Does tendering conservation contracts with performance payments generate additional benefits?

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Abstract

Policy makers aiming to get private landholders to supply non-marketed environmental services may need to provide efficient economic incentives. Two ideas have been explored to achieve this: linking contract payments to environmental outcomes and submitting the contracts to competitive tender. This paper investigates whether there are any gains to be had by combining the potential benefits of both approaches. Landholders' risk aversion to only partially controlled outcomes may offset incentive effects if the fall in participation outweighs any increases in individual effort. Controlled lab experiments were designed on the basis of a theoretical model and were run in two countries, with varying rates of payments linked to environmental outcomes. Results suggest that it can be counter-productive in terms of expected environmental outcomes to combine tenders with incentive payments, especially when the target population is known to be risk-averse.

Keywords: Conservation tenders, auctions, incentive contracts, agricultural policy, environmental policy, market-based instruments, experimental economics

JEL: C92, D44, D82, D86, H57, Q24, Q28

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1. Introduction

1.1 Motivation

In the last three decades, governments around the globe have developed market-based policy instruments to procure environmental services from private landholders. Conservation contracting represents the most commonly used policy instrument in this respect. The increased importance of environmental contracting has, to date, not been reflected in innovative policy design. It remains the norm in most conservation programs to offer a uniform payment for compliance with a uniform set of management prescriptions. This approach has been criticized on two accounts: First, prescription or action-based payments fail to provide incentives for producers to seek out new methods of reducing costs, to introduce innovative approaches, or to take risks in seeking to provide environmental benefits [4]. In fact, action-based payments may tempt their recipients not to honor their contracts to the letter, giving rise to a moral hazard problem. Second, uniform payments may cause another incentive problem, that of adverse selection, by failing to cater for the heterogeneity of compliance costs and resource settings among landholders. Any uniform payment for voluntary participation will thus attract low-cost farmers who are over-rewarded whilst failing to attract higher-cost farmers who might deliver additional benefits.

This paper sets out to explore two proposals that have been made to that effect: linking contract payments to environmental outcomes (rather than management prescriptions) and putting the contracts up for tender (rather than paying landholders uniform prices). Whereas the two aspects have mostly been studied in isolation in the literature, the focus of the present paper is on exploring the combined effect of outcome-based payments and tendering on conservation behavior and the resultant performance of conservation contracting. In the interest of clarity, we will however explore the two aspects consecutively. We will first investigate the impact of linking payments to environmental outcomes in a non-tendered setting. Subsequently, we will study the additional impact on conservation behavior of putting such incentive contracts up for tender.

Theoretical predictions are far from clear. Outcome-based payments do harness the self-interest of their recipients to act in the interest of the conservation agency by optimizing their stewardship effort. At the same time, such payments create previously absent risks for landholders, some or many of which are beyond their control. It can happen that, due to factors such as disease, pest invasions, fire, drought, or natural fluctuations in wildlife populations, the environmental outcome is much diminished or even nil – in spite of the fact that costly on-ground actions have been carried out. This is likely to reduce participation in the scheme and thereby its environmental effectiveness. There is thus a tradeoff to be studied between an incentive effect on the one hand and a participation effect on the other. If the latter outweighs the former, linking payments to uncertain outcomes will be counterproductive.

The motivation for studying the impact of tendering lies with two key properties of auctions. First, properly designed, auctions create scarcity amongst landholders in that the number of contracts on offer is set to be (much) less than the potential demand for them. As a result, tendering creates competition among potential bidders, thereby reducing the incentive to overbid above real costs. Second, and as a consequence of the previous point, auction bids reveal information on bidders' costs, thereby mitigating information asymmetry and adverse selection. Putting incentive contracts up for tender thus has the potential to kill two birds with one stone: the moral hazard problem and the adverse selection problem. At the same time, this approach involves the danger of exposing landholders to excessive risks so that they refuse to participate in conservation schemes in the first place.

1.2 Previous work

This study builds on three strands of previous work: the problem of efficiently allocating conservation contracts; the theory of auctioning incentive contracts; and the design and implementation of conservation auctions. These represent a logical progression from how to get landholders to provide conservation services efficiently, to the idea of tendering incentive contracts and finally to investigating how far this idea can be made to work for conservation policy. The problem of optimally selecting conservation actions and sites includes investigations by Van Teefelen

and Moilanen [34] and by Costello and Polasky [3]. Casting the solution of this problem into an appropriate analytical economic framework includes work by Moxey et al. [26] and Davis et al. [5]. This framework highlighted the key issue, that of moral hazard in a principal-agent relationship [8,15]. Accordingly, the problem of how to design contracts in such a way as to address this problem was studied by authors like Moxey et al. [27], Ozanne and White [28] and Ferraro [7]; White[35] also analyzed the correlative issue of contract monitoring.

Getting the contracted parties to provide the necessary effort to deliver the contracted goods to quality specifications was a problem first clearly formulated by Green [13] in 1979. This problem was cast into the analytical framework of the principal-agent relationship by McAfee and McMillan [25], Laffont and Martimort [22] and Laffont and Tirole [19]. Leitzel and Tirole [21] applied this framework to the procurement setting. This idea had also been pursued by Laffont and Tirole [18] by combining and integrating the linking of contractual payments to outcomes and the auctioning of the contracts in a competitive setting; Branco [1] generalized some of the results obtained by Laffont and Tirole in 1987. The static setting was also expanded to the dynamic setting by Laffont and Tirole (1988), with a follow-up by Sun Ching-jen [33] in 2007. This work provided the theoretical bedrock on which applications to environmental policy could be formulated.

The key problem in the present study was how to optimally select contracts for conservation works that are to be carried out by landholders [16]. Latacz-Lohmann and Schilizzi [24] review the literature on how ideas from auction design and implementation have been applied to conservation contracting, and Latacz-Lohmann and Van der Hamsvoort [23] propose a specific model for doing so when budgets are constrained (which is normally the case). A number of policy implementations were reviewed, mainly in the USA and Australia [29,31]. Evaluation of this experience by Grafton [12], Gole et al. [10] and Connor et al. [2] highlighted the problematic nature of paying landholders uniquely on actions or inputs, e.g. fencing, weeding or planting trees, without specific reference to the actual environmental outcomes, such as streamwater quality, a measure of biodiversity or the rate of soil erosion. At this juncture, the idea of tendering contracts to landholders and that of linking contract payments to environmental outcomes were brought together, linking the two previous strands of

literature. This integration has now begun to be investigated both theoretically [11] and practically, with The Australian Auction for Landscape Recovery Under Uncertainty (ALRUU) leading the way [36], and some explorations also carried out in Europe, e.g. in Germany [14,17] and Sweden [37]. This latter work, as well as that by Goldman et al.[9], has also highlighted the importance of landholder cooperation in achieving the contracted environmental outcome: the effects of individual landholder actions extend beyond the boundaries of their private properties, especially when mobile species are involved, and synergistic ecological effects are often involved.

1.3 Objectives and organization of the paper

The present paper aims to further current knowledge in the field of conservation contracting by clarifying key aspects of tendering contracts with payments linked to uncertain outcomes. In order to examine the effect of the two opposing forces, the incentive effect and the participation effect, we shall study several points on the continuum between no payments linked to uncertain outcomes and the totality of payments thus linked.

The second section studies the basic implications of tendering incentive contracts using theoretical analysis based on contract and auction theory, and makes a number of predictions regarding the results to be expected from tendering contracts with payments linked to uncertain outcomes. Because of the complexity of the interactions involved, we need to gain some confidence in the theoretical predictions theory. We therefore set up in section 3 an economic experiment meant to test the predictions of our theoretical model. Section 4 presents the results from the experiments which were carried out in two countries. In order to disentangle the effects of the two policy variables – the contracting on uncertain outcomes and the tendering of such contracts – we first examine contracts that are not tendered, then compare the results under tender. In this way we are able to address the combined effect of tendering outcome-based contracts. A final section concludes.

2. Theoretical propositions

In this section, we develop a decision-making framework to study the tradeoff between the incentive effect and the participation effect. In the following exposition, we assume that a landholder aims at maximizing expected utility E[U] by choosing effort level x.

(1) $$\max_{x} E\left[U\left(\tilde{\boldsymbol{\pi}}\right)\right]$$

with $\tilde{\boldsymbol{\pi}}$ representing uncertain profit. If the landholder chooses to opt out or does not win a contract, profit is assumed to be zero.

2.1 Non-tendered setting

In the non-tendered setting, the landholder faces two distinct profit outcomes depending on whether or not he/she achieves the environmental outcome threshold $\bar{y}$:

(2) $$\begin{aligned} \pi_p &= p_f + p_p - C(x) \quad \text{if} \quad y \geq \bar{y} \quad \text{else} \\ \pi_0 &= p_f - C(x) \end{aligned}$$

y is the actual environmental outcome; C(x) is the cost of effort x which is monotonously increasing; p_f is the fixed payment; p_p is the performance payment which is tied to the achievement of the environmental outcome threshold $\bar{y}$. Environmental outcome is monotonously increasing in effort and also depends on factors beyond the control of the landholder. The two possible profit outcomes in (2) form the distribution of profits $\tilde{\boldsymbol{\pi}}$ for a contract. Expected utility is the utility from both outcome states weighted by the respective probabilities.

(3) $$E\left[U\left(\tilde{\boldsymbol{\pi}}\right)\right] = g(x)U\left(p_f + p_p - C(x)\right) + \left(1 - g(x)\right)U\left(p_f - C(x)\right)$$

with g(x) representing the probability of achieving $\bar{y}$ which is monotonously increasing and concave in x. An agent will be willing to sign a contract if individual rationality constraint (4) holds:

(4) $$E\left[U\left(\tilde{\boldsymbol{\pi}}\right)\right] = g(x)U\left(\pi_p\right) + \left(1-g\left(x\right)\right)U\left(\pi_0\right) > E\left[U\left(0\right)\right] = U\left(0\right) \qquad \text{for some x.}$$

Else he/she will reject the contract.

The first-order conditions (foc) for optimal effort are found by taking the derivative of (3) with respect to x

(5)

$$\frac{\partial E\left[U\left(\tilde{\boldsymbol{\pi}}\right)\right]}{\partial x} = \frac{\partial g(x)}{\partial x}U\left(\pi_p\right) - g(x)U'\left(\pi_p\right)\frac{\partial C(x)}{\partial x} - \frac{\partial g(x)}{\partial x}U\left(\pi_0\right) - \left(1-g\left(x\right)\right)U'\left(\pi_0\right)\frac{\partial C(x)}{\partial x}$$

and setting it equal to zero. Rearranging terms yields

(6) $$\frac{\partial g(x)}{\partial x}\left(U\left(\pi_p\right) - U\left(\pi_0\right)\right) = g(x)U'\left(\pi_p\right)\frac{\partial C(x)}{\partial x} + \left(1-g\left(x\right)\right)U'\left(\pi_0\right)\frac{\partial C(x)}{\partial x}$$

According to (6), effort is optimal at the level where the marginal change in expected utility due to a higher probability for the higher profit must equal the marginal loss of utility due to higher cost of effort. The second-order condition (to ensure a maximum) is shown in Appendix 1 (A1). In our experiments we lowered the fixed payment and raised the performance payment by the same amount. From Appendix 1 (A3) we can conclude that optimal effort rises as this substitution continues. We thus obtain

Proposition 1 (incentive effect): Given a constant total payment, individual effort increases with the proportion linked to environmental outcome.

The condition relating to the decision to participate or not is intuitive: increasing the proportion of outcome-based payment will cause some risk-averse agents to opt out if and only if

negative profits from a contract are possible. If only positive profits are possible the profit distribution of participation is first-degree stochastically dominant over that of non-participation and agents will choose to participate irrespective of their risk attitudes. If $p_f < C(x)$, non-achievement of $\bar{y}$ can result in a net loss. This loss increases with the share of payment linked to outcome. We thus obtain

Proposition 2 (participation effect): If agents are risk-averse and scheme participation can result in a net loss, an increase in the share of outcome-based payments leads to declining participation rates.

A less obvious effect of risk aversion is that it can also affect optimal effort levels. To examine this effect, we rewrite (5) by replacing $U(\pi_p) - U(\pi_0) \approx U'(\pi_0)(\pi_p - \pi_0) = U'(\pi_0)\, p_p$. Setting $\pi_p - \pi_0 = p_p$ follows directly from (2). Likewise, we set $U'(\pi_0) - U'(\pi_p) \approx U''(\pi_0)\, p_p$. This substitution yields:

(7)

$$\frac{\partial E\left[U(\tilde{\boldsymbol{\pi}})\right]}{\partial x} \approx \frac{\partial g(x)}{\partial x} U'(\pi_0)\, p_p - g(x) \frac{\partial C(x)}{\partial x} U''(\pi_0)\, p_p - U'(\pi_0) \frac{\partial C(x)}{\partial x}$$

The foc can now be rearranged for the coefficient of constant absolute risk aversion r:

(8) $$r = -\frac{U''(\pi_0)}{U'(\pi_0)} \approx -\frac{\frac{\partial g(x)}{\partial x} p_p - \frac{\partial C(x)}{\partial x}}{g(x) \frac{\partial C(x)}{\partial x} p_p} = \frac{\frac{\partial C(x)}{\partial x} - \frac{\partial g(x)}{\partial x} p_p}{g(x) \frac{\partial C(x)}{\partial x} p_p} = \frac{1}{g(x) p_p} - \frac{\frac{\partial g(x)}{\partial x}}{g(x) \frac{\partial C(x)}{\partial x}}$$

For a given degree of risk aversion, an agent chooses optimal effort such that the right-hand side of (8) equals r. To find out whether optimal effort is higher or lower for more risk-averse agents, we take the derivative of (8) with respect to x (see the Appendix 1(A2) for a full exposition):

(9)

$$\frac{\partial r}{\partial x} \approx \frac{\partial g(x)}{\partial x}\left(\frac{\partial C(x)}{\partial x}\left(p_p \frac{\partial g(x)}{\partial x} - p_p \frac{\partial^2 g(x)}{\partial x^2} g(x)\left(\frac{\partial g(x)}{\partial x} \right)^{-1} - \frac{\partial C(x)}{\partial x} \right) + p_p g(x) \frac{\partial^2 C(x)}{\partial x^2} \right)$$

The sign of (9) is ambiguous, implying that higher degrees of absolute risk aversion can result in either higher or lower levels of effort being chosen in the optimum. We have calibrated our experiments such that the sign of (9) is strictly positive. From this we postulate that the following proposition holds for our experimental results:

Proposition 3: Higher degrees of absolute risk aversion correspond to higher levels of individual effort being chosen.

2.2 Tendered setting

In our model and experimental setup, agents in the tendered setting compete for contracts through effort. The conservation agency selects winning bids by the level of effort offered. This is in contrast to ordinary procurement auctions where bidders compete through financial bids for contracts with predetermined tasks. To explore the impact of bidding competition on participation and optimal effort, we embed the above contract model into a procurement auction framework. The landholder's utility function in the tendered setting then becomes

(10) $$E\left[U\left(\tilde{\tilde{\boldsymbol{\pi}}}\right)\right] = h(x)E\left[U\left(\tilde{\boldsymbol{\pi}}\right)\right] + \left(1 - h(x)\right)U(0)$$

(11) $$E\left[U\left(\tilde{\tilde{\boldsymbol{\pi}}}\right)\right] = h(x)g(x)U\left(\pi_p\right) + h(x)\left(1-g\left(x\right)\right)U\left(\pi_0\right) + \left(1-h(x)\right)U\left(0\right).$$

with h(x) being the subjective probability of winning a contract which is strictly increasing in x.

Neglecting transactions costs of bid preparation and submission, the necessary condition for offering a bid is identical to individual rationality constraint (4) in the non-tendered setting (see Appendix 1 (A4) for a formal proof). We thus obtain

Proposition 4: Participation rates in the non-tendered setting equal bidding rates in the tendered setting.

To derive the first-order condition (foc) for optimal effort in the tendered setting, we take the derivative of (11) with respect to x and rearrange terms[1]:

(12) $$\frac{\partial E\left[U\left(\tilde{\tilde{\boldsymbol{\pi}}}\right)\right]}{\partial x} = h\left(x\right)\frac{\partial E\left[U\left(\tilde{\boldsymbol{\pi}}\right)\right]}{\partial x} + \frac{\partial h(x)}{\partial x}\left(g(x)U\left(\pi_p\right) + \left(1-g(x)\right)U\left(\pi_0\right) - U\left(0\right)\right)$$

The first summand on the right-hand side is the foc for optimal effort in the non-tendered setting weighted by the probability of winning a contract. The second summand in (12) is the individual rationality constraint weighted by the marginal change in the probability of winning a contract. To study the impact of tendering on optimal effort, we check whether (12) equals zero when evaluated at the optimal effort level in the non-tendered setting. In that case, the first summand must be zero for the foc under non-tendering to hold. The second summand, representing the individual rationality constraint, must be strictly positive. Otherwise an agent would not participate. As a consequence, the sign of (12) must be strictly positive under tender. From this we can formulate

[1] There might be one or two maxima in (10). This issue is elaborated in Appendix 1 (A5).

Proposition 5: As long as individual rationality constraint (4) holds, individual effort is higher when contracts are allocated by tender.

Indeed, tendering adds a second layer of uncertainty, that of not being selected, over and above the risk of not achieving the BV threshold. A higher level of effort thus reduces the risk of not being selected as well as that of not achieving the threshold.

The effect of risk aversion on optimal effort cannot, however, be predicted under tender. In analogy to the non-tendered scenario, the foc for optimal effort (12) can be solved for r to yield:

$$\textbf{(13)} \qquad r = -\frac{U''(\pi_0)}{U'(\pi_0)} = -\frac{h(x)\frac{\partial g(x)}{\partial x}p_p + \frac{\partial h(x)}{\partial x}\left(p_f + g(x)p_p - C(x)\right) - \frac{\partial C(x)}{\partial x}}{g(x)\frac{\partial C(x)}{\partial x}p_p}$$

Whether the right-hand side increases or decreases with the level of effort depends on h(x), the probability of winning a contract. Since agents will have different perceptions of h(x), we cannot determine whether it will increase or decrease.

3. Experimental design

The experiments did not aim to study the effort response to performance payments *per se*, but rather whether any efficiency gains, both in terms of effort provision and in terms of expected environmental outcome, could be obtained by the combination of performance payments and tendering. To disentangle these two effects, it was necessary to compare the tendered and non-tendered contracts.

The non-tendered scenario was implemented through a contract experiment which systematically varied the proportion of payment linked to environmental outcomes from zero per cent

through 50 and 67 to 100 per cent of the total payment. The core idea is to examine how the substitution of a sure fixed payment with an uncertain performance payment, while holding total payment constant, affects the supply of individual effort (as per Proposition 1) and participation (Proposition 2) and whether the supply of effort is affected by risk attitudes (Proposition 3). The combined effect of individual effort and participation rate yields total effort which determines expected environmental benefits generated by the scheme.

The tendered scenario was implemented through a procurement auction experiment which asked experimental subjects to bid for a limited number of contracts with performance payments. As spelled out above, bidding occurred through effort: the more effort somebody offered, the higher the probability of winning a contract. The purpose of the auction experiment was to study whether competition creates an additional incentive for effort (Proposition 4) or participation (Proposition 5) and whether risk attitudes play a role in these relationships (Proposition 6). Unlike in the non-tendered scenario, total effort obtained, and thus expected environmental benefits generated, not only depends on the participation rate but also on the selection rate, as decided by the tendering authority. Table 1 provides an overview of the experimental setup.

[Table 1 about here]

TABLE 1

EXPERIMENTAL RESEARCH PLAN

SESSIONS	Effort (0 to 10)	Fixed payment	Performance payment
Non-tendered contracts			
1) NT 0% (calculated)	✓; min 3	300	0
2) NT 50%	✓; min 3	150	150
3) NT 67%	✓; min 3	100	200
4) NT 100%	✓	0	300
Tendered contracts			
5) T 0% [(2)]	✓; min 3	300	0
6) T 50%	✓; min 3	150	150
7) T 67%	✓; min 3	100	200
8) T 100%	✓	0	300

Legend: ✓ = bidder's decision (There was no minimum effort when no fixed payment was offered.)

NT = Non-tendered scenario; T = tendered scenario

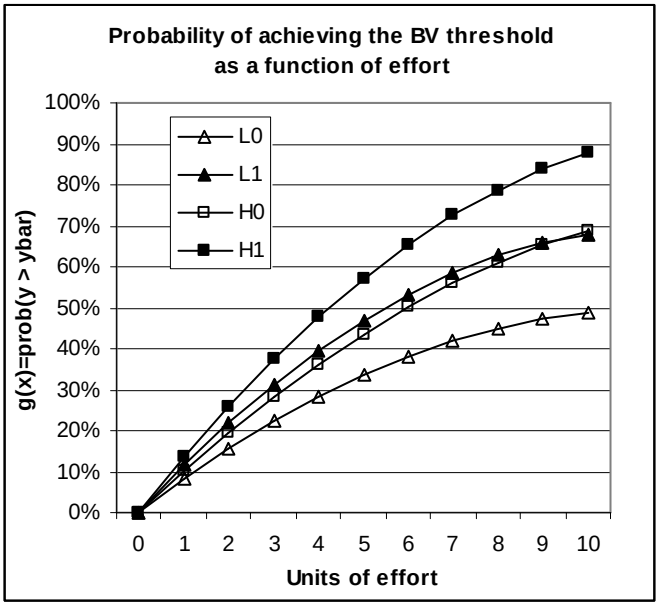
Payment amounts in ECUs (experimental currency units)

The conservation contracts referred to biodiversity enhancement in farmed landscapes. Experimental subjects were given information about the environmental goals of the conservation scheme and the conservation activities (actions) that they could carry out to that effect. These activities translated directly into 'effort', which could vary between 0 and a maximum of 10 units. Whenever a non-zero fixed payment was offered, a minimum level of effort was also required as per Table 1. Effort was costly, with a linear cost function of 10 ECUs (Experimental Currency Units) per unit. An 'environmental production function' defined the probability of achieving a 'biodiversity

[2] The computation of this scenario was actually based on another series of similar experiments, where bidders competed through payment (price) bids with predetermined fixed effort, instead of through supply of effort with given payments. The 0%PP results were used and recalibrated using effort-to-payment ratios.

value' threshold (BV) as a monotonously increasing function of effort. This probability had two possible values for any given level of effort: a higher and a lower value, representing, respectively, a favorable and an unfavorable series of uncontrollable environmental events (disease, drought, fire, etc.), thereby defining a state-contingent production function. Each of these two states of nature was equiprobable. In addition, participants were divided into two groups equal in numbers: half had a higher environmental productivity, and half had a lower productivity. For the same level of effort, a more productive participant had a higher average probability, across the two states of nature, of achieving the environmental (BV) threshold than a less productive participant. This distinction was included to investigate the capacity of the tender to mitigate the adverse selection problem present with non-tendered contracts[3]. The combined effect of two environmental states and two participant types yields the four environmental productivity curves depicted in Figure 1.

[Figure 1 about here]



Legend: y bar represents $\overline{y}$

L0, L1 = Low productivity type: unfavorable and favorable states of nature

H0, H1 = High productivity type: unfavorable and favorable states of nature

[3] This aspect is not reported in this paper.

FIGURE 1

ENVIRONMENTAL STATE-CONTINGENT PRODUCTION FUNCTIONS FOR TWO STATES AND TWO PRODUCER TYPES

These quadratic production functions were calibrated using the values shown in Table 2.

[Table 2 about here]

TABLE 2

PRODUCTION FUNCTION COEFFICIENTS

Common equation $g(x\|\theta) = ax - bx^2$	Favorable envir. $\theta = 0$	Unfavorable envir. $\theta = 1$
For low productivity type	$a = 0.085$ $b = 0.0036$	$a = 0.120$ $b = 0.0052$
For high productivity type	$a = 0.105$ $b = 0.0036$	$a = 0.140$ $b = 0.0052$

$g(x|\theta)$ = probability of achieving the biodiversity threshold conditional on the state of nature

x = participant's level of effort provided

a and *b* = production function coefficients

Participants in the experiment were given a table showing the probabilities of achieving the BV threshold as a function of effort for each of the two states of nature. They were also told what productivity type they were (low or high) and were reminded that effort was costly. They were informed that the total payment consisted of a fixed and a performance payment and that the latter would only be paid if the BV threshold was achieved. They were also informed of the procedure for assessing the biodiversity outcome at the end of the contract period. This was done by two random draws at the end of each experimental session: one which determined the state of nature (favorable or unfavorable), and one that determined whether the threshold had been achieved or not. The resolution of the state of nature was done by tossing a coin (the two states being equiprobable). The odds for the

second draw were determined by the units of effort a participant had offered, depending on his or her productivity type and given the state of nature. This determined for each participant whether they had achieved the BV threshold or not. The information provided was sufficient to enable participants to balance the cost of effort and its benefit in terms of achieving the uncertain outcome. If they did not find the contract attractive enough they had the opportunity to reject it by ticking an opt-out box.

In the auction experiment, the tender mechanism was of the target-constrained rather than of the budget-constrained type (see [30] for an analysis of their comparative advantages). Bidders were informed that only two-thirds of them would be selected starting with the highest effort supply. Ties were selected randomly.

So as not to distract from the main focus of the experiments, participation costs were equal for all, and consisted of a fixed transaction cost of 50 ECUs and a variable cost of 10 ECUs per unit effort. In order to make the individual rationality constraint (4) binding, experiments were calibrated so as to allow the possibility of net losses from participation. At the end of the experiment, participants' net gains were converted to local currency in proportion to net gains in ECU terms. To avoid net losses in real money, participants were endowed with an amount of initial wealth equal to the maximum possible net loss. Initial wealth endowments were added to net gains at the end of the experiment.

Since the results were likely to be affected by risk attitudes, we submitted all participants with a simple lottery, which asked them to consider a lottery ticket that had a 50% chance of earning them $1000. They were then asked the maximum amount they were willing to pay to purchase one. A number below the expected gain of $500 was a measure of risk aversion, while a number above $500 was a measure of risk taking. As the results below suggest, the data, however crude, proved sufficient to shed some light on the role of risk attitudes. This was all done prior to, and independently of, the core part of the experiment, albeit in the same session and with the same participants.

The experiments were carried out in two different countries, in X, at the University of XXX, and in Y, at the University of YYY, to control for robustness of the results.[4] The X experiment was carried out with postgraduate students in agricultural economics. Participants in the Y experiment were both undergraduate and postgraduate students. The number of participants in each session varied somewhat but averaged 20. The environmental context for the experiment was chosen in a way that reflected the participants' experience with the issue: enhancement of skylark populations in X and conservation of remnant vegetation on private land in Y. An overview of the experimental parameters and their values is given in Box 1.

BOX 1

EXPERIMENTAL PARAMETERS

- Two locations (X and Y): to control for robustness of results
- Number of groups (2 x 2) and group size (≈ 20)
- Participant types (low and high productivity, in equal proportions)
- States of nature, uncertain (0 and 1: unfavorable & favorable ex-post coin toss)
- Risk spread between the two states of nature: probability of achieving the BV threshold, g(x), held constant in this study for given productivity type
- Incentive contracts: 50%, 67% and 100% PP (The 0% case was computed)
- Freedom not to participate (opt-out)
- Tender type: target-constrained (as opposed to budget-constrained)
- Type of bid: through supply of effort; effort could be chosen on a scale from 0 to 10 units
- Selection ratio (under tender): 2/3 of bidders in each session by effort level; no selection in the non-tendered case
- Decision variables: participation; individual effort offered
- Policy parameters: fixed payment; performance payment

[4] XXX and YYY are used in lieu of actual institution and location names to preserve anonymity in the reviewing process: they will be replaced by the original names in the final version of this paper.

- Participation costs: equal for all = fixed transaction cost + cost per unit effort
- Initial wealth: 0; 50; 100 ECUs: to avoid net real final losses
- Information given after each round: none (one-off bid, no learning)

PP = Performance Payment, linked to achievement of outcome: it constitutes the incentive payment

BV = Biodiversity Value threshold, which defines the achievement target

4. Experimental results

4.1 Organization of results

Examining the impact of performance payments on participant effort carries its own value in terms of research results; however, the main focus of this study was to assess the value of tendering the contracts and therefore also how to disentangle the two aspects when combined. In the non-tendered treatment, we focus on the effects of increasing the proportion of performance payments relative to fixed (input) payments, while in the tendered treatment, we focus on how tendering the contracts modifies the non-tendered results. Accordingly, we present the non-tendered treatment (henceforth NT) results separately from the tendered treatment (henceforth T) results.

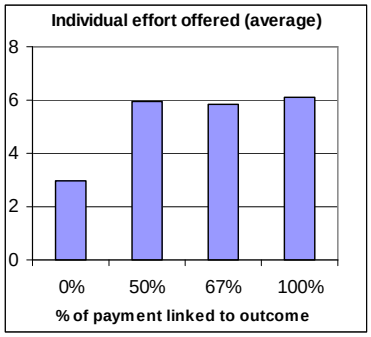
The following sections present first the NT treatment followed by the T treatment. The results reported here focus primarily on across-group averages; group-specific results are reported if any were observed. Except where indicated, all results were tested for statistical significance at the 5% confidence interval.

4.2 Non-tendered treatment (NT)*: impact of increasing performance payments*

4.2.1 Supply of individual effort

The prediction from Proposition 1 in section 2 is that the supply of individual effort should increase with the proportion of the total payment, kept constant, that is linked to the environmental

outcome (henceforth %PP). In the %PP scenario, a minimum level of effort of 3 units was required. Although this specific value is arbitrary, the important point to keep in mind is that, left to themselves, participants would have chosen the smallest level of effort possible, either 0 or 1, depending on their perceptions of what was acceptable. As Figure 2 shows, our experimental results do not completely bear out Proposition 1. At 50%PP, individual effort is indeed much higher than the strict minimum (be it 0, 1 or 3), but it then remains constant as %PP is raised further – an observation consistent across the four experimental groups. Do risk attitudes help explain this result?



[Figure 2 about here]

FIGURE 2

INDIVIDUAL EFFORT OFFERED AS A FUNCTION OF THE SHARE OF PAYMENT LINKED TO OUTCOME (STATISTICS GIVEN IN APPENDIX 2)

4.2.2 Effect of risk attitudes on supply of effort

Proposition 3 in section 2 predicts that, all other things held equal, a higher degree of risk aversion should increase optimal effort. Our experimental results vary somewhat from this prediction, as Table 3 shows. Read vertically (to keep the treatment parameter constant), risk attitudes appear to have no effect on the supply of individual effort, except at the highest %PP rate. At 100%PP, risk-averse individuals do supply a level of effort that is about 23% higher than non risk averse individuals. To understand this discrepancy, we need to know what happens to the participation rate, given that the effort shown in Figure 2 and Table 3 only relate to those who did not choose to opt out.

[Table 3 about here]:

TABLE 3: Risk attitudes and individual effort provision, read vertically

(all four groups, N = 77)

	NT	**50%PP**	**67%PP**	**100%PP**
RA	5.9	5.9	**7.2**
RN	5.7	5.6	5.8
RP	6.1	5.8	5.9

Legend: RA = risk averse; RN = risk neutral; RP = risk prone

4.2.3 Participation rate

The theoretical prediction from Proposition 2 was that as %PP increases, participation should fall, due to the increasing likelihood of net losses if effort is invested but the environmental threshold is not achieved. This is borne out by our results, on average and consistently across all four experimental groups (Figure 3). In our experiments participation started dropping at around 67% PP, but only became substantial at 100% PP, where the participation rate fell to 60%. The exact numbers for opt-out rates depend of course on the specific values for probabilities, effort productivity, costs and payments as per Figure 1 and Table 2. However, a clear pattern emerges: up to a certain point, increasing %PP has no impact on participation, but past that point, increasing %PP reduces participation: an increasing proportion of individuals end up deciding that the risk of a net loss is not worth the minimal effort required for receiving the fixed payment; they decide to 'opt out' and not sign a contract. This simply reflects the fall in expected net profits from participation as riskiness increases and the fact that individuals respond to the individual rationality constraint of equation (4).

[Figure 3 about here]

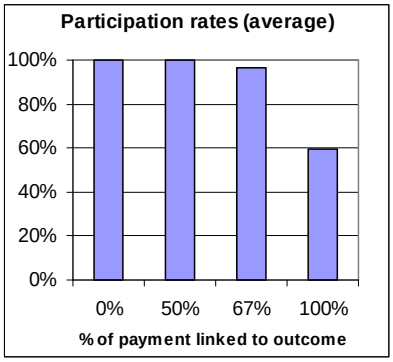


FIGURE 3

PARTICIPATION RATES AS A FUNCTION OF THE SHARE OF PAYMENT LINKED TO OUTCOME

Does participation explain the difference in individual effort shown in Figure 2, in particular between 100%PP and the lower %PP scenarios? More precisely, does the composition and risk profile of those who 'stay in' change as the number of drop-outs increases in the 100%PP scenario? Table 4 provides perhaps part of the answer, in that we do observe across all four experimental groups such a change. As one would expect, at high levels of risk (100%PP), the number of risk-averse individuals drops while the number of risk-prone individuals increases (this holding under both non-tendered and tendered scenarios); but the magnitude of the changes remain rather small.

TABLE 4: Average risk profiles in the 100%PP scenario relative to the whole population

	ALL	**100%PP**	**100%PP**
	(Certainty Equiv.)	**NT**	**T**
RA	**63**	**–9%**	**–5%**
RN	**100**		
RP	**144**	**+2%**	**+10%**

Legend: RA = risk averse; RN = risk neutral; RP = risk prone

[Table 4 about here]

4.2.4 Effect of risk attitudes on participation rate

From Propositions 2 and 3 taken together, one would expect that higher risk aversion should reduce participation. However, as Table 5 indicates, this is not quite as straightforward as theoretical analysis might suggest. Risk-averse participants opt out only at the highest %PP rate, while non risk-averse participants exhibit the same pattern. The effect is of second-order only: risk-averse participants only drop out more than non risk-averse ones do, and only marginally more so than risk-neutral ones. .

[Table 5 about here]

TABLE 5: Risk attitudes and participation rates (all four groups, N = 77)

NT	**50%PP**	**67%PP**	**100%PP**
RA	100%	100%	**57%**
RN	100%	95%	**62%**
RP	100%	100%	**87%**

Legend: RA = risk averse; RN = risk neutral; RP = risk prone

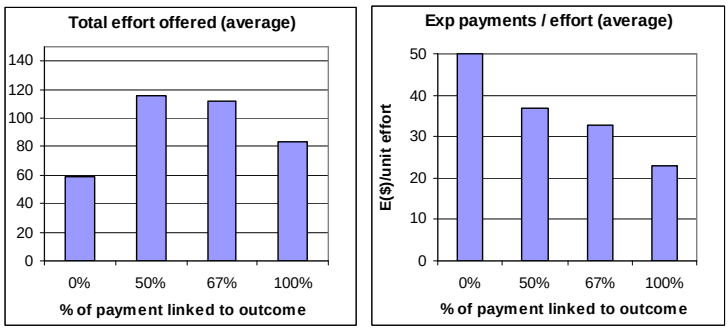
These results help us explain the discrepancy between theoretical prediction and observed results regarding the role of risk aversion on the supply of individual effort. Recall that the numbers in Table 3 exclude those who decided to opt out, which mainly concerns the 100%PP case. In Table 5, to the extent that risk aversion reduces participation rates, it counter-acts the increase in the supply of individual effort. The interpretation must therefore be as follows: higher risk aversion ends up reducing participation, but, for those who do decide to participate, it extracts a higher effort level. From the risk-averse individual's point of view, the decision seems to be: either opt out or, if not, put in a high level of effort to reduce the risk of not achieving the BV threshold.

This allows us to refine the theoretical prediction: for high %PP rates, higher risk aversion should end up reducing average individual supply of effort in that the drop in participation ends up outweighing the increase in individual effort. This comes out clearly in our results: in the 100%PP case, participation drops with rising risk aversion from 87% to 57%, or by −30% (Table 5), whereas effort increases from 5.8 or 5.9 to 7.2, or by +22%, +23% (Table 3). In relative terms, the drop in participation is thus greater than the rise in individual effort, but not substantially so, and only for the highest %PP rate.

4.2.5 Scheme performance implications: environmental outcomes and cost-effectiveness

Total effort and expected outcome. Total effort results from the combination of individual effort and participation. Since increases in %PP were shown to initially increase effort but reduce participation, it is not surprising that total effort exhibits an inverse U curve, as per Figure 4a. There thus exists an optimum level of %PP. In our experiments, it ranged between 50%PP and 67%PP. Since expected outcome is a monotonously increasing function of total effort, as per Figure 1, this result also extends to the expected level of environmental outcome.

[Figures 4a and 4b about here]



FIGURES 4a and 4b

TOTAL EFFORT (4a) AND BUDGETARY COST-EFFECTIVENESS (4b) AS A FUNCTION OF THE SHARE OF PAYMENT LINKED TO OUTCOME
(AVERAGES ACROSS ALL FOUR GROUPS)

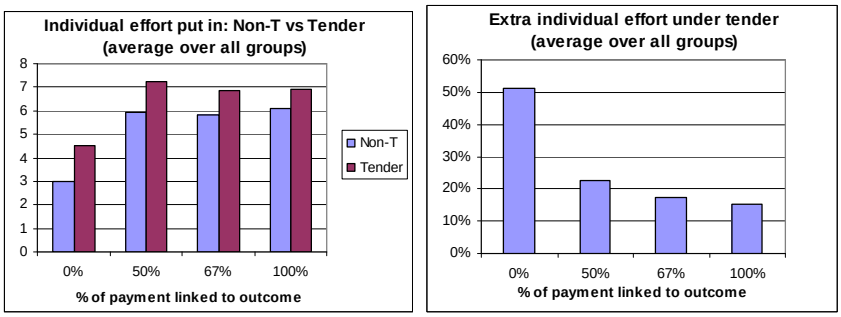
Cost-effectiveness. Defining cost-effectiveness by the payment outlay per unit of total effort or, equivalently, per unit of expected outcome, the story changes: in this case, the higher the %PP, the lower the payout per unit of environmental outcome obtained, and so the higher the cost-effectiveness, as shown in Figure 4b. From a policy perspective, when deciding what %PP rate is best, one must make trade-offs between the two objectives of outcome level and cost-effectiveness.

4.3 Tendered treatment (T)*: impact of tendering the contracts*

4.3.1 Supply of individual effort under tender.

Proposition 5 in section 2 predicted that tendering should increase the supply of individual effort of those who have decided to put in a bid. This extra individual effort obtained by tendering is visible over the whole range of performance payments, from 0%PP to 100%PP (Figure 5a). However, as Figure 5b shows, a second-order effect also emerged from our experiments: consistently across all four groups, the rate at which tendering extracts additional effort falls as %PP rises. For non-incentive 0%PP contracts, tendering extracts about 50% more effort, but this figure drops to 20% for 50%PP and further to 15% for 100%PP. This is a result that theoretical analysis was not powerful enough to predict. If the transaction costs of organizing and running a tender are taken into account, then a compromise must again be struck between performance payments and tendering the contracts. From Figure 5a, it is clear that, on average, tendering does extract more effort, but there is no advantage in increasing %PP beyond 50%. Thus, what was true in the NT case remains true under tender.

[Figures 5a and 5b about here]



FIGURES 5 a,b

IMPACT OF TENDER ON INDIVIDUAL EFFORT OFFERED

4.3.2 Participation rate.

It appeared from Proposition 4 in section 2 that tendering should not modify the participation rates obtained in the non-tendered case. Figure 6 shows however this not to be entirely true, at least for high values of %PP. Although the 1% lower participation rate at the 67%PP level is negligible, the 7% average drop at the 100%PP level, from 59% to 53%, is significant and consistent across all four experimental groups. This drop in participation may be related to two possible causes, though these are only hypotheses at this stage. One is the extra mental loading of having to also include the uncertainty of being selected, a form of transaction cost. The other is the possible role of ambiguity aversion, as opposed to risk aversion, in Ellsberg's [6] sense: total uncertainty is greater under the combined tender and incentive scheme than in the NT case alone.

[Figure 6 about here]

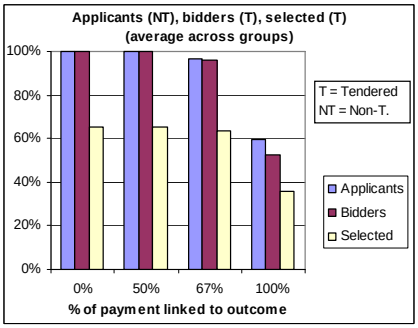


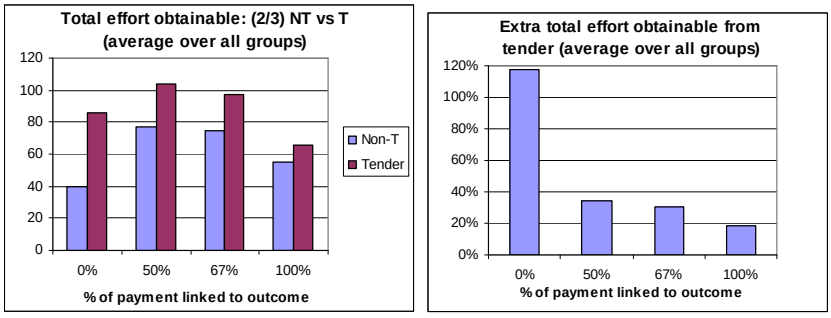
FIGURE 6

IMPACT OF TENDERING ON PARTICIPATION RATES

4.3.3 Scheme performance implications: environmental outcomes and cost-effectiveness

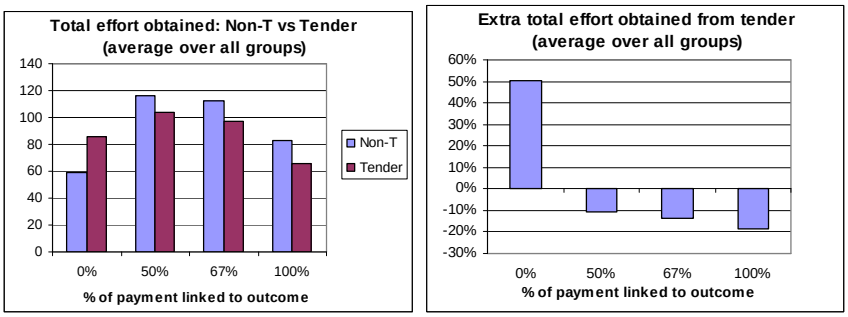
Total effort and outcome obtained. Participation rates and individual supply of effort combine with the selection rate to yield total effort obtained, which directly translates into the expected level of environmental outcome, as per Figure 1. Here, one needs to distinguish between a theoretical and a pragmatic aspect. For the NT and T scenarios to be directly comparable, one must apply the same selection ratio to both. But in practice, the NT setup will accept all participants whereas in T a selection criterion will apply. Figures 7a and 7b present the theoretical comparison and Figures 7c and 7d present the pragmatic one, assuming a selection ratio of 2/3 of bidders, a reasonable ratio that is close to what has been chosen by policy-makers using conservation tenders (e.g. BushTender in Australia)..

[Figures 7a to 7d about here]



FIGURES 7a,b

IMPACT OF TENDER ON TOTAL EFFORT OBTAINED WITH IDENTICAL SELECTION RATIOS



FIGURES 7c,d

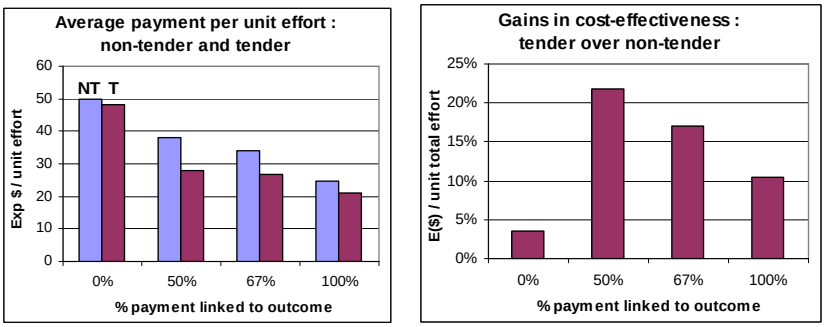
IMPACT OF TENDER ON TOTAL EFFORT OBTAINED WITH A 2/3 SELECTION RATIO ONLY UNDER TENDER

Figures 7a and 7c show that tendering does not modify the pattern observed in the NT case, namely, that there exists an optimal %PP, between 50% and 67%, which yields maximum total effort and expected outcome. The incremental second-order effects, as shown in Figures 7b and 7d, also exhibit similar trends, in that the advantage of tendering rapidly falls as payments linked to uncertain outcomes are introduced (see decrease between 0%PP and 50%PP). However, their absolute values now strongly depend on the policy-determined selection ratio: if equal to 2/3, total incremental effort goes negative even before reaching 50%PP, and tendering *reduces* the expected level of environmental outcome[5]. The difference between Figures 7b and 7d will be smaller if the selection criterion is greater than 2/3 and tends towards 1 and greater if it is less than 2/3 and tends towards 0.

Cost-effectiveness. If we now focus on budgetary cost-effectiveness, the picture again changes, in a similar way it did in the NT scenario. Figure 8a shows that the higher the %PP, the better the cost-effectiveness; that is, the smaller the budgetary outlay per unit of total effort or expected environmental outcome. The marginal value of running a tender is however greatest in cost-effectiveness terms for contracts with only moderate payments linked to outcomes (around 50%PP), as Figure 8b suggests.

[Figures 8a and 8b about here]

[5] The statistical fit is similar to the one in Figure 5b: $dx = -0.50 \ln(\%PP) + 0.41$, ($R^2$=0.85), and the log slope coefficient is indeed about double the previous value (– 0.50 rather than – 0.26).



FIGURES 8a,b

IMPACT OF TENDER ON TOTAL AND MARGINAL COST-EFFECTIVENESS

5. Conclusions

5.1 Summary of results: theory and experiments

Based on a theoretical model, controlled laboratory experiments were designed and carried out with four different groups of university students in two countries. The purpose was to investigate the effects of tendering incentive conservation contracts on the supply of effort and on participation, as well as the effects of different risk attitudes.

Experimental results for the non-tendered contracts by and large confirmed the theoretical predictions, but also added new insights in the form of second-order effects. As the proportion of the payment linked to uncertain outcomes increases at the expense of the fixed up front payment, the total expected payment remaining constant, the participation rate falls, and the supply of individual effort increases, but only up to a point, after which it levels off. This results in a trade-off between maximizing the expected level of environmental outcome and maximizing budgetary cost-effectiveness. Maximizing environmental outcome requires one to limit incentive payments to

moderate levels, whereas cost-effectiveness is maximized when 100% of the payment is outcome-based.

Taking the previous results as benchmarks, tendering contracts which are subject to varying rates of performance payments has the following impacts: with only a slight fall in participation at high rates of performance payments, it further increases the supply of individual effort, but at a decreasing rate as the proportion of performance payments increases. It thus further exacerbates the trade-off between maximizing environmental outcome and maximizing cost-effectiveness. Except for very low rates of performance payments, when most of the payment is made up front, and taking into account the policy-determined selection ratio, tendering actually reduces the expected level of environmental outcome. However, tendering raises even further the cost-effectiveness of the scheme for all values of performance payments; but the marginal value of the tender peaked at moderate performance payment rates of around 50%.

5.2 Limitations and further research

Theory and experiments, as shown in this study, can usefully complement each other. Experiments only partly confirmed theoretical predictions, and more importantly, revealed second-order effects not predicted by our model; theory allowed for an interpretation of experimental results that was not limited by the specific choice of experimental parameters, as per Box 1 and Table 1. Results remain however mostly qualitative; in order to gain deeper insights into the magnitude of the effects, changes in the following parameters would need to be done following a systematic experimental plan:

- The probability spread between favorable and unfavorable environments;
- The relative values of effort cost and total payment (sum of fixed and performance payments);
- The degree of heterogeneity across bidders, in particular in their opportunity costs;
- The difference in productivity between the two agent types (not reported on in this paper), in terms of probabilities of achieving the environmental outcome for the same level of effort;

- Different participant composition in terms of risk attitudes, for example by sorting participants according to their measured risk preferences;
- The degree of competition, viz. the number of bidders relative to the available budget;
- Format of tender; e.g. discriminatory versus uniform price; target versus budget constraint; selection by payment bid instead of by effort provision.

Selection by payment bid was investigated as an extension to this study, the results of which will be reported in another publication. Clearly, however, there is still more work to be done before gaining a thorough understanding of the factors that determine the desirability of tendering incentive contracts for environmental conservation. The introduction of transaction costs and uncertainty in the measurement of environmental outcomes could drastically modify the results obtained in this study. It should then become clearer whether conservation contracts involve any specific features when compared to more general propositions, such as those that were theoretically studied by Laffont & Tirole in their 1993 work.

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Appendix 1

A1. Second-order condition for optimal effort in the non-tendered setting:

From marginal utility (5) follows

$$\frac{\partial^2 E\left[U(\tilde{\boldsymbol{\pi}})\right]}{\partial x^2} = \frac{\partial^2 g(x)}{\partial x^2}\left(U(\pi_p) - U(\pi_0)\right) + \frac{\partial g(x)}{\partial x}\left[U'(\pi_p) - U'(\pi_0)\right]\frac{\partial C(x)}{\partial x}$$
$$-\left(\frac{\partial g(x)}{\partial x}U'(\pi_p)\frac{\partial C(x)}{\partial x} + g(x)U'(\pi_p)\frac{\partial^2 C(x)}{\partial x^2}\right)$$
$$-\left(-\frac{\partial g(x)}{\partial x}U'(\pi_0)\frac{\partial C(x)}{\partial x} + (1-g(x))U'(\pi_0)\frac{\partial^2 C(x)}{\partial x^2}\right) < 0$$

$$\frac{\partial^2 E\left[U(\tilde{\boldsymbol{\pi}})\right]}{\partial x^2} = \frac{\partial^2 g(x)}{\partial x^2}\left(U(\pi_p) - U(\pi_0)\right) - \left(g(x)U'(\pi_p)\frac{\partial^2 C(x)}{\partial x^2} + (1-g(x))U'(\pi_0)\frac{\partial^2 C(x)}{\partial x^2}\right) < 0$$

The first term on the right-hand side is negative if probability g(x) is concave and monotonously increasing in effort x. The second term is non-negative as long as the marginal costs are non-decreasing in effort.

A2. Impact of risk aversion in the non-tendered setting

$$\frac{\partial r}{\partial x} \approx \frac{-\frac{\partial g(x)}{\partial x}p_p}{\left(g(x)p_p\right)^2} - \frac{\frac{\partial^2 g(x)}{\partial x^2}g(x)\frac{\partial C(x)}{\partial x} - \frac{\partial g(x)}{\partial x}\left(\frac{\partial g(x)}{\partial x}\frac{\partial C(x)}{\partial x} + g(x)\frac{\partial^2 C(x)}{\partial x^2}\right)}{\left(g(x)\frac{\partial C(x)}{\partial x}\right)^2}$$

$$\frac{\partial r}{\partial x} \approx \frac{-\frac{\partial g(x)}{\partial x}\left(\frac{\partial C(x)}{\partial x}\right)^2}{\left(g(x)\frac{\partial C(x)}{\partial x}\right)^2 p_p} - p_p\frac{\frac{\partial^2 g(x)}{\partial x^2}g(x)\frac{\partial C(x)}{\partial x} - \frac{\partial g(x)}{\partial x}\left(\frac{\partial g(x)}{\partial x}\frac{\partial C(x)}{\partial x} + g(x)\frac{\partial^2 C(x)}{\partial x^2}\right)}{\left(g(x)\frac{\partial C(x)}{\partial x}\right)^2 p_p}$$

$$\frac{\partial r}{\partial x} \approx -\frac{\frac{\partial g(x)}{\partial x}\left(\frac{\partial C(x)}{\partial x}\right)^2 + p_p\left(\frac{\partial^2 g(x)}{\partial x^2}g(x)\frac{\partial C(x)}{\partial x} - \frac{\partial g(x)}{\partial x}\left(\frac{\partial g(x)}{\partial x}\frac{\partial C(x)}{\partial x} + g(x)\frac{\partial^2 C(x)}{\partial x^2}\right)\right)}{\left(g(x)\frac{\partial C(x)}{\partial x}\right)^2 p_p}$$

$$\frac{\partial r}{\partial x} \approx -\frac{\partial g(x)}{\partial x}\left(\frac{\partial C(x)}{\partial x}\right)^2 - p_p\left(\frac{\partial^2 g(x)}{\partial x^2} g(x)\frac{\partial C(x)}{\partial x} - \frac{\partial g(x)}{\partial x}\left(\frac{\partial g(x)}{\partial x}\frac{\partial C(x)}{\partial x} + g(x)\frac{\partial^2 C(x)}{\partial x^2}\right)\right) > 0$$

$$\frac{\partial r}{\partial x} \approx \frac{\partial g(x)}{\partial x}\left(p_p\left(\frac{\partial g(x)}{\partial x}\frac{\partial C(x)}{\partial x} + g(x)\frac{\partial^2 C(x)}{\partial x^2}\right) - \left(\frac{\partial C(x)}{\partial x}\right)^2\right) - p_p\left(\frac{\partial^2 g(x)}{\partial x^2} g(x)\frac{\partial C(x)}{\partial x}\right) > 0$$

A3. Optimal effort as a function of the proportion of the performance payment

In the experiment we look at changes of the form $\Delta p_p = -\Delta p_f$, i.e. the fixed payment is lowered by the same amount as the performance payment is raised. Substitution of p_f for p_p results in higher optimal effort if derivative (5) increases in response to $\Delta p_p = -\Delta p_f$. We first repeat the foc based on (125)

$$\frac{\partial E\left[U(\tilde{\boldsymbol{\pi}})\right]}{\partial x} = \frac{\partial g(x)}{\partial x}\left(U(\pi_p) - U(\pi_0)\right) - g(x)U'(\pi_p)\frac{\partial C(x)}{\partial x} - \left(1 - g(x)\right)U'(\pi_0)\frac{\partial C(x)}{\partial x}$$

Note that $\frac{\partial \pi_p}{\partial p_p} = \frac{\partial \pi_p}{\partial p_f}$ and $\frac{\partial \pi_0}{\partial p_p} = 0$. Then

- The utility difference in the first summand $U(\pi_p) - U(\pi_0)$ increases by substituting the fixed payment for the performance payment because π_0 decreases while π_p is not affected.
- The marginal utility for the profit $U'(\pi_p)$ does not change because π_p does not change. A change in fixed payment is exactly outweighed by the reverse change in the performance payment.
- In the third summand, the marginal utility $U'(\pi_0)$ increases with lower levels of the fixed payment because π_0 decreases.

Thus, the (positive) first and the (negative) third effect have to be compared.

First effect:

$$\frac{\partial g(x)}{\partial x}\frac{\partial\left(U\left(\pi_p\right)-U\left(\pi_0\right)\right)}{\partial p_f}\Delta p_f$$
$$=\frac{\partial g(x)}{\partial x}\left(U'\left(\pi_p\right)\left(\frac{\partial \pi_p}{\partial p_p}\Delta p_p+\frac{\partial \pi_p}{\partial p_f}\Delta p_f\right)-U'\left(\pi_0\right)\left(\frac{\partial \pi_0}{\partial p_p}\Delta p_p+\frac{\partial \pi_0}{\partial p_f}\Delta p_f\right)\right)$$
$$=\frac{\partial g(x)}{\partial x}\left(-U'\left(\pi_0\right)\frac{\partial \pi_0}{\partial p_f}\Delta p_f\right)=-\frac{\partial g(x)}{\partial x}\left(U'\left(\pi_0\right)\frac{\partial \pi_0}{\partial p_f}\Delta p_f\right)>0$$

Third effect:

$$-\left(1-g\left(x\right)\right)\frac{\partial\left(U'\left(\pi_0\right)\frac{\partial C(x)}{\partial x}\right)}{\partial p_f}\Delta p_f=-\left(1-g\left(x\right)\right)\frac{\partial C(x)}{\partial x}U''\left(\pi_0\right)\frac{\partial \pi_0}{\partial p_f}\Delta p_f<0$$

Optimal effort increases in the performance payment if the sum of the first and the third effect is positive:

$$-\frac{\partial g(x)}{\partial x}\left(U'\left(\pi_0\right)\frac{\partial \pi_0}{\partial p_f}\Delta p_f\right)>\left(1-g\left(x\right)\right)\frac{\partial C(x)}{\partial x}U''\left(\pi_0\right)\frac{\partial \pi_0}{\partial p_f}\Delta p_f$$
$$\frac{\partial g(x)}{\partial x}U'\left(\pi_0\right)>-\left(1-g\left(x\right)\right)\frac{\partial C(x)}{\partial x}U''\left(\pi_0\right)$$
$$\frac{\partial g(x)}{\partial x}\left(1-g\left(x\right)\right)^{-1}\left(\frac{\partial C(x)}{\partial x}\right)^{-1}>-\frac{U''\left(\pi_0\right)}{U'\left(\pi_0\right)}=r$$

Since the left-hand side is always positive, the inequality holds for all risk-neutral and risk-prone agents with $r \leq 0$. We have calibrated the experiment such that the inequality also holds for risk-averse agents. The smallest value for the left-hand side in our experiment is 0.0038, which is more than eight times higher than the highest absolute risk aversions assumed e.g. in Hanson and Ladd (1991) or Lien and Hardaker (2001) for landholders. Consequently, we expect that experimental subjects will offer higher effort when faced with a higher proportion of payments linked to environmental outcomes.

A4. Individual rationality constraint in the tendered setting

The necessary condition to offer a bid is

$$E\left[U\left(\tilde{\tilde{\boldsymbol{\pi}}}\right)\right] > E\left[U\left(0\right)\right] \qquad \text{for some x.}$$

It follows from (11)

$$h(x)g(x)U\left(\pi_p\right) + h(x)\left(1-g\left(x\right)\right)U\left(\pi_0\right) + \left(1-h(x)\right)U\left(0\right) > E\left[U\left(0\right)\right]$$

$$h(x)g(x)U\left(\pi_p\right) + h(x)\left(1-g\left(x\right)\right)U\left(\pi_0\right) > h(x)E\left[U\left(0\right)\right]$$

$$h(x)E\left[U\left(\tilde{\boldsymbol{\pi}}\right)\right] > h(x)E\left[U\left(0\right)\right]$$

$$E\left[U\left(\tilde{\boldsymbol{\pi}}\right)\right] > E\left[U\left(0\right)\right]$$

which is the individual rationality constraint in the non-tendered setting (4).

A5. Expected utility maxima under tender

The number of nulls for the marginal utility under tender (12) depends on h(x) for which agents form subjective expectations. Obviously, $0 \leq h(x) \leq 1$ and h(x) is non-decreasing in x. The probability of winning a contract is close to zero for very low effort levels while it is close to 100% for very high effort. For these levels, the probability of winning a contract is not affected substantially by offering more effort. We thus think that it is reasonable to assume that h(x) is increasing only marginally both at very small and very high effort levels. Between these extreme values the probability is increasing at a higher rate. Consequently, we assume the shape of h(x) being similar to a probability function of a normal distribution, i.e. it is (monotonously) increasing, convex for small values and becomes concave for higher values of effort.

Given this shape of h(x), expected utility function under tender (10) may have several turning points. If (10) has only one turning point then this must be a maximum: multiplying an inverse U-shaped expected utility function under non-tender with a non-decreasing probability h(x) cannot result in a U-shaped function under tender. Thus, the non-tender expected utility function with a maximum cannot become a function with only a minimum or a minimum and a maximum in the tendered setting. Then it also follows: if (10) has more than one turning point under the assumed shape of h(x) it has two (local) maxima and one local minimum. Otherwise the function cannot decrease for very small and very high effort levels.

Appendix 2: Statistical analysis of key experimental comparisons

Treatment A	Treatment B	Wilcoxon test z-value	α one sided
NT 50	NT 67	1.89	3%
NT 50	NT 100	0.72	ns
NT 67	NT 100	1.27	ns
T 50	T 67	2.13	2%
T 50	T 100	1.34	9%
T 67	T 100	1.65	5%
NT 50	T 50	6.16	0.01%
NT 67	T 67	5.74	0.01%
NT 100	T 100	3.75	0.01%

Legend: NT = Non-tendered; T = tendered

50, 67, 100 refer to the %PP, the share of given payment linked to outcome

ns = non-significant at the 10% confidence level