Bidding behavior in contract auctions with incomplete monitoring

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It is well known from the compliance literature that whenever it costly to monitor agents' compliance to contract terms, compliance is likely to be incomplete. This paper goes one step further by examining the implications of incomplete compliance on agent bidding behavior for contracts.

Auction result in more effective resource allocation. From a monitoring perspective we show allocation contracts to least cost also produces another gain – that less resources need to be spend on monitoring and enforcement. To get full use of this insight one needs to have auction procedures that provide incentives for truthful revelation of agents' private alternate incomes.

Our second result is that this property is lost when monitoring is incomplete unless the expected value of compliance exceeds the expected value of noncompliance. We demonstrate this result using an economic experiment for a reverse multi unit auction.

Key words: Vickrey auctions, contracts, monitoring and compliance, truthful revelation.

JEL-codes: D82, D86, Q28

1 Introduction

This paper is about bidding behavior, monitoring and enforcement in contract auctions when it is costly for the buyer to monitor whether the seller is following the contract. Costly monitoring and enforcement are frequent issues in the supply of public goods that are not directly observable – like biodiversity, but are issues of more general interest as the use of contract auctions spreads to other goods and services.

Keeping monitoring and enforcement costs down may alter the ranking of policy alternatives. When it is costly for the regulator to monitor contract compliance, it may be optimal not to monitor agents' compliance with probability one. This opens for agents behaving differently than if they where monitored with certainty.

The literature on environmental contract auctions is of particular interest as compliance issues loom in the background. Latacz-Lohman and Van der Hamsvoort (1997) is regarded as the first paper on auctions of environmental management contracts. The Australian bush tender scheme is probably the most well known contract auction scheme with quite promising results on allocating contracts to least cost providers (Stoneham *et al.* 2003). Experimental auctions for environmental goods and services have also taken place (see for example Taylor *et al.* 2004). A common feature of the early literature on environmental management contracts is that compliance issues do not have a prominent role, per se or related to the impacts of compliance on bidding behavior.

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Hart and Latacz-Lohmann (2005) were among the first to focus on the compliance issue in environmental contract schemes. Citing other publications they note mixed noncompliance to contract terms, ranging from four percent (US conservation payments, 1997) to about one third (German nature conservation scheme, 1993). This mixed empirical evidence suggests that that compliance issues related to the supply of goods that require (costly) monitoring is called for.

Moxey *et al.* (1999) propose an initial contract offer and renegotiation of the contract in cases where contract terms are violated. One weakness with a renegotiation approach is that some agents may have gotten the initial contract offer on false merits, implying that the initial contracts may not be allocated to the least cost providers. In a recent survey article Ferraro (2008) lists several aspects related to the performance of auctions. The impacts of compliance on bidding behavior is not among the issues Ferraro (ibid.) mentions. This is where our main contribution is.

From the monitoring and enforcement literature it is well known that compliance depends on the relative profits of cheating or not cheating (Shavell, 1987; Mitchell and Shavell, 2000). Hence, truth telling auction schemes that provide reliable information about the value of not meeting contract obligations appear highly pertinent for the design of monitoring regimes. In this paper, we investigate whether a uniform-price auction, which is an incentive compatible method for eliciting alternative value when all sellers comply are able to allocate contracts to least cost provides when compliance is not guaranteed. We have not found any works in the literature looking at this relationship between compliance and bidding behavior.

A side result in our analysis is that we also get information about inferring compliance behavior using agents' bids as a proxy for the information rents, and hence the value of (non)-compliance. We use an economic experiment to gain insights on the bidding and compliance behavior when contract compliance is not fully monitored.

This paper proceeds as follows. Section two gives a brief overview of the monitoring and enforcement literature that we deem relevant for our setting, and addresses some issues pertaining to auction schemes. In section three we discuss the linkages between monitoring and bidding behavior, while we in section four motivate our experimental design. Section five describes the experimental setting, and section six provides our results and discussion. The last section concludes and suggests further research.

2 Theory overview

2.1 Compliance, monitoring and enforcement

From the literature on monitoring and enforcement we know that the relative payoff of compliance and noncompliance determines agents' choices. Let π_i^c and π_i^n denote the respective payoffs of compliance and noncompliance for a representative agent. Moreover, let γ_m denote the monitoring probability, and *S* the penalty if monitored (and caught). Compliance requires that its expected payoff exceeds the expected payoff of noncompliance:

$$\gamma_m \pi_i^c + (1-\gamma_m)\pi_i^c = \pi_i^c > \gamma_m(\pi_i^n - S) + (1-\gamma_m)\pi_i^n \quad [1]$$

After some simple transformations we get the basic condition for expected compliance:

$$\gamma_m > \frac{\pi_i^n - \pi_i^c}{S} = \frac{\varphi_i}{S} \quad [2]$$

where $\varphi_i = (\pi_i^n - \pi_i^c)$ is the value of cheating or noncompliance for the agent if not caught.[2] The basic insights from [2] are:

(1) An increase in the penalty increases number of agents who will find it optimal to comply.

(2) An increase in the value of cheating requires a higher monitoring probability, γ_m , or a higher penalty, *S*, to induce compliance.

(3) With a fixed *S*, allocating contracts to providers with small gains from not complying, reduces the needs for costly monitoring compared to when contracts are allocated to producers with large gains from not complying.

An implication of result [2] is that being able to differentiate γ_m results in less costs exerted on monitoring to reach a certain compliance level, or in its dual formulation – for a given total monitoring effort, compliance can be increased.

From Greenberg (1984) it is well known that differing the monitoring probability based on agents' past compliance record may provide substantial savings over a monitoring regime with uniform monitoring probabilities. When new regulations or contracts are implemented, agents have not yet had the possibility to establish a reputation (of compliance).

2.2 Contract auctions

Contract auctions are auctions with one buyer and many sellers where the sellers bid to deliver something to the buyer. In the contract auctions everything is reversed compared with the more studied auctions with one seller and many buyers. In this paper we use a uniform-price contract auction where the buyer wants to buy *n* units of a goods and each of the sellers can offer only one unit. The price in this auction equals the *n*+1 lowest bid, and the sellers with the *n* lowest bids are allowed to sell to the buyer.

This auction mirrors the uniform-price auction discussed by Vickrey (1961). The sellers are unit-sellers, the buyer buys multiple objects to one prize, and the price is determined by the first rejected (*n*+1) bid. We follow Vickrey's line of reasoning[3] and construct an optimal bidding rule.

Bidding rule: *In a uniform-price contract auction with one multiple-object buyer, multiple unit-object sellers, and the price equal to the lowest rejected bid, the optimal strategy for each seller is to make his bid equal to that price at which he would be on the margin of indifference as to whether he wins the contract or not.*

In the standard case, where the buyer knows with certainty whether he has got the product or not, and there is a positive penalty for noncompliance, all sellers will comply to the contract. Moreover, sellers have incentives to truthfully reveal their alternative value because the auction separates what they say from what they get paid. Overbidding sellers risk foregoing a profitable contract, whereas underbidding sellers risk making an unprofitable contract.

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2 Equation [2] is the origin of Gary Becker's (1968) famous "hang the prisoner with probability zero" proposition. In settings where there is uncertain whether agents have complied or not, it is troublesome to say the least to make *S* extremely large. For further discussions on this, please see Shavell (1987) or Mitchell and Shavell (2000).

3 Vickrey concluded that in the in the case with multiple unit sellers and unit-number buyers "the optimal strategy for each bidder ... will obviously be to make his bid equal ... to that price at which he would be on the margin of indifference as to whether he obtains the article or not" (Vickrey, 1961: 20).

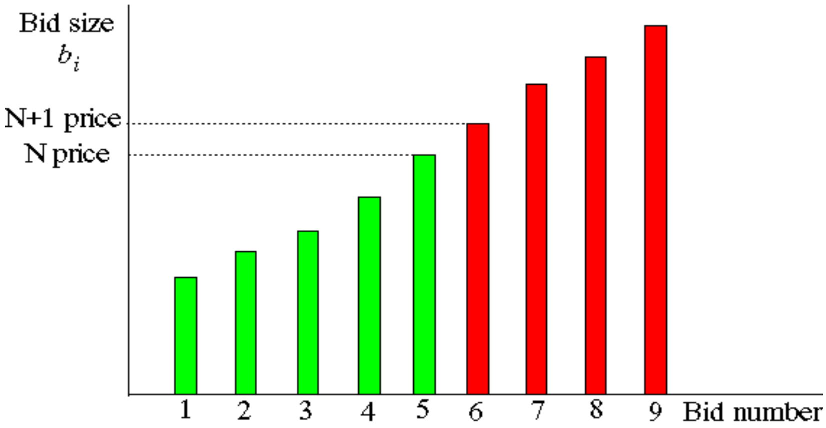


Figure 1: Uniform-price contract auction with one buyer and N sellers.

Figure 1 illustrates the price setting and the determining of the winners in a uniform-price contract auction were the buyer wants to buy five units, the price is determined by the size of the first rejected bid, the sixth smallest bid. The bids are sorted in ascending order, i.e., $b_1 \leq b_2 \leq ... \leq b_k$, and all agents who gets a contract are paid equal to the bid of the sixth (n+1) bidder. At the time of the auction no bidder nor the regulator knows whose bid will be the one that sets the price. Hence, the price is not known until the auction has been completed.

2.3 Bidding and Compliance

This section demonstrates that bidding and compliance are connected. In most contract auction the buyer knows with certainty whether he has received the product or not. In the auction we are investigating the buyer has a monitoring cost and must decide how many of the sellers to monitor and the sellers must decide whether to comply with the contract or not. We will investigate the optimal bidding strategies in a uniform-price contract auction where the sellers know the penalty and the monitoring probability.

We start with the compliance. For it to be optimal for the seller to comply with the contract, the expected payoff from compliance must exceed the expected payoff of noncompliance. Hence, compliance implies that:

$$p^A > \gamma_m (p^A + v_i - S) + (1 - \gamma_m)(p^A + v_i) \qquad [3]$$

where p^A denotes the endogenously determined auction price that is unknown to agents until the auction is completed. After some simplification, we find that equation [3] simplifies to:

$$v_i < \gamma_m S \qquad [4]$$

which we recognize as equation [2]. From[4] it follows that the decision to comply with the contract only depends on the value of the expected penalty.

Let us first look at the optimal strategy when [4] holds, i.e., it is optimal to comply to the contract. Using the bidding rule, we have that if the auction price equals the bid, then the seller should be indifferent whether he sells the product or not. If he sells in the auction he receives the auction price p^A, and if does not sell he keeps the value v_i, hence the optimal bid equals the value of the contract.

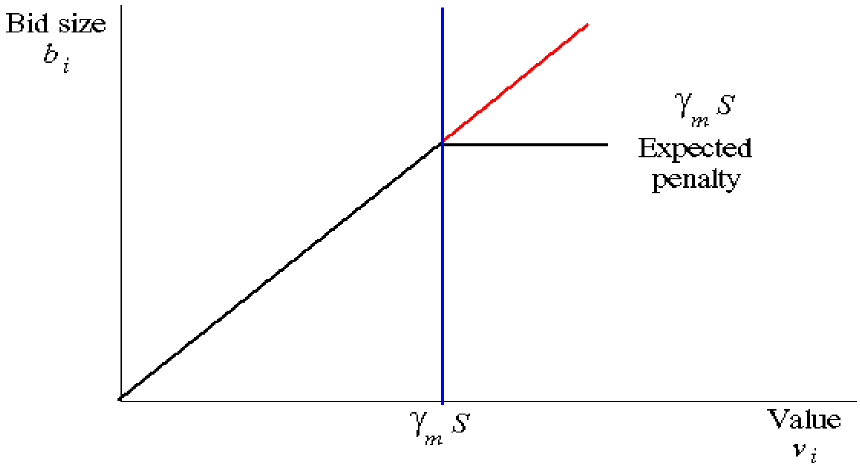
Now, consider an agent where [4] does not hold. Again using the bidding rule, we have that if auction price equals the bid then the seller should be indifferent between (a) selling the product, not complying and with a given probability be monitored and receiving a penalty, and (b) keeping the value v_i.

For such an agent it could be optimal to get a contract if the contract price exceeds the expected penalty, i.e., $p^A > \gamma_m S$, but never to comply with the contract terms. To get a contract under these terms the optimal bid equals the expected penalty, i.e., $b_i > \gamma_m S$. The joint bidding and compliance behavior that we have deduced is then:

$$b_i^x = v_i \quad \text{if} \quad \gamma_m S \gg v_i \qquad [6a]$$

$$b_i^x = \gamma_m S \quad \text{if} \quad \gamma_m S < v_i \qquad [6b]$$

Figure 2 illustrates the bidding-compliance relationship.



If the value of noncompliance is low relative to the punishment, then it is a weakly dominant strategy to bid the true value of the contract. This is the case for all agents whose induced value is less than $\gamma_m S_i$. Conversely, if the value of noncompliance is high relative to the punishment, then the weakly dominant strategy is to bid $\gamma_m S_i$, which in this case will be lower than the value of the contract, v_i. In this context $\gamma_m S_i$ can be seen as an outside option. If the auction price is lower than $\gamma_m S_i$, the participants in this case will be better of not getting the contract.

If the auction price is higher than $\gamma_m S_i$, the participant in this latter case will be best of if they get the contract, but do not comply. As a result we get a kinked relationship between induced value and bid. As long as the induced value is lower than $\gamma_m S_i$, the optimal bid is to bid the induced value. However, when the induced value is higher than $\gamma_m S_i$, the optimal bid is to bid $\gamma_m S_i$.

3 The experimental setting

We test our hypotheses in an economic experiment involving 23 students. We ran to identical sessions, one with 12 and one with 11 students. Prospective participants were told that the payoff of participating in the experiment was NOK 100-500, with a guaranteed payoff of NOK 100. Hence, their individual performance in the experiment would be important for their actual payoff.

The participants were endowed with numbered induced value cards. One for each round of the experiment. A series of contract auction was conducted for contracts of not selling the induced value cards to a third party that wanted to buy these cards at the induced value. The participants that did not win a contract, sold their induced value card to the third party. The winners of the contracts could choose to comply with the contract, or cheat and receive money both from the auction and from the third party.

We started with a training auction with no monetary awards to make participants familiar with the auction mechanism and the monitoring and enforcement regime. Second, we conducted a contract auction with full monitoring. Third, we conducted round of auctions where a known fraction (1/4) of the winners was monitored to check if they had resold their induced value card. Winners who were found to have resold their induced value card had to pay a fine.

Each round of experiment consisted of the following steps:

(1) Each participant receives an induced value card. The value of the card was their private information.
(2) A uniform-price contract auction for *n* contracts where conducted.
(3) Auction price and winners announced.
(4) Possibility of not complying to the contract, i.e., selling the induced value cards to a third party at a price equal to the induced value by marking this on the sales form (that is private information vis-a-vis the auctioneer).
(5) Monitoring of a percentage of the winners to see if they have complied to the contract of not selling to the third party, or if they have broken the contract and sold to the third party. In the first auction all winners were monitored, while in the second auction 25% of the winners where monitored.
(6) The participants get their monetary rewards.

The auction non-winners get the money from the sale to the third party. Auction winners get one of the following payoffs:

(a) the price from the auction if they have complied to the contract,
(b) the price from the contract + the money from the sale to the third party, if they broke the contract and they were not monitored, or
(c) the price from the contract + the money from the sale to the third party − the fine, if they broke the contract and was monitored.

Participants were informed that in each bidding round there would be a maximum amount of funds available for us to use in the auction. This maximum sum was not made public to the participants, and matches the setup of Romstad and Polasky (2008). Hence, if bids were high fewer participants would get contracts than if bids were low.

In the first part of non-hypothetical auctions, hereafter referred to as *Experiment I,* the participants were told that all winners would be monitored. The induced values were in the range of NOK 11-24. The contract auction was carried out, and six of the participants got a contract, and the price equaled the seventh lowest bid. Those not getting a contract were free to sell their induced value cards at their face value. The winners could also sell their induced value cards to the third party, however if monitoring revealed that they had done so they would be punished. Since this was an auction with full monitoring, it would not be rational to resell the induced value card if you had won the auction, and no one did.

In the second part of the non-hypothetical auctions, hereafter referred to as *Experiment II,* the participants were told that 25% of the winners would be monitored. The setup was as experiment I with one exception: This was a three-period game. The contract sold in the first round was for not reselling to a third party in period 1, 2 and 3. The contracts sold in period 2 was for not reselling in period 2 and 3. And the contracts sold in the period 3 was for not reselling in period 3. Furthermore, in each time period the monitoring probability would be 25 %. If monitored and found in noncompliance, they would have to pay a fixed fine plus being kicked out of any remaining period of that game. This implies the following structure of the *t* time period penalty if monitored:

$$S_{i,t} = F + (3-t)(p^A - v_i) \forall v_i < P^A \text{ and } F \text{ otherwise} \quad [7]$$

where F is the fixed penalty equaling NOK 60, and $t = \{1,2,3\}$. Hence, the effective penalty would decrease with each period, t. Asset values were in the range of NOK 11-29. The mean penalty over the three time periods then becomes:

$$S_{i,t} = F + (p^A - v_i) \forall v_i < P^A \text{ and } F \text{ otherwise} \quad [8]$$

To maximize the numbers of possible cheaters, we announced a price that was above the highest induced value, and allowed those with higher bids to revise their bids. Hence all 23 bidders were winners.

4 Results and discussion

4.1 The bidding procedure

Experiment I differs from experiment II as the monitoring probability was set to one. This makes experiment I a choice between two certain alternatives, and with the penalty for non-compliance being set so high that compliance is the only rational choice for any utility maximizing agent. Experiment I therefore tests the basic properties of the bidding mechanism as indicated by [6a], and that agents understand the monitoring scheme. The latter was found to be the case. In experiment II only a known fraction of all agents was monitored. Agents with high induced values should therefore bid according to equation [6b].

Table 1: Number of agents and their expected bidding behavior

Expected bidding behavior	Experiment	
	I	II
According to [6a]	23	12
According to [6b]	0	11

An extended model for the two experiments was estimated to check if other explanatory variables than those in equations [4] and [5] influenced the bidding behavior. This was found not to be the case. The following simplified models were then estimated:

$$b_i = \hat{\alpha}_0 + \hat{\alpha}_1 v_i + \varepsilon_i \quad \forall \quad v_i \leq \gamma_m S_i \quad [9]$$

$$b_i = \hat{\theta}_0 + \hat{\theta}_1 \gamma_m S_i + \mu_i \quad \forall \quad v_i > \gamma_m S_i \quad [10]$$

One implication of [10] is that we would expect the bids not to be influenced by the induced value, v_i. We can therefore rewrite [10] and add v_i to get:

$$b_i = \hat{\theta}_0 - \hat{\theta}_1 v_i + \hat{\theta}_1(\gamma_m S_i + v_i) + \mu = \hat{\beta}_0 + \hat{\beta}_1 v_i + \mu \quad \forall \quad v_i > \gamma_m S_i \quad [11]$$

where one expects β_1 not to be significantly different from zero.

Table 2: Regression results for the two experiments
(*parameter estimates first row, standard errors second row - marked yellow*)

Experiment	[9] value less than expected penalty				[10] value greater than expected penalty			
	F-value	R^2	α_0	α_1	F-value	R^2	β_0	β_1
I	26.05	0.554	1.006	1.140	-	-	-	-
			3.843	0.223			-	-
II	37.15	0.788	0.600	1.081	0.39	0.042	30.753	0.727
			2.773	0.177			29.096	1.164

The estimation results for the participants where the induced value is less than the expected penalty are quite promising for both experiments. The overall regression statistics suggest a good fit to the data, in particular for experiment II where this simple model explains almost 80 percent of the variation in the biding behavior. For both experiments the estimated constant terms are close to zero and not significant, while the parameter estimates are close to one. This is as it should be according to equation [9], and well in line with similar experiments in Vickrey style auctions (Kagel and Roth, 1997).

For the participants whose induced value is greater than the expected penalty the results are not at all assuring. The overall model fit is poor in both cases. Moreover, the parameter estimates appear somewhat unreasonable compared to the expected behavior. Hence, this gives reason to suspect that participant's bidding behavior was not according to equation [10].

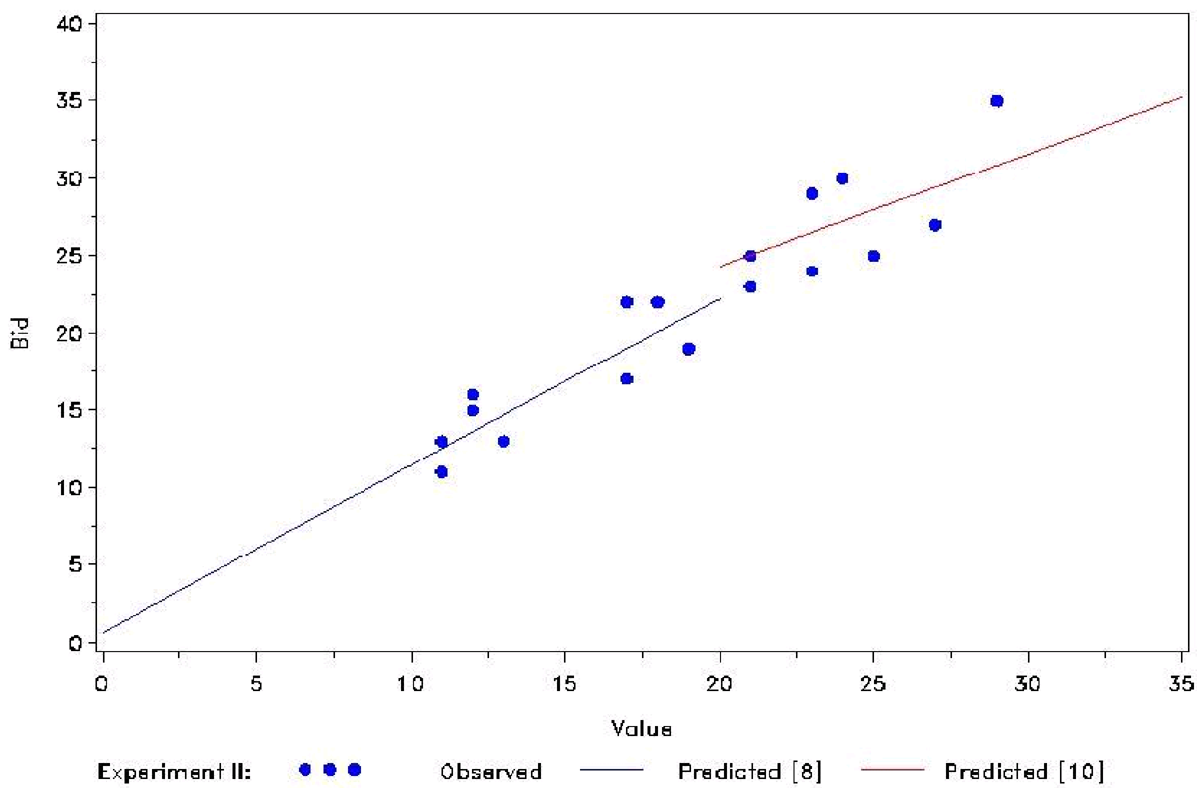


Figure 3: Experiment II - plot of bid as a function of value
($b_i = \hat{\alpha}_0 + \hat{\alpha}_1 v_i$ for $v_i \leq \gamma S_i$ and $b_i = \hat{\beta}_0 + \hat{\beta}_1 v_i$ for $v_i > \gamma S_i$).

Figure 3 clearly suggests that there is some strategic adjustment to the bids. However, our results need to be interpreted with care as the number of participants in the experiment is low. That makes our estimates highly sensitive to the behavior of single agents.

4.2 Bidding and compliance

One result of equations [5a] and [5b] is that it is only rational for agents to underbid if they plan to cheat at some later stage in the game, and cheating increases their expected payoff. This cannot be the case in experiment I as the monitoring probability is set to one.

The penalty of noncompliance declines from round 1 to round 3 as shown in equation [7]. Consequently, it does not suffice only to check the likelihood of cheating using equations [5a] and [5b]. The penalty needs to be included as well, and the following equation was therefore estimated:

$$\Pr\{\text{cheat}_{i,t}=0\} = f(\alpha_0+\alpha_1 S_i, t+\alpha_2 d_i+\xi) \qquad [12]$$

where $S_{i,t}$ is the penalty, and d_i is a dummy variable that takes on the value one if $v_i > \gamma_m S_i$ and the bid is less than the induced asset value. Table 3 shows the results of the estimations[4].

Table 3: Estimation results of [12] - $\Pr\{cheat_t = 0\}$

Model statistics		Estimates			
χ^2-value	P-value	Type	α_0	α_1	α_2
16.99	0.0002	Parameter	-12.43	0.2149	-0.4181
		Std. deviation	5.03	0.0812	0.7139

Our results on bidding and compliance support the impression from the bidding behavior part, namely that participants sought ways of increasing their expected payoff.

4.3 Compliance

Testing compliance behavior is meaningful only in experiment two as it has monitoring probabilities less than one. As mentioned in section 3 the induced asset value is the individual participant's private information in the sense that in a real setting neither the regulator nor other participants know this. This gives room for comparing two models: **model 1**, using the penalty function as perceived by each participant with a contract, i.e.,

$$S_{i,t}=F+(3-t)(p^A-v_i) \qquad [7]$$

and **model 2**, using the implied penalty function the regulator can deduce by replacing the asset value with the bid, i.e.,

$$S^r_{i,t}=F+(3-t)(p^A-b_i) \qquad [13]$$

In both model specifications F denotes the fixed penalty (that equals 60), t denotes the round (1 to 3), and p^A is the contract price. As for the bidding behavior extended models were estimated first to test for the influence of personal characteristics. The only variable besides the asset value or bid that came out significant was sex. Table 4 shows estimation results of the following model:

$$\Pr\{\text{cheat}_{i,t}=0\} = f(\beta_0+\beta_1 penalty(\text{¿}implied\ penalty)+\beta_2 sex+\xi) \qquad [14]$$

4Model estimations were performed using the PROC LOGIST procedure in SAS for logistic regression.

Table 4: Estimation results of [14] - Pr{cheat=0} *in experiment II*

Model	Model χ^2-value	Estimate	β_0	β_1	β_2
Model 1 (asset value in penalty function)	16.75	Parameter	-12.108	0.2076	-0.2233
		P-value	0.0113	0.0062	0.7425
Model 2 (bid in penalty function)	11.41	Parameter	-10.470	0.1871	-0.3856
		P-value	0.4012	0.0234	0.5530

The estimation shows that when the participant's private information (the asset value) is replaced with the bid, the model performance declines. As expected the estimate for β_1 (the penalty calculated using the privately known asset value or the public bid) parameter falls and becomes less significant. However, for both specifications, the penalty estimates have the expected sign (compliance increases with higher penalties), and are highly significant. This is promising for using the bid values to predict participant compliance. In both cases, the sex variable (male is zero and female is one) is not significant.

5 Concluding remarks

The main purpose of this paper is to shed light on the interaction between compliance and bidding behavior in auctions. We have found that in order to preserve truthtelling in the bidding procedure, the expected value of noncompliance must be less than the expected value of compliance. Increasing the expected penalty of noncompliance so that the expected penalty, $\gamma_m S_i$, always exceeds the contract price solves the problem of compliance as noncompliance no longer is profitable. Such a penalty will not be perceived as excessive for two reasons. First, because the penalty is closely linked to the contract price, and second because the auctions yield lower contract prices than what otherwise would have been the case.

Our results also support the general notion from the monitoring and enforcement literature that compliance will not be uniform, but depends on the individual agents' relative payoff of compliance and noncompliance. That is, by allocating contract to agents with the least to gain from not meeting contract terms, lowers overall monitoring costs. However, our results are less good when it comes to further utilizing the auction bids to target monitoring probabilities according to the bid sizes. In a sense this is also as expected given that we have identified increased risks of strategic bidding behavior when compliance to contract terms is not guaranteed.

In the experiment conducted we have a small number of participants. That makes our results more sensitive to the behavior of single agents than if we had more participants. Repeated experiments pursuing our kind of experiments may therefore be called for.

Further experiments may also seek to exploit differences in agents' bids further to better target the monitoring probabilities. Designing such schemes to preserve the incentives for truth telling will, however, not be a trivial task. A tempting, but not recommended alternative may therefore be to adjust monitoring probabilities according to bids without telling agents. This conflicts with the old saying "you cannot fool all the people all the time". A possible way out is to use bids to obtain starting monitoring probabilities, and gradually move to a reputation based monitoring regime in line with Greenberg (1984). Then the regulator only needs to "fool all the people for some time".

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