Truthful revelation in nonmarket valuation

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Abstract

A major criticism of contingent valuation methods relates to their hypothetical nature, where truthful revelation of willingness-to-pay is not secured because of the missing link between stated willingness-to-pay and the respondent's budget constraint. Large deviations between stated willingness-to-pay and actual payments in both field and experimental studies where actual payments were collected lend support to these claims. In its utmost format this lends contingent valuation studies vulnerable to strategic behavior.

This paper combines the truthful revelation properties of multi-unit uniform price auctions and the median voter theorem to induce truthful revelation. The intuition is as follows: Let the price in the auction be set by the median bid, and pass this price onto a referendum. The expected net gains of passing the referendum would then be positive, implying that the budget constraint would be introduced in a probabilistic manner.

Key words: multi-unit uniform price auctions, Becker-deGroot-Marschak mecahnism, truthful revelation, budget constraint.

1 Introduction

This paper deals with valuation of natural resources and environmental amenities that do not have well defined market prices. Contingent valuation (CV) methods are commonly used to value such goods and services. However, the use CV is not without problems. A major critique of CV relates to the hypothetical nature of many such studies. One of the most troublesome hypothetical features is that respondents express their valuation without fully considering their budget constraint. That opens for strategic responses, which commonly leads to inflated valuation estimates.

Much attention has been devoted to the issue of truthtelling among CV-researchers and skeptics (for an excellent summary see of this debate, see Hanemann 1994, Diamond and Hausmann 1994). Mitchell and Carson (1989) argue that dichotomous choice formats solve the issue of truthful revelation. It is possible to show that closed ended CV makes truthfulness a weakly dominant strategy when agents consider their budget constraint. Harrison (2006) argues that this condition is not met in many CV studies. He supports this claim through a series of economic experiments.

Several ways of reminding respondents of their budget constraint have been proposed. "Mental accounts" (Magnussen 1992) is one such approach, building on Thaler (1990) and dating back to Lancaster (1966). The basic idea here is to ask respondents about their overall WTP for environmental goods and services, or their expenditures on other goods and services before asking for their WTP for the environmental good or service in question. While this approach has succeeded in reducing apparent overstatement of WTP, the degree of this success is uncertain.

This paper seeks an alternate way of reminding respondents of their budget constraint: respondents are asked to state their bid in a survey using the uniform price auction format where the cut-off point is determined by the median bid. A desirable property of the proposed set-up is that respondents are reminded of their budget constraint in the following way: a policy where the median bid is used would pass a referendum, and hence respondents risk to be held accountable for their bidding behavior. By asking open-ended questions issues of anchoring biases (Holmes and Kramer 1995, Chien *et al.* 2005), of close ended questions are avoided.

The proposed method is highly similar to the Becker-de Groot-Marshak (BDM) mechanism (Becker *et al* 1964). In the BDM agents formulate their bids, and if an agent's bid exceeds or equals a randomly drawn cutoff price, the agent pays the cutoff price and receives the auctioned item. Otherwise, the agent pays nothing and receives nothing. While the random setting of the cutoff price in the BDM limits its applicability, it was long believed that the BDM had the necessary incentives for truthful revelation (Latacz-Lohmann and Schilizzi 2005). However, Horowitz (2006) showed that truthful revelation of the BDM may not hold if an agent's bid is affected by the distribution of bids. As the proposed mechanism works like the BDM with the exception of how the cut-off price is determined, the Horowitz critique of the BDM may also apply to the proposed mechanism. Hence, some work still remains to pin down the size of this deviation from truthful bidding. Most likely, the magnitude of this deviation is case specific.

This paper proceeds as follows. The next section presents a short review of auction mechanisms, before the proposed model is presented in section 3, and the truthful revelation properties of the proposed model in light of the Horowitz' (ibid.) criticism of the BDM are discussed in section 4. Section 5 concludes.

2 Valuation and auction theory

Adverse selection (hidden type) issues in principal-agent frameworks (Stiglitz 1989) means that the agent – the best informed party on the issue at hand – is able to benefit (to reap information rents) by not fully revealing her demand for the auctioned good to the principal (the policy agency). This corresponds to meeting the incentive compatibility condition for truthful revelation in the mechanism design literature (Campbell 1987). Already at this stage the parallel nonmarket valuation is self-evident as only to the respondent knows her own willingness-to-pay (WTP).

Moreover, in an auction setting agents will only place bids that make them at least as well of as they initially were. This is required in auctions since bidding is voluntary. Again, the parallel to nonmarket valuation is clear as respondents will only state WTP that make them better off than they were initially. However, auctions and nonmarket valuation differ on the issue of free riding – because in the latter a respondent would be even better off if the public good was provided without the respondent having to pay.

There exists three ways of inducing agents to reveal their true valuation, self selection mechanisms, auctions, and the Becker-de Grooth-Marschak (BDM) mechanism. The BDM (Becker *et al*. 1964) has many similarities with uniform price auctions. In the case of nonmarket valuation self selection mechanisms are ruled out because of free riding. We are hence left with auctions or the BDM as viable alternatives for nonmarket valuation.

Auction theory distinguishes between single and multi unit auctions. In the case of nonmarket valuation agents place their own (private) bids for a the public good in question, not unlike what happens under Lindahl pricing. Also, recall the definition of a public good – it non-divisible and non-exludable in consumption (Randall 1982). This implies that a public goods can be viewed as a multiple unit good. In terms of auctions this implies that only sealed-bid auctions are This calls for the multi unit auction formats, which implies that bids must be sealed to avoid obvious strategic bidding behavior. The two basic sealed bid auctions are:

(1) *First-price sealed-bid auctions* require bidders to submit confidential bids to the seller. As the name reveals, bidders cannot observe the size of the competing bids when placing his bid. This is in contrast to the English auction where other bids are observable. The bidders with the highest bids win and pay their respective bid.

(2) *Second-price sealed-bid auctions* (Vickrey 1961), also denoted Vickrey auctions, differ from the first-price sealed-bid auctions as the highest bidder wins the auction, but only pays the price of the second-highest bidder. This separation between the bid and the price paid makes it a dominant strategy for agents to bid their true subjective valuation. Bidding above the subjective valuation increases the risk of having to pay more for the auctioned item than what the bidder perceives it is worth. Contrary, bidding below the subjective valuation increases the risk of loosing out on a good where one would have been willing to pay more.

When multiple units of a good are auctioned off, the *Revenue equivalence theorem*, that Vickrey (1961) also pointed to, no longer holds because the condition of selling a single item is not met (see Chan *et al*. 2003 for full details, summarized by Latacz-Lohmann and Schillzi 2005:18). Still, these two auction formats maintain the desirable property that winners are the persons with the highest subjective valuation.

Discriminatory price auctions, where the payment equals the stated WTP, belong to the wider class of *first-price sealed-bid auctions*. By adjusting her bid downward, a bidder may get one of the copies of the good for less than her true WTP. To see this, consider some bidder who feels reasonably

certain that her true WTP belongs to the high end of the WTP distribution. This is an essential weakness of all *discriminatory price auctions*. However, this strategic adjustment entails some risk of not getting the good, which works in the direction of truthful revelation in the way that the strategic bid adjustment cannot be excessive.

Second-price (Vickrey) auctions can be modified to a setting where multiple goods are auctioned off. Suppose that N itmes of a good are offered for sale. Then the N highest bidders gets copies of the good for the price of the first non-winning bid, the N+1 ranked bid, giving rise to the name N+1 *price auctions*. As all winners pay the same price, such auctions are also denoted *uniform price auctions.* Uniform price auctions belong to class of Vickrey style (second price) auctions, and they maintain the desirable property of truthtelling found in Vickrey auctions because of the separation between of the bid and the payment. Figure 1 provides an illustration with four winning bids and the fifth bid setting the cutoff price, which then is paid by all the winners.

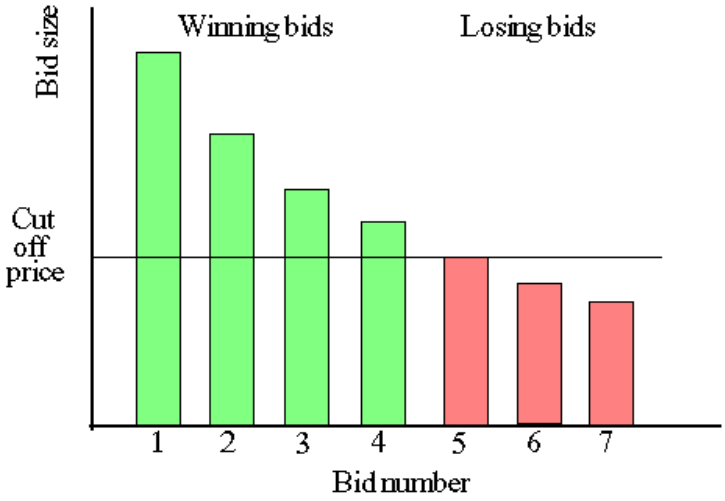

Figure 1: N+1 price auction when N is 4.

To see that this induces truthful revelation, consider an agent who bids less (b) than her true WTP (e) such that $e > p \geq b$, where p denotes the cutoff price, i.e., the highest non-winning bid. In that case the agent would miss getting a good she would be better off having. Similarly, if an agent bids more that here true WTP such that $e < p \leq b$, this agent would get a good she would have been better off without. It is only by bidding trutfully, i.e., $e = b$, the agent is certain the transaction is welfare enhancing.

The Becker-de Groot-Marshak (BDM) mechanism and uniform price auctions share the property of separation off the bid size and the compensation paid. This makes it a weakly dominant strategy for bidders to equate their bids with their opportunity value or costs. BDM and uniform price auctions only differ in the way the price is determined: in BDM the price is randomly drawn, while in uniform price auctions the price is usually set by the first non-winning bid. The Horowitz (2006) critique of BDM therefore also applies to N+1 price auctions.

Some concerns have been raised related to BDM like auctions because agents may consider them complicated, and that agents who consider their WTP to belong to the tails of the WTP distribution. Experimental auctions like Shogren *et al.* (2001) lend support to such claims. A counter argument against this claim in nonmarket valuation settings is that respondents with high or low WTP are those who feel most strongly about an issue and therefore are more secure about their WTP. The Shogren *et al.* (ibid.) results actually suggests that respondents who think they are the marginal

(here the median) bidder have stronger incentives in such auctions to bid their true valuation. This result works in favor of the proposed mechanism.

Finally, note that due to the sealed bid format, using uniform price auctions or the BDM to value nonmarket goods is compatible with using the standard CV survey techniques (postal, interview or online). Hence, the proposed approach does not entail any additional survey challenges besides those already familiar to CV researchers.

3 Model specification

In the proposed mechanism respondents are asked to state their WTP in a uniform price auction format, where the cutoff price is determined by the median bid. This introduces the budget constraint in a probabilistic sense – a policy based on the median bid would stand a reasonable chance of passing in a referendum, implying that respondents would be held accountable for their bids.

The theoretical justification for nonmarket valuation comes from the indirect utility function with public goods, where respondent *i* is asked to state the WTP that makes her indifferent with or without the project:

$$V_i(p^0, z^0, M_i) = V_i(p^1, z^1, M_i - e_i) \quad [1]$$

where superscript 0 denotes without the project and superscript 1 denotes with the project, p is a vector of prices, z is the public good in question, M is money income, and e is the expenditures to provide the public good.[1] Under truthful revelation e_i would equal agent *i's* maximum WTP.

In a standard uniform price auction only respondents with WTP above the cutoff price, c, would get the good, that is $e_i > c$. This implies that

$$V_i(p^0, z^0, M_i) < V_i(p^1, z^1, M_i - c) \quad \text{when} \quad e_i > c \quad [2]$$

However, public goods are usually non-divisible as noted by Randall (1982), implying that if a project is implemented, agents with $e_i \leq c$ would not have the welfare gains indicated in [2]. Here, the good is non-divisible. Hence, all agents have to pay the cutoff price, c, which gives

$$V_i(p^0, z^0, M_i) \geq V_i(p^1, z^1, M_i - c) \quad \text{when} \quad e_i \leq c \quad [3]$$

Under uniform price auctions the cutoff price, c, is not known in advance. With the possible exception of the Horwitz (2006) critique, we saw in the previous section that agents should state their true WTP so that [1] holds. Any agent with $e_i > c$ is then secured a welfare gain by [2], while agents with $e_i \leq c$ at best is equally well of with or without the project. The next section investigates if the Horowitz arguments apply to the proposed median bid BDM valuation mechanism.

For a project to be implemented the total costs of the project, T, should not exceed the revenues collected. With K individuals in the economy, this implies that $T \leq Kc$. Hence, the surplus of winning in the auction may be even larger. This does not change the basic property of [1] because an individual who responds anything else than e_i, i.e., does not state her true WTP, would be worse off as the median bid is not known in advance.

1 Following Hammond (1984) this paves the road for the money metric utility function, $V(p^1, \varphi(x, z); z^1)$, but for our purpose the representation using the indirect utility function works equally well.

4 Truthful revelation - revisited

The BDM is frequently used for eliciting agent's individual valuation of a good, and was believed to produce incentives for truthful bidding behavior. Horowitz (2006) showed that truthful revelation does not hold in lottery settings under non expected utility (EU) preferences like disappointment aversion or regret. As EU is frequently violated, it is risky to ascertain EU preferences for a valuation method that may be used under a large variety of settings.

A key issue for the general usability of the proposed valuation mechanism is therefore if the valuation mechanism can be shown not to be a lottery or lottery like. Horowitz (2006:7) helps us out to clarify this issue: "Because the potential price of of the idem is random, the individual's bid is potentially affected by the distribution of prices". As the median is a random variable drawn from the distribution of bids, it is a random variable. Hence, the proposed valuation method fails in this regard as it has lottery like features.

We therefore need to estimate the direction and preferably the size of the error. Horowitz shows in lotteries and non-EU preferences agents may be better off adjusting their bid upward. This is exactly the error the proposed mechanism seeks to avoid as our primary concerns relate to respondents failing to fully incorporate their budget constraint when stating their WTP, leading to overstated WTP answers. My claim is that this error is so small it becomes negligible for practical uses.

Under the proposed regime, the main condition for a project being implemented is that the median bid, i.e, the cutoff price c is sufficiently high to cover the project costs. Hence, it is the costs of the project that becomes the first active constraint. Denote these per capita costs $a = T/k$, where T denotes total project costs and k denote the number of agents in the economy. Under full certainty about a the standard BDM result holds, i.e., bid $b = e$. If bids are sufficiently high, the median bid $c > a$, with the welfare impacts shown already shown by equations [2] and [3]. With full certainty about the costs it should be noted that the proposed mechanism collapses to a standard dichotomous choice experiment where everyone with $e > a$ votes yes, while those with $e \leq a$ votes no. Figure 2 depicts the choice setting for a bidder with EU preferences. There is no principal difference for non-EU preferences under certainty.

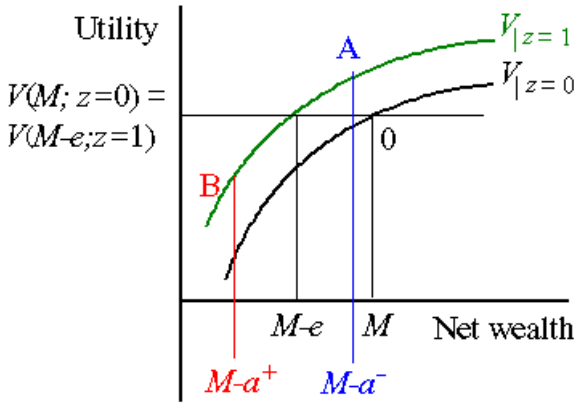

Figure 2: Bidding under no uncertainty.

Without the project, the respondent is left at the indifference curve $V_{|z=0}$ at the point 0. With the project and $a < e$, the respondent is better of with the project than without, indicated by the point A on the curve $V_{|z=1}$. Similarly, if $a > e$, the respondent is worse of with the project than without, indicated by the point B on the curve $V_{|z=1}$.

Under uncertainty the respondent's indifference bid, *e*, is adjusted somewhat. The intuition behind this adjustment is that respondents favor the certain no-project alternative over the more risky with-the -project alternative. To see this, assume that if the project is implemented, there is a fifty-fifty chance of ending up in A or B, implying that the mean value of these two outcomes is given by the straight line between A and B as illustrated in Figure 3, giving a risk premium adjustment, *RP*, and the new indifference bid e^{RP}.

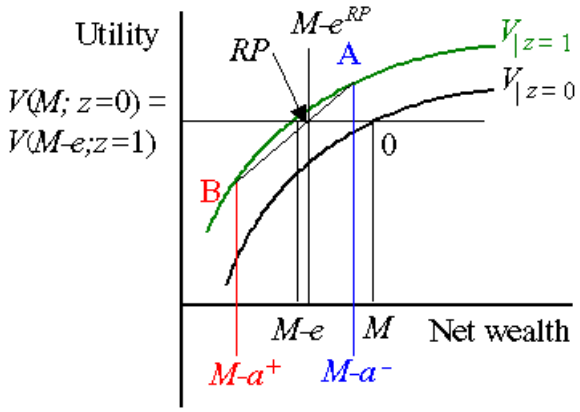

Figure 3: Adjustment of the bid in lottery settings.

For agents with EU preferences, the risk premium adjusted bid e^{RP} and the new indifference condition:

$$V_i(p^0, z^0, M_i) = V_i(p^1, z^1, M_i - e_i^{RP}) \qquad [1']$$

follows from the shape of the agents vonNeumann-Morgenstern utility function and the distribution of bids. This risk adjustment is in line with EU theory, and under the lottery setting, agents expectations about the bid distribution leads to an adjustment in the bid. It should be noted that this adjustment is not a deviation from truthful revelation.

Now, consider non-EU preferences, exemplified by a kinked utility function, and a similar lottery setting as above with a fifty-fifty chance of ending up in A or B with the project. The payment *e* that makes the respondent indifferent between getting or not getting the public good according to [1] can either be placed at either side of the kink, or at the kink. Figure 3 depicts the least special situation where the indifference point is not at the kink.

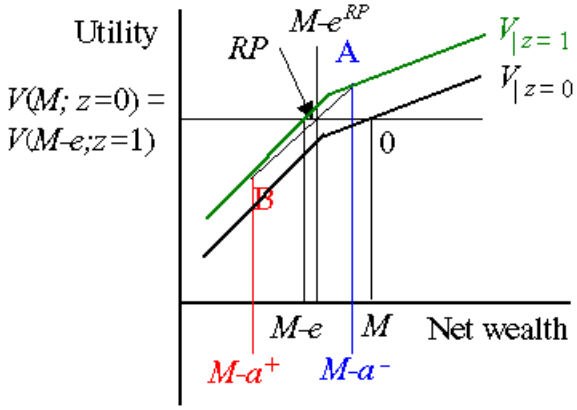

Figure 4: Bidding under uncertainty under non-EU preferences

As was the case under EU preferences, there exists some optimal adjustment of the bid, e. The difference is that while under EU preferences the respondent cannot increase her payoff by bidding different from e^{RP}, this may not the case here. Due to the kinked utility function the risk premium adjusted bid, e^{RP}, is highly sensitive to the location of kink relative to the points A, B, and 0. the utility function in Figure 4 is a special case with linear segments that demonstrates the challenges of non-EU preferences: if A and B both are located on the same linear segment, there is no risk adjustment. At the same time it is self-evident that the expected size of the risk adjustment increases with the difference between $M - a^+$ and $M - a^-$ for two reasons: (i) it increases the probability that the kink will be within the interval $[M - a^+, M - a^-]$, and (ii) the standard result for any concave utility function (or her more accurately: a utility function with concave elements).

Please also note that if $M - e < M - a^+$ then the respondent would gain from having the project implemented, and there is no lottery. Similarly, for $M - a^- > M - e$ there is also no lottery. In both cases, risk considerations vanish.

Now, consider a person with a concave and everywhere increasing utility function that is not consistent with EU preferences. Following Horowitz (2006) this adjustment may differ from the adjustment under EU and hence be interpreted as a strategic move. However, if the distance between $M - a^+$ and $M - a^-$ is small, the utility function between the two points A and B can be quite well captured by a linear approximation, implying that the risk adjustment is small.

Under the BDM the random price is drawn from a distribution with a potentially wide spread. This makes the impact of non-EU preferences potentially large. In the proposed mechanism the median defines the cutoff price. The median has two very desirable properties in this regard. First, the median is stable in the sense that it is relatively unaffected by changes in the value of a single observation. This means that single respondents in general cannot influence the median to such a degree that gaming behavior is not worth while if this was its sole purpose.

Second, the confidence interval of the median is relatively narrow as order statistics are relatively stable for reasonable sample sizes. This implies that with some prior knowledge, the expected value of the median is known with some certainty, Hence, the lottery element is reduced, reducing the impacts of non-linearity in the vonNeumann-Morgenstern utility function less.

Moreover, when the expected costs of providing a public good are known with reasonable certainty, this upwardly bounds respondents' expected payment, which further reduces the lottery impact of the valuation exercise. On the other hand, knowledge about the project costs may introduce starting point biases similar to those of the closed ended dichotomous choice CV formats.

The above three aspects all reduce the size of any adjustment away from the true WTP. Still, the exact size of this adjustment depends on respondents' preferences (recall that under EU there is no adjustment), the degree of non-linearity of the utility function, and the exactness of agents' expectations about the cutoff price. Truthful revelation under the proposed mechanism is therefore not secured, but there are good reasons to expect the deviations between the stated and true WTP to be minor. On this, more work is needed.

5 Concluding remarks

In the proposed mechanism respondents are asked to state their WTP in a uniform price auction format, where the cutoff price is determined by the median bid. This introduces the budget constraint in a probabilistic sense – a policy based on the median bid would stand a reasonable chance of passing in a referendum, implying that respondents would be held accountable for their bids.

The similarities of the proposed approach with the Becker-de Groot-Marshak (BDM) mechanism (Becker *et al.* 1964) suggest that truthful revelation does not hold as Horowitz' (2006) concerns about the BDM under non-EU preferences and lottery like settings remain. However, as the median is likely to vary less under the proposed mechanism than the randomly drawn number used in the BDM, the degree of strategic responses is likely to be less. Work remains to find out how large these deviations are under various settings. Possibly, these deviations are case specific, implying that care needs to be taken when using the proposed method. On the other hand, it may very well happen that the size of these adjustments are so minor that they are well within the range of the respondent's tolerable uncertainty.

In terms of applicability, the proposed mechanism is expected to fare better than ordinary open-ended responses (that are prone to strategic answers), or closed ended responses (due to starting point biases and the remoteness of the agent's budget constraint). In terms of statistical estimation and inferences, the proposed mechanism does better than the closed ended formats on three counts: (i) open-ended answers require smaller sample sizes under which the statistical properties are reliable, (ii) easier estimation as open-ended responses allows for using OLS in the estimation, and (iii) confidence intervals can be directly calculated while closed-ended approaches require the use of bootstrapping techniques (see Efron 1979) to obtain quasi estimates of confidence intervals.

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