WHAT DO WE KNOW ABOUT THE PERFORMANCE OF THE BECKER-DEGROOT-MARSCHAK MECHANISM?

by

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1. Overview

Economists are often interested in knowing how much an individual would pay for some item. Although the researchers' main interest is frequently in knowing how much someone would be willing to pay for provision of a *public* good, many inferences are made from *private*-good experiments. Private goods experiments allow researchers to observe (i) individual behavior; that is, to assess how individuals would likely behave in the context of real-world public goods mechanisms; and (ii) actual values of public goods in those situations where the public good can also be privately provided, such as health and safety.

The Becker-deGroot-Marschak mechanism (BDM) is a common method for eliciting willingness to pay for a private good. Under the BDM, an individual reports a bid; an item cost is then randomly drawn. If the individual's bid is above the cost, the individual receives the good and pays the drawn cost. If the bid is below the cost, the individual does not receive the good and pays nothing.

This mechanism is simple and presumed to induce truth-telling. Individuals have the incentive, it is believed, to report their true maximum willingness-to-pay. This incentive is supposedly "robust" in the sense that truth-telling is a dominant strategy and therefore independent of risk attitudes and even of whether the individual is an expected-utility maximizer. Recent claims that the BDM is incentive-compatible (without conditions) for non-random goods can be found in Davis and Holt (p. 461), Kahneman, Knetsch, and Thaler (p. 1336; KKT), Rutstrőm (p. 428), and Shogren *et al*. (p. 98).

This presumption about the BDM is false. In an important paper, Karni and Safra showed that the BDM is not incentive compatible when the object being valued is a lottery. The applicability of this result to the case of non-random goods has not been recognized. I show in this paper that the BDM is not incentive-compatible even when the individual is perfectly certain about the utility he will receive from the good.

The argument is as follows. The "value" an individual places on an item is not independent of the circumstances in which he is asked to pay for it. Under the BDM, the individual is uncertain how much he will be asked to pay. Thus, his willingness-to-pay would reasonably be expected to depend on the distribution of potential costs. In general, the individual's theoretically optimal bid when he faces an unknown cost (that is, an *ex ante* demand revelation problem) need not be the same as his cut-off price in an *ex post* choice problem, in which he either buys or does not buy the good at a known price.

There is another simple way to frame this argument. After an individual reports his bid, he still faces uncertainty: uncertainty over whether his bid will be accepted and what the cost will be. Given that the nature of this uncertainty will be determined, in part, by his bid, it follows that his bid will depend on the distribution of potential costs.

The reason why the BDM has been presumed to show incentive compatibility appears to be the same trap that researchers fell into prior to Karni and Safra's paper. If the utility for an item is summarized by its value under certainty (the certainty equivalent, for lotteries) then the BDM does induce truth-telling, a result based only on dominance. This trap has led researchers, myself included, to wrongly think that a random price was irrelevant for items whose utility involved no uncertainty (Horowitz and McConnell; Horowitz, List, and McConnell). However, in general it is wrong to replace the preferences embodied in a utility functional with a certainty equivalent.

This non-incentive-compatibility result also holds for the Vickrey auction and, more generally, nth-price auctions (NPA), which are also common methods for demand elicitation.[1] The logic is the same as for the BDM: Because the potential cost of the item is random, an individual's bid is potentially affected by the distribution of costs (and his risk attitude.) Thus, the individual might not bid his true cut-off price.

We focus in this paper mainly on the BDM, however, because the auction literature has more often explicitly recognized the dependence of results on risk-neutrality or expected-utility maximization (*e.g.*, Kagel; Milgrom and Weber), even though this dependence is not always recognized.[2] One incidental role for this paper is as a reminder to researchers that most auction theory results depend on an assumption of expected utility, not simply dominance.

The main practical purpose of this paper is to help researchers who are interested in valuation and who must therefore choose, at times, between the BDM and the NPA. The Becker-DeGroot-Marschak mechanism and the nth-price auction differ in the distribution of costs that potential buyers face. Under the BDM, the distribution of costs that a buyer faces can be controlled by the researcher. Under the NPA, the distribution of costs depends on the subjects and cannot be controlled by the researcher. Which of these frameworks is most appropriate will depend on the researcher's purposes.

Under the NPA, a bidder will understand that the distribution of costs depends on what other individuals are willing to pay for the item.[3] The highest possible cost (*i.e.*, nth

[1]In an NPA, individuals submit a single round of sealed bids for n-1 items. The highest n-1 bidders get the items, but pay the amount of nth highest bid. A Vickrey auction has n=2.

[2]For example, Laffont's description of preference revelation, which is the source for the claim in Knetsch, Tang, and Thaler, mentions expected utility just once, somewhat obliquely, and without an explicit connection to the dominant strategy result.

[3]A second distinguishing feature of NPAs is that the distribution of costs is endogenous, and the Nash equilibrium therefore complex and not even necessarily unique (Neilson.) Equilibrium bids are,

highest bid) will be connected to the highest value that one of the subjects might place on an item. That is, a winning bidder will face "reasonable" costs that are tied to societal values for the item.

Under the BDM, the subject faces costs that may be "unreasonable," either particularly high or particularly low. Further, the ambiguity of the potential costs may be greater or less than under the NPA. For example, if the researcher tells subjects what the cost distribution is, then there is no ambiguity. On the other hand, if the researcher chooses to reveal nothing about the cost distribution, then the subject will be in a more ambiguous situation than under the NPA, where at least he can begin to assess his fellow subjects and their likely valuations for the item.

Finally, this inquiry is not without policy implications. Valuation questions (*i.e.*, those whose purpose is (ii) from the first paragraph) should attempt to mimic the decision that we truly face as a society. This framework thus suggests using a BDM to find public willingness-to-pay for some public project, with the distribution of costs equal to what we think the possible project costs actually might be. Any other valuation mechanism – whether a difference distribution of costs in a BDM or an auction-type mechanism – should be pursued only if the behavioral evidence suggests that these mechanisms are roughly equivalent.

Researchers will also want to know whether any of these effects are large enough to matter. This is the main topic of this paper.

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presumably, still closely tied to the underlying values (cut-off prices) that individuals place on the item.

2. Review of the Empirical Evidence

None of these results matter if, as an empirical finding, bids are largely unaffected by the distribution of potential costs. Although real-world decision makers often behave as non-expected utility maximizers, this regularity does not mean they will do so in a BDM setting nor, if they do behave as such, that this departure affects bids in any substantial way.

The BDM has been used primarily to value lotteries. Choice under uncertainty was the subject of Becker, deGroot, and Marschak's original 1964 paper. The BDM was particularly widely used in the late 1970's and 1980's in studying preferences over lotteries and then in uncovering preference reversal (*e.g.*, Grether and Plott). In 1987, Karni and Safra published their seminal paper on the non-incentive compatibility of the BDM for lotteries.

The first explicit migration of the BDM to non-random items that I can identify is Kahneman, Knetsch, and Thaler's 1990 study of willingness-to-pay for mugs. This shift in the item being valued seems not to have been remarked upon, either by KKT or others, and subsequent researchers adopted the BDM without any recognition of the drift in its application. Of course, this change from random to non-random items has no particular significance, so the lack of mention is not itself not significant.[4] Researchers did continue to use the BDM even after Karni and Safra (*e.g.*, Kachelmeier and Shehata.) This choice is perfectly understandable given the intuition and ease of the BDM and the

[4]To be precise: After Karni and Safra, researchers would be correct in not using the BDM to value lotteries, but they would have believed themselves to be on firm ground in using it to value non-random items. In retrospect, the shift in item type is still not important, because the mechanism is similarly non-incentive-compatible even for non-random items.

fact that Karni and Safra did not attempt to show empirically that the NEU effect was substantial.

There is at least one earlier "non-explicit" use of the BDM for non-random items; that is, a research design in which a BDM was used without its being explicitly labeled as such. Loewenstein used a BDM in his 1988 paper on intertemporal choice. I suspect that other such applications exist.

The empirical evidence regarding risk attitudes is either hard to tease out or sparse. Researchers could, in principle, use results from BDM experiments involving lotteries to infer the nature of the preference functional for choice uncertainty *taking into account the role of the BDM* (but see Keller, Segal, and Wang.) These inferences would be extremely difficult to draw, however, given the complex uncertainty that individuals face in these situations.

Inferences should be easier to draw from situations where the BDM or a similar mechanism is used to value *non-random* items. This is the approach taken by the current paper. Such evidence could come from studies where the distribution of potential costs differed across experiments. This is a rather small group of studies. We divide it into five groups. Only non-random items are considered.

1. *BDM with different distributions of random cost*. This situation is the most explicitly connected to our paper. The sole paper that we have found that examines this issue directly is Bohm, Lindén, and Sonnegård, who used a BDM to elicit willingness-to-pay for 30 litres of petrol. There were three relevant treatments based on the highest possible randomly-drawn cost, denominated in Swedish kronor: (a) Upper limit = 225, the approximate market value of the item. (b) Upper limit = 300. (c) Upper limit not

revealed, but described as not exceeding what the researchers thought was the highest amount an experimental subject would be willing to pay.

The main result is that bids were significantly higher when the explicit upper limit was higher and above the market value (a *vs*. b). This is the most direct evidence that the distribution of potential costs affects subjects' bids. The authors report that there was no significant different between (a) and (c). Yet another treatment in which the upper limit was not revealed, but with no claim about its magnitude, also gave bids significantly higher than (a).

2. *BDM compared to* 2^{nd}*-price auctions*. Recall that the BDM and Vickrey auction differ in the distribution of prices that a winning bidder might expect to pay. The two mechanisms also differ in the explicitness of that distribution.

Rutström used a BDM and Vickrey auction to elicit values for a box of gourmet chocolates. Her BDM had an explicit distribution with an upper bound of $48, clearly much higher than the item's value. She found average bids significantly lower (by about 50 percent) in the BDM than the Vickrey auction.

Shogren *et al*. used a BDM and Vickrey auction to elicit values for candy bars and mugs. The BDM had an explicit upper bound that appears to have been roughly twice as high as the item's market value. The analysis focused on the WTA/WTP ratio and its behavior over multiple trials rather than on a comparison of BDM and Vickrey bids. If we focus on mean WTP bids in the first trial, then average bids were higher in the BDM than in the Vickrey, although the differences do not appear to be significant. In the 10^{th}

trial, mean WTP bids were consistently lower (by roughly 30 percent) in the BDM. This latter result is similar to Rutström.[5]

Lusk, Feldkamp, and Schroeder used four mechanisms (BDM, Vickrey, random-n^{th}-price, and English auction) to elicit willingness-to-pay for different kinds of beef. They found that BDM bids were significantly below Vickrey bids.

3. *N^{th}-price auctions with different values for n.* This paper is interested in how bidding behavior is affected by the distribution of potential prices. With auctions, the experimenter has limited ability to control that distribution; furthermore, he will not, in general, be able to describe the distribution *ex ante* to the bidders. The main form of control is the experimenter's choice of *n* in an n^{th} price auction.[6] The experimenter affects the distribution of the price through his choice of *n* because the distribution of the n^{th} highest price is shifted to the left of the $(n-1)^{th}$ highest price.[7] Several papers have compared Vickrey (2^{nd} price) auctions with n^{th}-price auctions where $n > 2$.

Shogren *et al*. used a random-n^{th}-price auction; that is, *n* was randomly chosen after bids were submitted ($n > 2$). We again focus on the first and 10^{th} trials. In each of the comparisons, three of the four mean WTP bids were higher in the random-n^{th}-price auctions than in the Vickrey auctions. The significance of the differences was not reported.

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[5]Comparison of experiments that have multiple trials with experiments that have a single binding trial is complicated. The first of multiple trials seems the best analog, but subjects may not behave the same in a multiple trial experiment when they know they will have future chances to get their bids "right."
[6]For expected utility maximizers, n^{th}-price auctions are incentive compatible for $n > 1$. (Kagel and Levin dispute this claim.)
[7]Note that for any given distribution of bids, the $(n-1)^{th}$ highest bid will be higher than the n^{th} highest bid. The support for these bids is the same, however. The claim follows.

Knetsch, Tang, and Thaler used a Vickrey and a ninth-price auction to elicit values for an embossed mug. Mean WTP bids were higher in the Vickrey auctions than the ninth-price auctions.

Lusk, Feldkamp, and Schroeder found that random-n^{th}-price bids were significantly below Vickrey bids.

4. *Incentive compatibility for induced values vs. "home-grown" values.* This paper's argument implies that the BDM and the n^{th}-price auction should be incentive compatible for induced values (values that are assigned to the participants, denominated in money terms), but not necessarily so for home-grown (participant-generated, derived from utility) values.

Irwin *et al*. studied the BDM using induced values and concluded that, for these values, the BDM as typically administered is incentive compatible. This conclusion is probably too strong for the data, since over one-third of the bids were not within the optimal range. Most of the erroneous bids were overbids. In a second treatment, Irwin *et al*. varied the distribution of the random cost; they found that this distribution had no significant effect on bids.

Kagel, Harstad, and Levin showed that Vickrey bids in induced value situations tended to be above the true valuation, a result that at least two later studies confirmed (Harstad; Kagel and Levin). Kagel and Levin also examined induced-value third-price auctions and found that third-price bids were higher than second-price bids on average.

Noussair, Robin and Ruffieux compare the BDM with a Vickrey auction using induced values. Their technique had the interesting feature that the distribution of random prices was the same distribution as the random induced values; this feature, roughly speaking, makes the Vickrey and BDM bidders face exactly the same distribution of random prices. Noussair, Robin, and Ruffieux found that both types of bids tended to be below valuations, although with repetition, Vickrey bids approached the valuation. Average BDM bids were consistently less than average Vickrey bids.

5. *Open-ended versus closed-ended valuation.* The most direct evidence about the incentive compatibility of the BDM or NPA should, in principle, come from comparing these mechanisms, which are both open-ended (*i.e.*, the subject's report is a continuous value), to dichotomous choice or closed-ended mechanisms (the subject's report is yes or no to a given offer.) Indeed, this is precisely the comparison that led to the uncovering of preference reversal for lotteries.

For non-random goods, there is a general belief that open-ended responses tend to be smaller than closed-ended responses (see reviews in Brown *et al*.; Huang and Smith; Schulze *et al*.; a more recent study is Bohara *et al*.). Unfortunately, none of the studies cited uses a BDM or NPA. Instead, the open-ended surveys either tend to have ambiguous incentives for truthful revelation or have clear incentives for free-riding. Thus, they provide little insight for this study.

Conclusion. There are two salient findings: (i) BDM bids are fairly consistently lower than Vickrey bids. (ii) BDM bids are not much affected by the underlying distribution of prices. This conclusion, however, is indirect and there is one prominent exception. A third conclusion is that this is a very small set of studies from which to draw inferences, and more research would be valuable.

Regarding the indirectness of (ii): BDM bidders face a distribution that is most easily characterized by the upper limit of potential prices. Yet BDM bids were equal to or below Vickrey bids when the upper limit was roughly the value of the item (Noussair, Robin, and Ruffieux); when it was twice the value of the item (Lusk, Feldkamp, and Schroeder; Shogren *et al*.)[8]; and when it was substantially above the value of the item (Rutström).

Note that Vickrey bidders in all auctions always face the same distribution of potential prices, roughly speaking; it is the distribution of "values in society." Thus, if the Vickrey bidding strategy is roughly the same across experiments, then BDM bidding is roughly independent of the underlying distribution of prices.

The prominent exception to this finding is Bohm, which showed that increasing the upper limit by 33 percent caused BDM bids to increase by 16 percent. One likely explanation, however, is that the upper limit (for this clear market good) was treated as an indication of current and future market prices, so that underlying valuations also rose, which would imply that behavior in (b) is not really different from (c).

3. Further comments

This evaluation of BDM and Vickrey bids is instructive and may find practical uses in the field. There are many elements, however, that complicate any conclusions about risk attitudes.

First, induced value experiments, which should be incentive compatible regardless of risk attitudes, do not yield incentive compatible responses; we feel that Irwin *et al*. are not very convincing that BDM is incentive compatible for induced values. Second, the invariance of the BDM with respect to the price distribution appears to contradict (in terms of a role for risk attitudes) the persistent difference between the

[8]Some of Shogren *et al*.'s results show BDM > Vickrey, although the magnitudes are small.

Vickrey and BDM. Third, the evidence from the four studies with n^{th} price auctions does not yield a consistent picture; furthermore, all of the authors attribute the differences to strategic effects rather than risk attitudes. Fourth, many studies have argued that there is a large role for subject error in these kinds of experiments (Harrison; Hey and Schmidt; see also Hey and Orme; Harless and Camerer), and this role may be particularly large in pricing experiments (Morone and Scmmidt), of which BDM and Vickrey are members. None of these regularities detracts from the two main findings, but they do complicate any inference about the role for risk attitudes.

The larger question, still unanswered, is whether bids in the BDM or Vickrey auction are equal to an individual's cut-off price. The dual to this claim is that while it seems reasonable to entertain the possibility that reported bids will be affected by the distribution of potential costs (because of non-EU preferences), it is not clear what properties any alternative non-EU model should have. These questions require further research to answer.

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