental targeting

## 5.1 Auctions, goals and targets

Many of the previously highlighted auctioning mechanisms in Australia (Stoneham et al. 2003; Connor et al. 2008; Kits et al. 2014), Canada (Brown et al. 2011) and elsewhere have applied information on so-called biodiversity or environmental benefits for increasing the cost-effectiveness of the programs by targeting landowners where benefits per cost were highest.

The targeting may be towards one goal (e.g. biodiversity or soil erosion). Targeting could also be towards multiple goals (e.g. biodiversity, water, carbon capture). Including more goals may complicate the calculation of effect of the conservation program. Effect assessment is usually based on current conditions. However, the modelling of expected effect is based on the current state and response to actions. Further, the baseline (or counterfactual) should ideally be included by incorporating risk and uncertainty into the calculation of expected effect. Estimating outputs and outcomes requires some predictive function to be generated based on the existing condition and the inputs (management actions) to be added. This is illustrated in Figure 5.1 showing that the potential aggregated biodiversity gains depend on the predicted loss (baseline), and how conservation action may contribute by maintaining status quo (maintenance) and lead to potential improvements. The figure shows the ideal effect assessment, however, in most cases such information is not available and only current status on biodiversity and environmental benefits are available. Therefore most approaches focus on immediate inputs (e.g. area set aside) instead of outcomes generated by the conservation action.

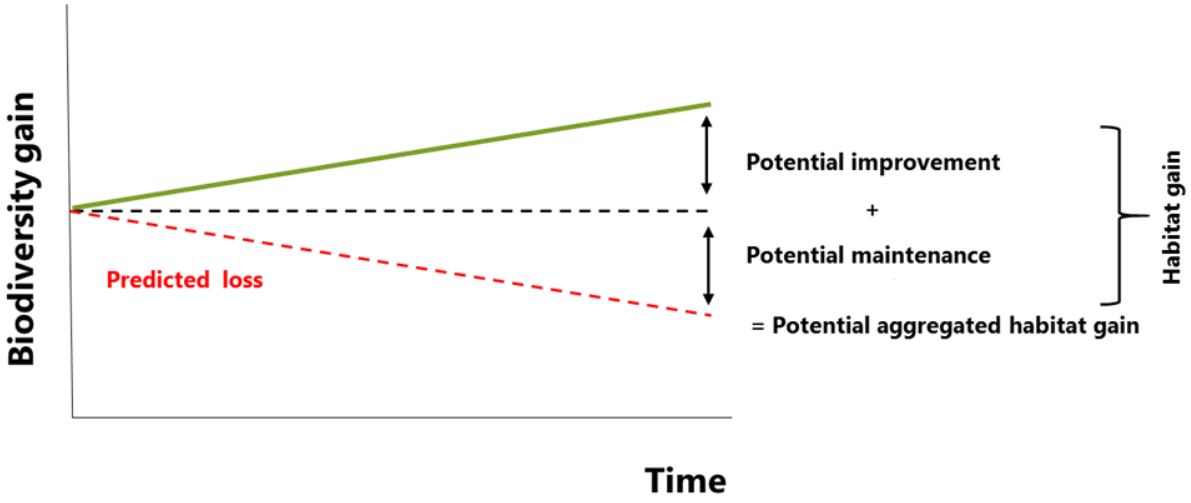


**Figure 5.1**. Concept of effect assessment over time. (mod. after O'connor 2015).

A large number of metrics have been developed. One common metric is to base the prioritisation of offers on the ratio between a biodiversity/environmental benefit index, and the offer. In its simplest version, offers with the highest ratios are selected. The use of metrics to better target the schemes may increase the cost-effectiveness considerably. Wunscher et al. (2006) simulated different targeting approaches for the Costa Rican payments for environmental services scheme and found that the use of a biodiversity benefit metric, compared to current practice ignoring such information, resulted in an increase of 14 per cent in benefits. The use of metrics is also discussed above in section 4.2.4. The mathematic formulations of the metrics vary from considering single goals to multiple goals, and additive weighted sum scoring to multiplicative weighted scoring systems. Table 5.1 describes some examples of auctioning schemes where the number of goals vary from single to multiple and the number of indicators from a few to many. The complexity increases with goals and targets.

Table 5.1. Examples of auctioning programs, the number of goals they target, and data

| Examples | Problem/context | Targeting data | No. of indicators |
|---|---|---|---|
| The Victorian BushTender Program, Biodiversity Benefits Index | One goal | Biodiversity<br>Price, Management effect | 12 |
| Conservation Reserve Program, Environmental Benefits Index-USA | Multiple goals | Biodiversity, erosion, water quality (sediments, nutrients, pesticides)<br>Price | 7 |
| The Western Australian Auction for Landscape Recovery | Multiple goals | Biodiversity, erosion, water quality (sediments, nutrients), agricultural production<br>Price, management effect | 48 |
| Forest Biodiversity Programme METSO – Finland | One goal | Biodiversity<br>Price | 2 (10+8 sub-indicators) |
| Tasmanian Forest Conservation | One goal | Forest Priority Score(2), Structural Condition, Current condition value, Regional Threat Index, Reserve value,<br>Price, Management effect (maintenance+improvement+security) | 10 |

## 5.2. Biodiversity data

Biodiversity can be described from the differences in genes, species and ecosystems. Ecosystems can be considered at many levels, from the global and down to a geographically defined area in nature, where plants and animals interact with each other and their physical environment. Despite the scientific evidence that the genetic variation and diversity of ecosystems are important components of biodiversity, diversity of species is the most widely used target for biodiversity. This is because, traditionally, there is high awareness of the species, and of the fact that the diversity of species is simpler than the other two categories. At the same time, there is a greater knowledge of species diversity and a positive link between the diversity of species and the diversity of genes and ecosystems (Vié et al. 2009). For these reasons, diversity of species is often used as an overall

indicator of biodiversity. However, the number of species at a specific site is not the only parameter relevant to land management in relation to biodiversity conservation. For example, it is of great importance, whether the species is a common or a threatened species. In addition, it is also relevant to include the possibility of species to survive in the long term, and here parameters about the geographical size of species habitats and correlation with the existing nature can be important.

In recent years, more biodiversity data has become available for large scale prioritization analysis (Petersen et al. 2012, 2016). They present distributional data for various species groups in Denmark compiled for a 10×10 km UTM grid cells covering all of Denmark. The data records the presence or absence of each of the species in each of the grid cells. The data set in Petersen et al. (2012) covers a total of 899 terrestrial and a few semi-aquatic species breeding in Denmark.[2] Earlier versions and subsets of this data set have been used for quantitative biodiversity analyses (Lund & Rahbek 2002; Strange et al. 2006; Larsen et al. 2008, 2009, 2012; Bladt et al. 2009). The data represents the most complete species distribution data in Denmark. However, currently the University of Copenhagen (Centre for Macroecology, Evolution and Climate) is developing a data set for the Danish State forests, which in principle allows assessing biodiversity at a much higher spatial resolution. The data combines available spatial presence/absence data and data from the national biodiversity map, which consists in a spatial prioritization of nature areas according to their significance for Denmark's biodiversity (Ejrnæs et al. 2014). The biodiversity map in Ejrnæs et al. (2014) contains a national priority in the form of an analytical designation of the most important 10×10 km squares and a local 10×10 m priority in the form of a species score indicating the importance of the area as habitat for red-listed species. Priority on a national scale is made on the basis of data for the national distribution of 537 endangered species in 633 squares at 10×10 km.

[2] These are 5 reptile species, 13 amphibians, 181 birds, 48 mammals, 41 dragonflies (Odonata), 23 grasshoppers (Orthoptera), 60 true bugs (Heteroptera: Pentatomidea, Coreoidea, Pyrrhocoridea), 21 click beetles (Coleoptera: Elateridae), 248 hoverflies (Diptera: Syrphidae), 58 butterflies (Lepidoptera: Hesperioidea, Papilionoidea), 154 large moths (Lepidoptera: Hepialoidea, Cossoidea, Zygaenoidea, Tineoidea, Yponomentoidea, Bombycoidea, Geometroidea, Sphingoidea, Notodontoidea, Noctuoidea), 6 club mosses (Lycopodiaceae) and 35 orchids. The data include the majority of the Danish species within each group except for the click beetles, which mainly include species associated with old forest. We excluded vagrant, casual and exotic species from the data set to avoid bias towards those species.

# 6. Considerations of the pros and cons of alternative designs in a Danish forest context

Chapter 4 outlined some of the key considerations in the choice of the design of a reverse auction of harvesting rights to forestland and section 5 outlined some of the key quality parameters. In this section, we aim to use existing data of the spatial distribution of forest owners, biodiversity indicators and the capital value of mature forests to get a sense of the critical assumptions determining the relative merits of alternative designs. We choose to illustrate four possible designs to highlight, when each of the designs is likely to be cost-effective. It must be stressed that the analysis rests on assumptions of key factors. Empirical data are not available to give any indication as to how plausible the assumptions might be. Nevertheless, the analysis gives some guidance how to reduce the risk that the cost of the reverse auction becomes excessive.

## 6.1 Alternative designs

All four designs are based on the assumption that each forest owner, who is interested in entering the form of contract, will submit an offer for five hectares. This is done for simplicity and should not have any qualitative effects. It is also assumed that each forest owner can submit one offer.

*Design A:* The reverse auction is purely based on price/ha. There is no distinction between areas based on quality, and the successful participants are paid based on their submitted offer.
*Design B:* The reverse auction is purely based on price/ha. There is no distinction between areas based on quality, and the participants are paid based on first rejected price principle.
*Design C:* The reverse auction is based on price per biodiversity point. The point system is based on a weighted sum of points for price and points for biodiversity. The points allocated to the price are scaled relative to the cheapest offer, where the cheapest offer gives 5 points. The points allocated to biodiversity are based on the bioscores for the area (Ejrnæs et al. 2014). The points allocated to the offer are relative to the highest bioscore, and the highest score gives 5 points. In the example illustrated below, price and biodiversity are weighted with 50 per cent each.
*Design D:* The reverse auction is purely based on price/ha. Two types of forests are eligible areas, one dominated by alder, the other type dominated by beech and oak. There is no discrimination between areas based on quality, and the participants are paid based on their submitted offer. It is assumed that it is equally likely that the forest owner submits an offer for each of the types.

For all designs, it is assumed that 1 per cent of the forest owners will be interested in submitting an offer, and we simulate a single auction. Therefore, we have not at this stage taken any potential learning effects into account. It is likely that the interest in the auction will vary across the four designs, but there is no data to give an estimate on the relationship and therefore, we have not included this aspect in the analysis.

### 6.2 Data

The data for the analysis originates from aggregated owner and property data analysed in Nielsen et al. (2017a) at a 10×10 km spatial resolution, covering 633 grid cells in Denmark (Figures 1A, 1C, 1D). Average biodiversity importance scores (Figure 1B), is based on species in the national Red Data Book and expert judgments (Ejrnæs et al. 2014).

The spatial distribution of broadleaved forest cover is not available at the resolution given in Figure 1. We have used the 10 Danish bioregions to represent the spatial distribution of forest productivity. In the initial analysis, we have assumed that forest owners with broadleaved forest of oak, beech or alder will exist across the country. We have used the capital value for mature forests of each of the three species in each of the bioregions to represent the opportunity cost of permanent harvesting rights. For oak, this is defined as the capital value of a 105-year-old stand. We have included a 20 per cent variability randomly to allow for local variability in ages and productivity. For beech, we have used an 85-year-old stand to represent maturity and have used 20 per cent variability in capital values. The capital value of alder stands at 55 years has been used to represent the value of less economically productive broadleaved areas. Again, we have used a 20 per cent variability in economic value. We use a 3 per cent discount rate.

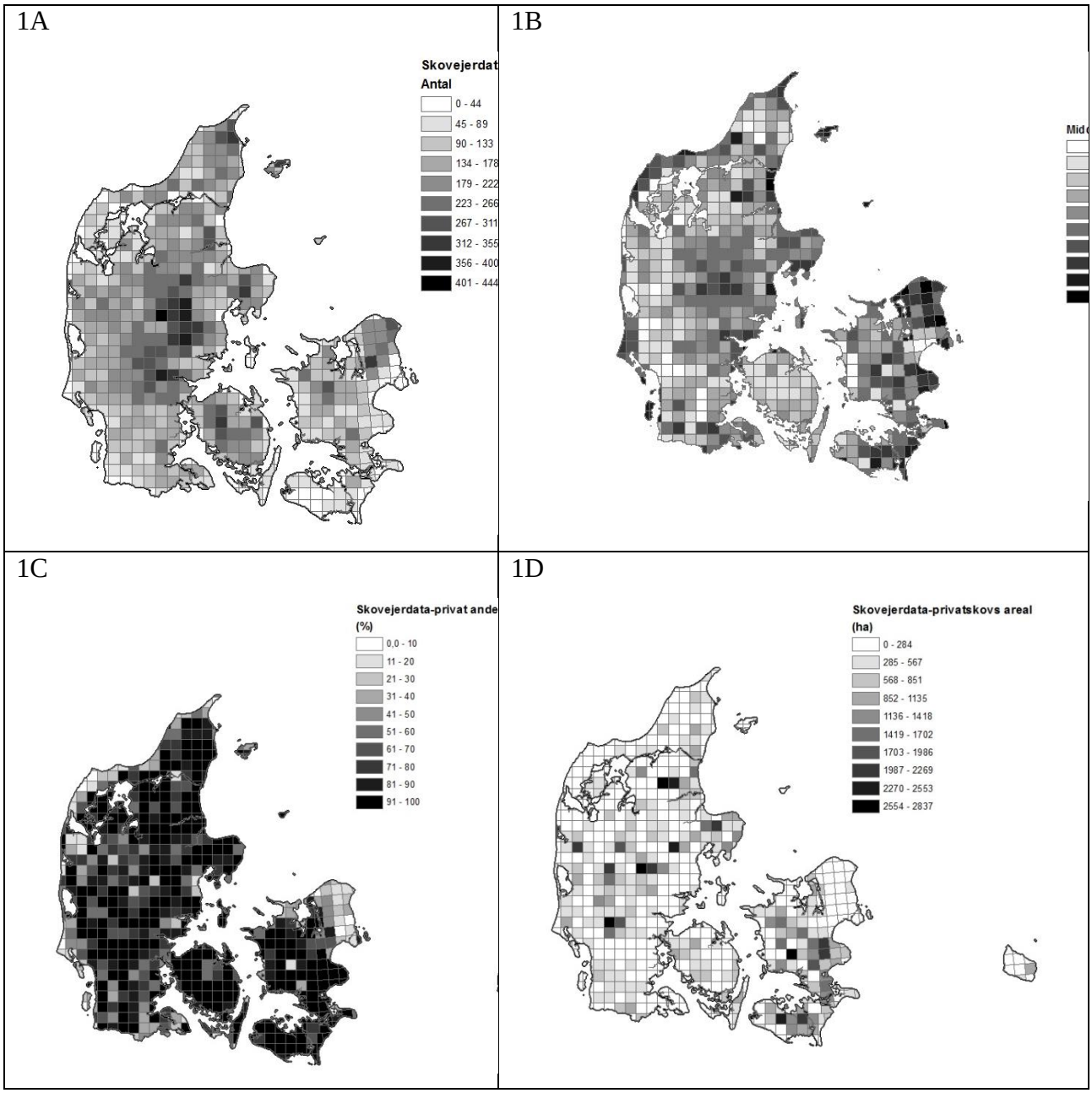


**Figure 6.1:** Spatial distribution of forest area (A), biodiversity importance score (B), number of private owners (C) and private forestland (D) in Denmark at 10×10 km resolution.

## 6.3 Results

The accumulated offer curve, using design A, is shown in Figure 6.2 (blue curve). This assumes that the contracts are allocated based on a discriminatory reverse auction and that the participants are equally likely to submit an area of the three different species and reveal their true opportunity costs. With a budget of 90 million DKK, harvesting rights on approximately 1100 hectares is purchased.

Using a first rejected price auction (Design B) increases the costs due to the relatively steep cost curve. With a budget of 90 million DKK just under 800 hectares are signed up. Even if forest owners offer the harvesting right at 50 per cent above their opportunity costs, a discriminatory reverse auction is more cost-effective. Figure 6.2 (green curve) illustrates an offer curve where the forest owners provide offers 10 per cent above their opportunity costs. Just below 600 hectares of the contracted area are alder forests following Design B.

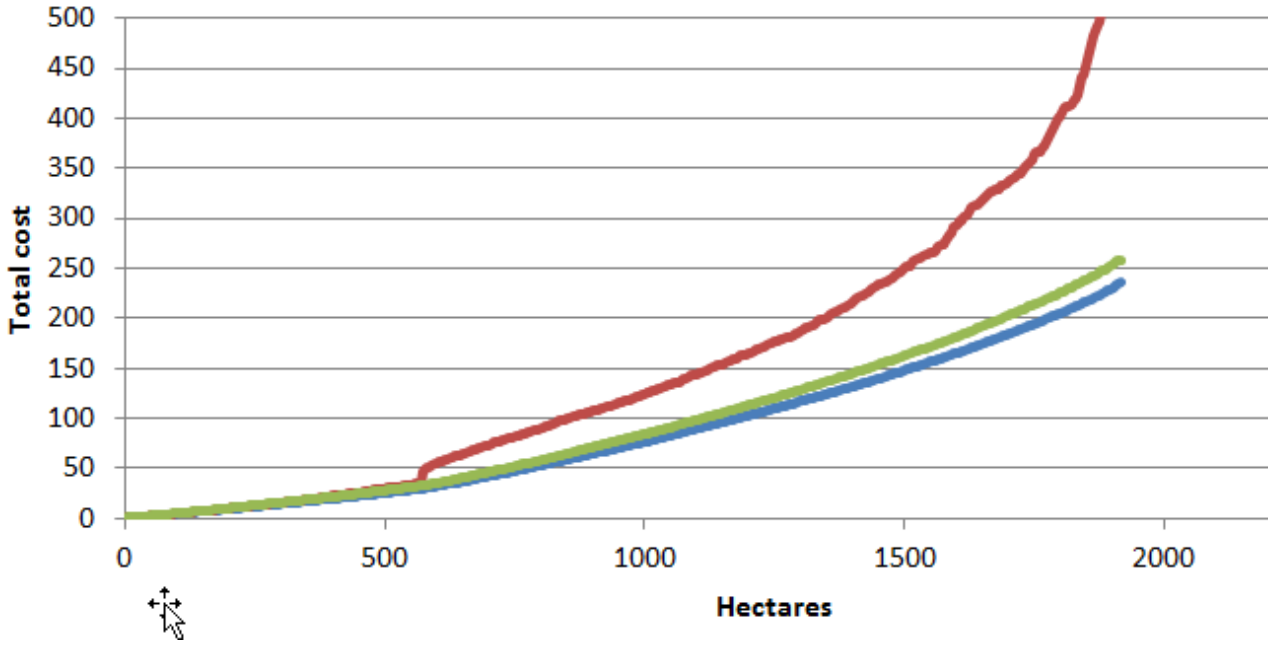


**Figure 6.2:** Total costs of auction illustration. Design A discriminatory pricing (blue). Design B first rejected price (red). Design A discriminatory pricing including 10 per cent information rent (green).

The accumulated offer curve, using Design C, is shown in Figure 6.3. This assumes that the contracts are allocated based on points where 50 per cent of the weight is given to the price and 50 per cent is given to the biodiversity score of the area. It is a discriminatory reverse auction and it is assumed that the participants are equally likely to submit an area of the three different species and reveal their true opportunity costs. With a budget of 90 million DKK, harvesting rights on approximately 1,000 hectares is purchased. Just below 600 hectares of the contracted area are alder forests, the same area as the areas contracted under Design A and B. This means that due to the large difference in opportunity costs of the three species, the ecopoints are not altering the composition of the types of areas contracted under the scheme.

**Figure 6.3**: The total cost of the reverse auction using Design C.

Dividing the auction into two sub-auctions with an allocated budget of 50 per cent for each sub-auction gives two accumulated offer-curves (Figure 6.4).

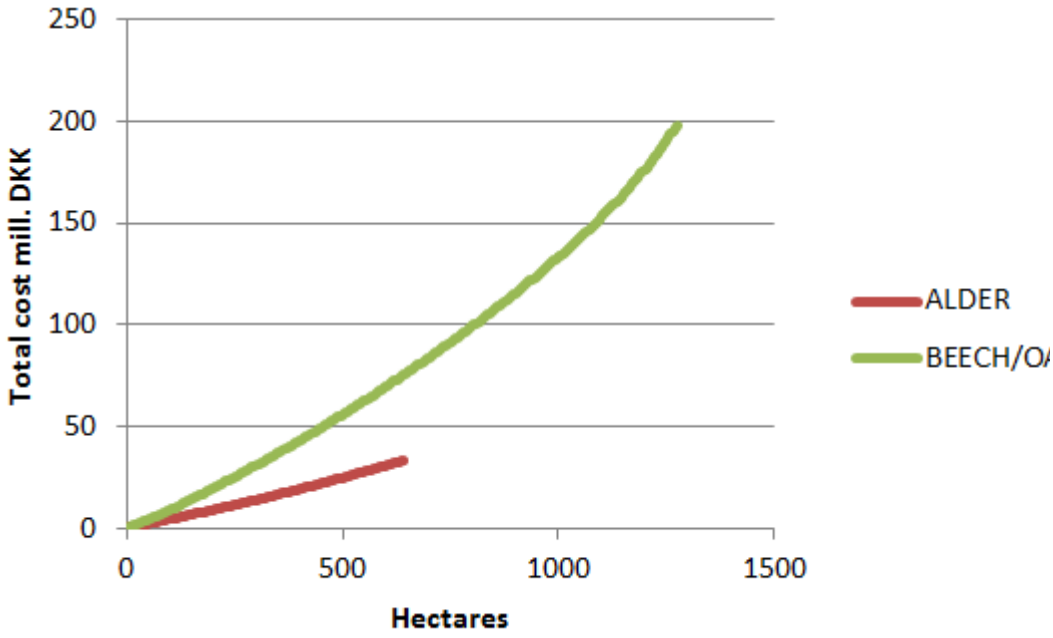


**Figure 6.4**: The total cost of the reverse auction using Design D.

All offers for contracts of alder area are successful with a budget constraint of 45 million DKK and 640 hectares are contracted. 415 hectares of forest dominated by oak and beech forest are contracted under this arrangement.

### 6.4 Conclusions from the simulations and the implications for the design

The analysis reported in this section serves as an illustration of the influence of some of the key considerations for a cost-effective design. Firstly, the large variation in capital value of forest areas mainly due to species and age composition is likely to determine the distribution of the offers. This is likely to be much higher in reality than by these averaged measures +/- 20 per cent. If the species distribution of the contracted areas is an important success parameter, it should be taken into account in the design phase. Ignoring this aspect is likely to lead to contracts only representing the less valuable forest types in market terms. Secondly, the analysis illustrates a system for including the biological value of the areas into the ranking of offers. Given the weight between offer and biological score (assumed equal weight in the analysis) and distribution of biodiversity values, the results indicate that the distribution of capital values of the offers is the determining factor for the contracted areas. The variation in biodiversity scores and spatial variation in productive potential of the forest is less influential, due to the fact that each bioregion is only represented by the average productive potential. Having said that, these illustrations are merely illustrations of principles and rest on strong simplifying assumptions.

# 7. Barriers for participation

It is essential for tenders and reverse auctions to reach an adequate level of participation from landowners in order to obtain the desired environmental effect and to secure competition, which is fundamental for minimizing the potential of information rent and thus securing cost efficiency. The more landowners that participate in a tender by making offers for conservation of their land, the larger a selection of offers the environmental agency will have to choose among. High participation is instrumental in securing that the environmental agency has an oversupply of offers either in terms of the conservation target or in terms of the budget for conservation. So ultimately, the attractiveness of the mechanism for landowners is of great importance for success. At the same time, Whitten et al. (2013) note that high participation naturally leads to higher costs of the environmental agency in terms of more site visits and administration in general.

But landowners in general have limited experience and knowledge about auctions, the involved process of bidding, and the competition they will face (Rolfe et al. 2017), which might reduce their willingness to participate in the auction. Looking at experience reported in the literature, this chapter aims at identifying potential barriers that may prevent forest owners from entering an auction, and initiatives that could promote participation. We present a 3-stage framework, which in detail is inspired by a framework developed by Whitten et al. (2013) and we look at how the different stages in the process of implementing tenders can impact the participation of landowners. We supplement with experiences from other sources including experiences related to implementation and adoption of the agri-environmental schemes. The boundaries between the different stages in the framework are not sharp as more of the factors influencing participation could belong to more than one of the stages.

## 7.1. Stage 1: Alignment

This stage refers to how landowners are aligned with the required conservation action(s) dictated by the conservation scheme. This includes their awareness, with respect to the degree of knowledge and the amount of time they had knowledge about the scheme, knowledge about how the conservation action will deliver the desired environmental outcome and whether they consider the actions appropriate. In a review of 23 studies of agri-environmental conservation programs, Knowler and Bradshaw (2007) find awareness of the environmental problem to be one of the few

universal factors to affect adoption of the programme. In addition, Wossink and Van Wenum (2003) find that the lack of farmer's awareness of an incentive programme offered for biodiversity conservation hampered participation. Awareness also implies that the landowners find the conservation strategy of potentially practical relevance (Pannel et al. 2006) and if landowners do not consider the projected conservation action as appropriate, it will also negatively affect their willingness to participate (Wossink and Van Wenum 2003). Morris et al. (2000) found that farmers demonstrated resistance to agro-environmental schemes, often associated with objection in principle to perceived constraints on the freedom to farm, reinforced by lack of knowledge of the scheme.

The previous call for a fixed price conservation scheme (Miljøministeriet 2016) using untouched forest as the conservation action and the research results published within the last couple of years (see e.g. Pedersen et al. 2016) including the surrounding debate and media attention would probably mean that most forest owners are aware of the untouched forest as a conservation strategy. However, a partnership with forest owner associations should be considered in order to raise awareness but also to facilitate that forest owners find untouched forest to be an appropriate mean to conserve biodiversity. Awareness campaigns and demonstration projects could also serve to raise awareness and knowledge.

### 7.2 Stage 2: Opportunity and engagement

In this context, opportunity should be interpreted as the relative advantage for the landowners to participate in the conservation scheme, and is defined as the landowners' perception of the marginal benefits relative to the marginal costs. In addition to the opportunity costs of leaving the forest untouched, the transaction costs related to making an offer are also relevant in the perspective. This is strongly related to engagement, which covers the communication, information exchange and preparation of offers related to the participation of reverse auctions (Whitten et al. 2013). Engagement also interacts with landowners' perception of eligibility for the conservation scheme, where a strict eligibility caused by e.g. segmentation as described in section 4.2.1 potentially could decrease participation. Another factor associated with eligibility is information about the parameters considered when evaluating offers. As previously mentioned, Connor et al. (2008) points out that rent seeking could be minimized if the evaluation parameters are not fully disclosed. This, on the

other hand, might have an adverse effect on participation. The yardstick price algorithms described above might provide a better balance between transparency and participation.
An important factor is the opportunity cost as perceived by the landowners, which includes both the direct and the indirect cost caused by the conservation action.

In the case of leaving a forest area untouched, there is uncertainty about e.g. draining of the forest stand on grounds of neighbouring plots, or how hunting rights and income would be affected. Also, obligations to clearing established access ways for recreation could influence the perceived costs. The better these possible uncertainties are handled and communicated, the clearer a perception the landowner will have of the opportunity.

Transaction costs arising from arranging the transfer of rights or land between landowner and the environmental agency, e.g. the costs related to offer preparation and submission of an offer is also of relevance. Mettepenningen et al. (2009) explore farmers' transaction costs entering an agri-environmental scheme and find the costs to be significant due to increased administrative workload combined with the fact that farmers in general appear to be averse to administration. Ducos et al. (2009) also find transaction costs to impede participation, and Ruto and Garrod (2009) find similar results in a choice experiment study based on farmers in 10 countries across the EU. They also found that farmers were less likely to join contracts with long duration and small levels of flexibility. Broch and Vedel (2012) also found that flexibility in terms of short contracts or being able to cancel the contract was important features for landowners. This indicates that contracts and application procedures would benefit from simplicity in terms of participation rates, which is confirmed by Falconer and Whitby (2010) who advocate scheme transparency and simplicity of schemes in order to reduce landowners' need to pay for professional advice. Furthermore, participation is often required within a reasonably short timeframe, which further emphasises the need for simplification and clarity.

When setting aside forest for biodiversity protection, the timeframe is by nature rather long, if not infinite. This obviously conflicts with creating short and flexible contracts. Falconer and Whitby (2010) suggest schemes where landowners can opt in or out of specific requirements in order to simplify the tender process. A few options could be considered to strike a balance between simplicity and flexibility. Some landowners would perhaps be reluctant to make commitments that

future generations would have to comply with. One opportunity could be leaving a window of opportunity to withdraw from the contract after a number of years, which has been found to have great importance for landowners (Broch and Vedel 2012). This would require thorough consideration about how the compensation should be adjusted in relation to interim growth, changes in timber prices, and interest rates etc., before it is returned from landowner to agency. Another opportunity could be allowing a pre-conservation harvest of timber. This flexibility could increase participation but would demand careful consideration of how this harvest would affect the biodiversity on location, and how it should be taken into account in relation to the selection of offers. Furthermore, the implications for biodiversity of pre-conservation harvest are likely to vary greatly between areas.

### 7.3 Stage 3: Contracting and post-participation

Contracting covers, the formal agreement between landowner and agency, and many of the considerations above about flexibility and transaction costs apply here as well. Whitten et al. (2003) also stress the importance of communication between landowner and agency throughout the contracting phase. This should also continue after the contracting phase with respect to general administration monitoring issues. Post-participation also relates to potential landowners, who did not offer their land for conservation, and landowners being unsuccessful in the selection of offers. Siebert et al. (2006) find that social networks in the local community of landowners play a significant role, with special importance to how the network has experienced negotiations with an agency. Therefore, unsuccessful participants with a positive experience about the process could be valuable in obtaining sufficient participation in future auction.

# 8. References


Anthon, S., P. Bogetoft and B.J. Thorsen, 2007: Socially Optimal Procurement with Tight Budgets and Rationing, *Journal of Public Economics*, 91: 1625-1642

Arozamena, L and E. Cantillon, 2004: Investment Incentives in Procurement Auctions. *The Review of Economic Studies*, 71: 1-18

Bakkegaard, R.K., J.B. Jacobsen, S. Wunder and B.J. Thorsen, 2017: Comparing tools to predict REDD+ conservation costs to Amazon smallholders. *Resource and Energy Economics*, 49: 48-61

Binney, J. and K. Whiteoak, 2010: *The Tasmanian Forest Conservation Fund and associated programs: purpose, performance & lessons*. Marsden Jacob Associates, report for Department of the Environment, Water, Heritage and the Arts, 45 pp.

Bladt, J., N. Strange, J. Abildtrup, J.-C. Svenning and F. Skov, 2009: Conservation efficiency of geopolitical coordination in the EU. *Journal for Nature Conservation*, 17: 72-86.

Bogetoft, P. and K. Nielsen, 2008: DEA based auctions. *European Journal of Operational Research*, 184: 685-700.

Broch, S.W. and S.E. Vedel, 2012: Using Choice Experiments to Investigate the Policy Relevance of Heterogeneity in Farmer Agri-Environmental Contract Preferences. *Environmental and Resource Economics*, 51: 561-581.

Brown, L.K., E. Troutt, C. Edwards, B. Gray and W. Hu, 2011: A Uniform Price Auction for Conservation Easements in the Canadian Prairies. *Environmental and Resource Economics*, 50: 49-60.

Cason, T.N. and L. Gangadharan, 2005: A laboratory comparison of uniform and discriminative price auctions for reducing non-point source pollution. *Land Economics*, 81: 51-70.

Connor, J.D., J.R. Ward and B. Ryan, 2008: Exploring the cost effectiveness of land conservation auctions and payment policies. *Australian Journal of Agricultural and Resource Economics*, 52: 303-319.

Dasgupta S. and D.F. Spulber, 1989: Managing procurement auctions. *Information Economics and Policy*, 4: 5-29.

Delacote, P., C. Palmer, R.K. Bakkegaard and B.J. Thorsen, 2014: Unveiling information on opportunity costs in REDD: who obtains the surplus when policy objectives differ? *Resource and Energy Economics*, 36: 508-527.

Ducos, G., P. Dupraz and F. Dupraz, 2009: Agri-environment contract adoption under fixed and variable compliance costs. *Journal of Environmental Planning and Management*, 52 (5): 669-687.

Dupraz, P., D. Vermersch, B.H. de Frahan and L. Delvaux, 2003: The Environmental Supply of Households. *Environmental and Resource Economics*, 25: 171-189.

Eigenraam, M., L. Strappazzon, N. Lansdell, A. Ha, C. Beverly and J. Todd, 2005: *EcoTender: Auction for multiple environmental outcomes*. Department of Primary Industries, Melbourne, Australia, 151 pp.

Ejrnæs R., A.H. Petersen, J. Bladt, H.H. Bruun, J.E. Moeslund, P. Wiberg-Larsen and C. Rahbek, 2014: *Biodiversitetskort for Danmark* [Biodiversity map of Denmark]. Videnskabelig rapport fra DCE – Nationalt Center for Miljø og Energi nr. 112, Aarhus Universitet.

Falconer, K. and M. Whitby, 2000: Untangling red tape: scheme administration and the invisible costs of european agri-environmental policy. *European Environment*, 10: 193-203.

Ferraro, P.J., 2008: Asymmetric information and contract design for payments for environmental services. *Ecological Economics*, 65: 810-821.

Hougaard, J.L., K. Nielsen and A. Papakonstantinou, 2016: A Sealed-Bid Two-Attribute Yardstick Auction Without Prior Scoring. *Group Decision and Negotiation*, 25: 827-843.

Iftekhar, M.S. and J.G. Tisdell, 2014: Wildlife corridor market design: An experimental analysis of the impact of project selection criteria and bidding flexibility. *Ecological Economics*, 104: 50-60.

Jacobsen, B.H., 2004: *Økonomisk slutevaluering af vandmiljøplan II*. [Final economic evaluation of Water Environment Plan II], Fødevareøkonomisk Institut, Rapport 169, 116 pp. København.

Jacobsen, J.B., S.E. Vedel and B.J. Thorsen, 2013: Assessing costs of multifunctional NATURA2000 management restrictions in continuous cover beech forest management. *Forestry*, 86: 575-582.

Jindal, R., J.M. Kerr, P.J. Ferraro and B.M. Swallow, 2013: Social dimensions of procurement auctions for environmental service contracts: evaluating tradeoffs between cost-effectiveness and participation by the poor in rural Tanzania. *Land Use Policy*, 31: 71-80.

Juutinen, A. and M. Ollikainen, 2010: Conservation contracts for forest biodiversity: Theory and experience from Finland. *Forest Science*, 56: 201-211.

Juutinen, A., E. Mäntymaa and M. Ollikainen, 2013: Landowners' conservation motives and the size of information rents in environmental bidding systems. *Journal of Forest Economics*, 19: 128-148.

Kits G.J., W.L. Adamowicz and P.C. Boxall, 2014: Do conservation auctions crowd out voluntary environmentally friendly activities? *Ecological Economics*, 105: 118-123.

Knowler, D. and B. Bradshaw, 2007: Farmers' adoption of conservation agriculture: a review and synthesis of recent research. *Food Policy*, 32: 25-48.

Kwasnica, A.M. and K. Sherstyuk, 2013: Multiunit Auctions. *Journal of Economics Surveys*, 27: 461-490.

Larsen F.W., A.H. Petersen, N. Strange, M.P. Lund and C. Rahbek, 2008: A quantitative analysis of biodiversity and the recreational value of potential national parks in Denmark. *Environmental Management*, 41: 685-695.

Larsen F.W., J. Bladt and C. Rahbek, 2009: Indicator taxa revisited: Useful for conservation planning? *Diversity and Distributions*, 15: 70-79.

Larsen F.W., J. Bladt, A. Balmford and C. Rahbek, 2012: Birds as biodiversity surrogates: Will supplementing birds with other taxa improve effectiveness? *Journal of Applied Ecology*, 49: 349-356.

Latacz-Lohman, U. and C. van der Haamsvoort, 1997: Auctioning conservation contracts: a theoretical analysis and an application. *American Journal of Agricultural Economics*, 79: 407-418.

Latacz-Lohman, U. and C. van der Haamsvoort, 1998: Auctions as a Means for Creating a Market for Public Goods from Agriculture. *Journal of Agricultural Economics*, 49: 334-345.

Latacz-Lohman, U. and S. Schilizzi, 2005: *Auctions for Conservation Contracts: A Review of the Theoretical and Empirical Literature*. Report to the Scottish Executive Environment and Rural Affairs Department, 101 pp.

Lund M.P. and C. Rahbek, 2002: Cross-taxon congruence in complementarity and conservation of temperate biodiversity. *Animal Conservation*, 5: 163-171.

Mettepenningen, E., A. Verspecht and G. Van Huylenbroeck, 2009: Measuring private transaction costs of European agri-environmental schemes. *Journal of Environmental Planning and Management*, 52: 649-667.

Miljø- og Fødevareministeriet, 2016: *Aftale om Naturpakke*. http://mfvm.dk/fileadmin/user_upload/Natturpakke-2016.pdf

Miljø- og Fødevareministeriet, 2017: *Bekendtgørelse om tilskud til privat urørt skov*. https://www.retsinformation.dk/pdfPrint.aspx?id=190125

Morris, J., J. Mills and J.M. Crawford, 2000: Promoting farmer uptake of agri-environmental schemes: the Countryside Stewardship Arable Options Scheme. *Land Use Policy*, 17: 241-254.

Narloch, U., A. Drucker and U. Pascual, 2017: What role for cooperation in conservation tenders? Paying farmer groups in the High Andes. *Land Use Policy*, 63: 659-671.

Nielsen, A.S.E., N. Strange, H.H. Bruun and J.B. Jacobsen, 2017a: Effects of preference heterogeneity among landowners on spatial conservation prioritization. *Conservation Biology*, 31: 675-685.

Nielsen, K., J.L. Hougaard and A. Papakonstantinou, 2017b: Yardstick Auction with Postponed Scoring. Work in progress. Department of Food and Resource Economics, University of Copenhagen.

O'Connor, P., 2015: Reversing the Auction: Conservation Auction Experiences in Australia. Presentation given at University of Alberta, October 27, 2015. http://www.albertalandinstitute.ca/news/post/reversing-the-auction#video

Pant, K.P., 2015: Uniform-Price Reverse Auction for Estimating the Costs of Reducing Open-Field Burning of Rice Residue in Nepal. *Environmental and Resource Economics*, 62: 567-581.

Parkhurst, G.M., J.F. Shogren, C. Bastian, P. Kivi, J. Donner and R.B.W. Smith, 2002: Agglomeration bonus: an incentive mechanism to reunite fragmented habitat for biodiversity conservation. *Ecological Economics*, 41: 305-328

Parks D.C. and J. Kalagnanam, 2005: Models for Iterative Multiattribute Procurement Auctions. *Management Science*, 51: 435-451.

Petersen A.H., N. Strange, S. Anthon, T.B. Bjørner and C. Rahbek, 2012: *Bevarelse af biodiversiteten i Danmark: En analyse af indsats og omkostninger*. Working paper 2:2012, The Economic Councils, Copenhagen.

Petersen, A.H., T.H. Lundhede, H.H. Bruun, J. Heilmann-Clausen, B.J. Thorsen, N. Strange and C. Rahbek, 2016: *Bevarelse af biodiversiteten i de danske skove: En analyse af den nødvendige indsats, og hvad den betyder for skovens andre samfundsgoder*. Center for Makroøkologi, Evolurion og Klima, Københavns Universitet.

Reeson, A.F., L.C. Rodriguez, S.M. Whitten, K. Williams, K. Nolles, J. Windle and J. Rolfe, 2011: Adapting auctions for the provision of ecosystem services at the landscape scale. *Ecological Economics*, 70: 1621-1627.

Rolfe, J., S. Whitten and J. Windle, 2017: The Australian experience in using tenders for conservation. *Land Use Policy*, 63: 611-620.

Rolfe, J., J. Windle and J. McCosker, 2009: Testing and implementing the use of multiple bidding rounds in conservation auctions: a case study application. *Canadian Journal of Agricultural Economics*, 57: 287-303.

Ruto, E. and G. Garrod, 2009: Investigating farmers' preferences for the design of agri-environment schemes: a choice experiment approach. *Journal of Environmental Planning and Management*, 52: 631-647.

Schilizzi, S. and U. Latacz-Lohmann, 2007: Assessing the Performance of Conservation Auctions: An Experimental Study. *Land Economics*, 83: 497-515.

Siebert, R., M. Toogood and A. Knierim, 2006: Factors affecting European farmers' participation in biodiversity policies. *Sociologia Ruralis*, 46: 318-340.

Stoneham G., V. Chaudhri, A. Ha and L. Strappazzon, 2003: Auctions for conservation contracts: an empirical examination of Victoria's BushTender trial. *The Australian Journal of Agricultural and Resource Economics*, 47: 477-500.

Strange N., C. Rahbek, J.K. Jepsen and M.P. Lund, 2006: Using farmland prices to evaluate cost-efficiency of national versus regional reserve selection in Denmark. *Biological Conservation*, 128: 455-466.

Thorsen, B.J., 1999: Afforestation as a real option: Some policy implications. *Forest Science*, 45: 171-178.

Vedel, S.E., J.B. Jacobsen and B.J. Thorsen, 2015a: Forest owners' willingness to accept contracts for ecosystem service provision is sensitive to additionality. *Ecological Economics*, 113: 15-24.

Vedel, S.E., J.B. Jacobsen and B.J. Thorsen, 2015b: Contracts for afforestation and the role of monitoring for landowners' willingness to accept. *Forest Policy and Economics*, 51: 29-37.

Vickrey, W., 1961: Counterspeculation, auctions, and competitive sealed tenders. *Journal of Finance*, 16: 8-37.

Vié, J.C., C. Hilton-Taylor and S. Stuart (eds.), 2009: *Wildlife in a changing world: an analysis of the 2008 IUCN Red List of Threatened Species*. The International Union for Conservation of Nature (IUCN).

Wätzold, F. and M. Drechsler, 2005: Spatially uniform versus spatially heterogeneous compensation payments for biodiversity-enhancing land-use measures. *Environmental and Resource Economics*, 31: 73-93.

Whitten, S.M, A. Reeson, J. Windle and J. Rolfe, 2013: Designing conservation tenders to support landholder participation: A framework and case study assessment. *Ecosystem Services*, 6: 82-92.

Wossink, G.A.A. and J.H. Van Wenum, 2003: Biodiversity conservation by farmers: analysis of actual and contingent participation. *European Review of Agricultural Economics*, 30: 461-485.