

**Combining Responses to Actual and Hypothetical Offers to Estimate WTA  
for Highly-Polluting Clunkers : Ordered Probit with Distinct, Noisy and Biased Bounds**

Edward R. Morey  
Department of Economics  
Campus Box 256  
University of Colorado  
Boulder CO 80309-0256  
[Edward.Morey@Colorado.edu](mailto:Edward.Morey@Colorado.edu)

Tymon S. Lodder  
Regional Air Quality Council  
1445 Market Street, Suite 260  
Denver, CO 80202

June 1999

*Abstract*

Accelerated vehicle retirement programs (AVRP) are receiving increasing attention as a possible means of cost effectively reducing air pollution. Whether AVRPs are efficient depends on the cost of acquiring vehicles as a function of the amount of pollution they produce. This paper estimates an individual's willingness to accept (WTA) an offer price for his or her vehicle in an AVRP. Data was collected from a pilot program in Denver.

Available information includes: the owner's response to the AVRP's actual offer of \$1000, and the owner's response(s) to hypothetical offers from the AVRP. The data is a combination of revealed and stated preferences. Our emphasis is on the information content of the responses to the hypothetical offers.

One model is a multiple-interval ordered probit model of WTA that assumes bounds generated by responses to actual offers are distinct and bounds generated by responses to hypothetical offers are noisy. A special case is the conventional all-bounds distinct. A more restrictive case is bounds generated by hypothetical offers are discarded.

The distinct/noisy model statistically dominates all-bounds distinct; both generate similar predictions. In contrast, discarding the bounds generated by the responses to the hypothetical responses generates significantly different predictions. Parameter estimates indicate that an individual's willingness to sell to an AVRP is a function of the characteristics of the vehicle, not the owner. A second model investigates the possibility that hypothetical responses are systematically biased.

While the application here is WTA for clunkers, the model could be used to estimate WTA or WTP (willingness to pay) with any data that provides bounds but where the responses that generate the bounds are thought to vary in informational content.

The authors would like to thank Bill Breffle, Nick Flores, Phil Graves, Howard Grunspecht, Steve McCannon, Harry Paarsh, Ken Small, and Don Waldman for their input and comments. We would also like to thank Total Petroleum for providing the funding to purchase the vehicles and gather the survey information. The surveys and data can be obtained from either author.

The intent is to estimate the minimum price an individual must be offered to sell her vehicle in an *Accelerated Vehicle Retirement Program* (AVRP). Refer to this minimum price as the individual's willingness to accept, WTA. The individual's WTA is a function of the characteristics of the vehicle and the characteristics of the individual. If  $WTA_i \leq P_i$ , where  $P_i$  is the price offered to individual  $i$  by the AVRP, individual  $i$  will sell the vehicle; if  $WTA_i > P_i$ , individual  $i$  will reject the offer.

Alberini et al. (1995 and 1996) estimate and discuss such a model with data from a 1993 AVRP in Delaware. While there is other literature on AVRPs, we know of no other models that estimate participation in an AVRP as a function of the offer price and characteristics of the vehicle.

AVRPs have been proposed as a cost-effective way of reducing aggregate auto emissions. These programs attempt to purchase older and/or poorly operating vehicles; hereafter, clunkers. Per mile, clunkers emit many times the level of pollution emitted by newer, well-maintained vehicles, so if the stock of such vehicles can be reduced; aggregate emissions will decrease. However, whether AVRPs are an efficient way to reduce aggregate auto emissions depends in part on the cost of acquiring the vehicles and the amount of pollution they produce. The program goal is to purchase highly polluting vehicles at low prices. Our intent is to estimate the probability that a vehicle will be purchased as a function of the offer price, factors influencing the retail value of the vehicle, how much the vehicle is driven, the owner's perception of her vehicle's emissions levels (such perceptions can be influenced by policy), and other characteristics of the owner.

Data is available from a pilot AVRP in Denver, Colorado. This pilot program, called the Total Clean Cars Program (TCCP) was funded by Total Petroleum and administered by the

Regional Air Quality Council. Vehicles were purchased from December 1993 - April 1994.

Vehicles were chosen for inclusion in the program from three groups of high polluting vehicles: vehicles for which the State's emissions standards have been waived; vehicles identified as high polluters by remote sensing; and vehicles reported to the *Smoking Vehicle Hotline*.<sup>1</sup>

Approximately one thousand owners were sent solicitation letters that described the program, described Denver's pollution problems, and offered to purchase the individual's targeted vehicle for \$1000. Those sent offers included all of the Denver owners of waived vehicles, all vehicles identified as high polluters by remote sensing, and all vehicles identified by the hotline number. Two hundred and seventy one vehicles were purchased and the owners filled out a participants' questionnaire when they surrendered the vehicle. Individuals who did not accept the offer within four weeks of the mailing were sent a second letter that repeated the offer and included a survey to fill out if the individual chose not to accept the \$1000 offer.<sup>2</sup> Two hundred and nine of those who were sent solicitation letters both rejected the offer and completed the nonparticipant questionnaire. Many of the remaining owners could not be located by mail, registered mail, or phone; some owners were ineligible because the vehicle had already been sold.<sup>3</sup>

---

1 All vehicles registered in the front range of Colorado require emissions permits; however, some vehicles receive permits even though they cannot fulfill the State's emissions standards for the vehicle's model and year. Specifically, the standards are waived for vehicles that can not pass the test even after the owner has spent at least \$50 on emissions related repairs if the vehicle is pre-1982 and \$200 if the vehicle is newer. Remote sensing uses a device that when pointed at a vehicle's exhaust measures the composition of the vehicle's emissions. The *Hotline* is a telephone number citizens can use to report the license numbers of visibly polluting vehicles.

2 Nonparticipants were promised and sent a coupon for \$5 of gas when their questionnaire was returned.

3 Ninety two of the letters were returned as undeliverable and attempts to locate the owners by telephone determined that an additional 32 of the addresses were incorrect. Of the remaining 294 letters outstanding, no telephone number could be found for 259 of these owners, so this group of 259 likely contains many individuals who did not receive the offer. Only 35 of the nonparticipants that were successfully contacted refused to answer the survey. The response rate for those contacted is approximately 75%.

The sample is representative of the vehicle owners in the targeted groups who can be found at a reasonable cost, and is a large proportion of the total number of vehicles in these target groups. Owners of old and poorly maintained vehicles will often be difficult to find. They tend to be poorer and more transient than members of the general population; they are also more likely to be non-English speaking.

Table 1. lists the information solicited from the surveys and other sources on the socioeconomic characteristics of the vehicle owner and his or her family, characteristics of the targeted vehicle, commuting distances, and perceptions with respect to pollution and other urban problems. Total Petroleum insisted that everyone contacted be offered the same price, \$1000. We would have preferred to have had variation in the offer prices. This restriction turned out to be severely limiting. We asked those individuals who accepted the \$1000 offer if they would have accepted a specific lower amount (we randomly choose either \$800 or \$600)<sup>4</sup>. Those who said they would have accepted an offer of \$800 were then asked if they would have accepted an offer of \$600. Those who were initially offered \$600 and said they would have accepted \$600, were then asked if they would have accepted an offer of \$400. Alternatively, those individuals who rejected the \$1000 offer were asked if they would have accepted a specific higher amount (we randomly chose either \$1400 or \$1600). Individuals who said they would have accepted an offer of \$1400 were then asked if they would have accepted an offer of \$1200. Those who said they would have accepted an offer of \$1600 were then asked if they would have accepted an offer of \$1300.

---

4 Before answering, individuals had the check for \$1000 in hand.

<b>Table 1. Description of Variables</b>	
Variable	Description
PART	Dummy variable: 1= accepted \$1000 offer
WAIV	Dummy variable: 1 = waived vehicle
HOTLI	Dummy variable: 1 = hotline identification
MODELYR	Model year of targeted vehicle
OWN	Q1. How long vehicle has been owned
MILES	Q2. Vehicle miles driven last year (1= <3500, 2= 3500 to 7000, .. 5= >13,000)
TOTMIL	Q3. Vehicle miles driven last Monday
COND	Q4. Condition of vehicle (1-5, 1=excellent, 5= very poor)
ADPRICE	Q5. What owner thought vehicle would sell for if advertised in paper
KEEP	Q6. How long owner expected to keep vehicle
POLLUTE	Q9. Perception of how much owner thinks vehicle pollutes compared to other vehicles (1-6, 1=less, 6= fifteen times as much )
MAINTAIN	Q10. Cost to maintain vehicle for 1 more year (1-6, 1= # \$100, 6= \$ \$500)
NUMVEHIC	Q11. Number of vehicles in household
DENPOLL	Q13. Contribution of Automobiles to Denver pollution (1-4, 1= #10%, 4= \$90%)
RACE	Q.15 What best describes you? (1=African American, 2=Asian, 3=Caucasian,...)
BORN	Q17. Year born
EDUC	Q19. Level of education completed
ADULTS	Q20. Number of adults in household
CHILDREN	Q20. Number of children in household
FULLTIME	Q20. Fulltime workers in household
TOTWORK	Q20. All work miles added up
SCHOOL	Q20. Number of household members in school
LICDRIVE	Q20. Number of licensed drivers in household
RETIRE	Q20. Number of retired people in household
WAGE	Q21. Average hourly wage
INCOME	Q22. Household income
BLUE	Blue Book value
WTAH	Q.14 Willingness to Accept high
WTAL	Q.14 Willingness to Accept low

Consider the two types of offer information collected. The initial offer of \$1000 caused the individual to reveal her preferences and either accept or reject the offer; that is, the individual's response committed her to either her vehicle or \$1000. In contrast, the offers at the other amounts were hypothetical, so the individual's answer committed her to nothing. The collected information on each individual's WTA is therefore a combination of *revealed* and *stated preference data*. An important question is whether the stated preference data provides the same amount of information as the revealed preference data, and whether the responses to hypothetical offers are somehow biased.

The responses to the offers generate interval data. We assume the individual's response to the \$1000 offer correctly identifies whether the individual's WTA is in the interval  $\#$  \$1000, or in the interval  $>$  \$1000. The hypothetical questions are intended to provide information that can be used to further restrict the WTA interval. This hypothetical response data suggests a narrower bound. For example, if the individual accepted the offer of \$1000, accepted the hypothetical offer of \$800, but rejected the hypothetical offer of \$600, the suggested WTA interval is  $600 < \text{WTA} \# 800$  and the interval is completely determined by the hypothetical responses. Alternatively, if the individual accepted the offer of \$1000, but rejects the hypothetical offer of \$800, the suggested WTA interval is  $\$800 < \text{WTA} \# \$1000$ , where the upper bound is determined by observed behavior and the lower bound is determined by a response to a hypothetical question. We use the adjective *suggest* because we admit the possibility that the individual's WTA might lie outside the bound or bounds suggested by the responses to the hypothetical offers.

Approximately half of the participants had suggested WTA intervals of either \$600-\$1000 or \$800-\$1000.<sup>5</sup> Those who participated thought their cars would sell for an average of \$699 if advertised in the paper, and those who chose not to participate thought their cars would sell for

---

<sup>5</sup> This is consistent with records compiled by the Colorado Department of Motor Vehicles that indicate the average sale price of pre-1982 vehicles is \$820.

an average of \$2,200. Owner's might sell the vehicle to an AVRP for a lower price than what it would sell for in the newspaper because there are significant transactions costs associated with selling a clunker through the paper, and selling to AVRP means the owner has contributed to reducing pollution. Fifteen percent of the owners indicated they would have accepted an offer from the AVRP that was less than ADPRICE. Alternatively, and equally reasonably, a third of the sampled owners rejected offers greater than ADPRICE. Doing so, reveals that their value of the vehicle exceeds its ADPRICE.

The first estimated model - denoted distinct/noisy - is a multiple-interval ordered probit model of WTA that assumes the bounds generated by the responses to the actual offers are distinct but the bounds generated by responses to hypothetical offers are noisy.<sup>6</sup> A special case is all-bounds distinct. A more restrictive case is bounds generated by responses to hypothetical offers are discarded (only revealed preference data used). The second estimated model - the hypothetical bias model - is a multiple-interval ordered probit model that allows the bounds suggested by the responses to a hypothetical offers to be biased.

Before detailing the specifics of the two models, we highlight some differences between this study and Alberini et. al (1995 and 1996). Those uninterested can skip directly to page 9. In some ways the surveys and models are quite similar, but in some ways quite different. The Delaware study actual offer price was always \$500, and those solicited were told that 125 cars would be purchased on a first come, first served basis. Approximately 3300 of the 4300 offer letters sent were sent to owners of pre-1980 vehicles randomly chosen from motor vehicle records, so not specifically high polluters. The other thousand were sent to most of the owners of pre-1980 waived vehicles. Most participants were surveyed but only a small subsample of nonparticipants. Those surveyed were asked to indicate the interval that contained their WTA in

---

6 We initially used the term *fuzzy* but switched to noisy so as to not suggest any relationship between this model and the notion of fuzzy sets.

\$100 intervals up \$500 if they accepted the \$500 offer, and \$100 intervals from \$500 to \$1000 if they rejected the \$500 offer. Exact WTA was asked of each nonparticipant that indicated her WTA was greater than \$1,000.

Our intent was to identify high polluters and then estimate participation and WTA for the population of high polluters that can be contacted at a reasonable cost. We feel that our sample is representative of this group. The intent of Alberini et al. (1995) was to estimate participation and WTA for the population of pre-1980 vehicles. However, as they explain, their sample is not representative of pre-1980 vehicles for three reasons: (1) approximately 1/3 of their sample is waived vehicles but less than 2% of pre-1980 vehicles are waived, (2) only a small proportion of their nonparticipants were interviewed, and (3) only 70% of those who desired to participate were interviewed. They adjust for these misrepresentations by assuming that those surveyed are representative of those not surveyed in terms of both whether they participated and whether their vehicle was waived, and then by weighting the observations in the likelihood function by estimates of the population proportions for participation and nonparticipation for waived vehicles and nonwaived vehicles, but such weights are difficult to construct.<sup>7</sup>

While our solicitation letter indicated a firm offer to purchase the vehicle, the Delaware solicitation letter indicated that only 125 vehicles would be purchased on a first come, first served basis.<sup>8</sup> While the recipient of the letter did not know how many solicitation letters were sent, the stated quota of 125 suggests that more than 125 owners will want to sell, and that the longer the

---

<sup>7</sup> Implicit in the construction of the weights is the assumption that the percentage successfully surveyed from the group of owners of nonwaived vehicles that were sent letters but did not participate, is the percentage of the population of nonwaived pre-1980 cars that would not accept the \$500 offer. This is a strong assumption. One justification for it would be that all those who were sent letters received the letter and decided whether to participate. This assumption seems implicit in their weighting scheme but is not stated. They do not report the percentage of letters returned as undeliverable or what percentage of the nonparticipants they attempted to survey they could not contact. In the Colorado program these percentages were quite high.

<sup>8</sup> Forty-eight owners wished to participate but could not because the quota had been met. These individuals were not surveyed.

recipient waits to accept the offer the greater the probability that their offer will not be accepted. For individuals who needed time to determine whether their WTA was below or above \$500, the quota might have significantly decreased the probability of calling to participate. Why bother to agonize over a deal if the deal is likely to be gone before the agonizing is over.

Alberini et al. (1995) estimate two types of models. In both models they found the following variables to be significant determinants of participation: the residual life of the vehicle, the bluebook value of the vehicle, the condition of the vehicle, and the anticipated expenses for the vehicle over the next year<sup>9</sup>. The first model assumes the individual has some constant WTA, and assumes the bounds on all WTA intervals are distinct independent of whether they were generated by the response to the actual offer of \$500 or a bound based on their stated interval from the payment card; that is, no hypothetical noise or bias.

Their second model specifies two separate  $\ln(\text{WTA})$  functions: one for the response to the actual offer, and one for the responses to the hypothetical offers. Specification of two separate WTA functions introduces the possibility that either the actual offer, the time between the actual and hypothetical offer, or some other factor caused the individual's preferences to change, and so his or her WTA. While changing preferences is an interesting possibility, Alberini et al. (1995) find little evidence for a preference change.<sup>10</sup> It is the possibility that responses to hypothetical offers contain less information about preferences or that they provide biased information that we find more interesting.<sup>11</sup>

---

9 Looking ahead, we also found Bluebook value, condition, and anticipated expenses to be significant determinants of participation.

10 Acquiring more information on the market value of the solicited vehicle and/or possible replacements might cause WTA to change. Deciding to sell at the actual offer price will at a minimum provoke the individual to acquire more information on the market value of possible replacements, and this new information could change his WTA for the old vehicle. In addition, one might acquire more information in response to the \$500 offer, independent of whether the offer was accepted or rejected, to determine whether one should regret or be content with his or her initial decision.

11 Alberini et al. (1996) estimate the expected life of a vehicle as a function of the vehicles characteristics and the  
(continued...)

## I. A Multiple-Interval Ordered Probit Model with Bounds that are Sometimes Distinct and Sometimes Noisy.

Assume

$$(1) \ln WTA_i = E(\ln WTA_i) + e_i + a + \beta X_i + e_i \quad i=1,2,\dots,N.,$$

where  $e_i$  is normally distributed  $N(0, s_{\ln WTA}^2)$ ,  $a$  is a scalar,  $\beta$  is a vector, and  $X_i$  is a vector of the relevant characteristics of individual  $i$  and her vehicle.<sup>12</sup> Equation (1) restricts  $WTA_i$  to be positive and implies that the distribution of  $WTA_i$  is skewed with a longer tail to the right, a specification consistent with the requirement that no  $WTA$  can be lower than the \$30 scrappage value, and consistent with individuals who require unusually large sums to part with his or her vehicle. We leave implicit the utility maximizing theory that implies  $WTA$  as a function of the characteristics of the car and owner.

Consider the possibility that the responses to hypothetical offers to sell contain less information than do the responses to actual offers. An individual does not walk around with her  $WTA$  at her cognitive fingertips. Introspection is required to determine if one's  $WTA \neq P_i$ .<sup>13</sup> If the offer is an actual offer, the individual cogitates long enough, but only long enough, to

---

11 (...continued)

owner's characteristics. We do not estimate expected life. Like  $WTA$ , remaining life is an important factor in determining the pollution reduction benefits that would result from an AVR.

12 Ordered probit models were developed by Zavoina and McElvey (1975) and are discussed in Green (1993). See Cameron and Huppert (1989) for an example of an ordered probit model of WTP.

13 Correct decisions require information, a decision process, and a sufficient allocation of time to the process. Given all the information, the decision process could be viewed as one of recovering one's preferences. Mistakes will be made if information is incomplete and/or the individual does not know her preferences perfectly well. That information is costly and decisions made with incomplete information can be wrong has a long tradition in economics and other behavioral sciences, and so does the notion that individuals have preferences but do not have instantaneous and costless access to their preferences. See, for example, DePalma, et al. (1994).

determine with certainty whether  $WTA_i \neq P_i$ .<sup>14</sup> So,  $WTA_i > WTA_{Li}$ , where  $WTA_{Li}$  is the highest actual offer the individual rejected and  $WTA_i \neq WTA_{Hi}$ , where  $WTA_{Hi}$  is the lowest actual offer the individual accepted. Recollect that each individual was made an actual offer of \$1000, so for each individual we observe either  $WTA_{Li} = \$1000$  (those who reject) or  $WTA_{Hi} = \$1000$  (those who accept)<sup>15</sup>. In addition, assume those who accepted the \$1000 offer ( $WTA_{Hi} = \$1000$ ) have  $WTA_{Li} = \$30$  (the scrap value), and those who rejected the \$1000 offer have  $WTA_{Hi} = \$10,000$ , a dollar value that is (almost) certainly higher than the value of the car.<sup>16</sup> Looking ahead, the empirical results are insensitive over a fairly wide range to the choice of the upper bound.

If the offer is hypothetical, the individual has less incentive to determine whether  $WTA_i \neq P_i$ .<sup>17</sup> Denote the highest hypothetical offer an individual rejected *Suggested Willingness to Accept Low* ( $SWTA_{Li}$ ), and denote the lowest hypothetical offer an individual accepted *Suggested Willingness to Accept High* ( $SWTA_{Hi}$ ). Interpret  $SWTA_{Li}$  and  $SWTA_{Hi}$  as  $WTA_{Li}$  and  $WTA_{Hi}$  measured with error; error resulting because the individual can be cavalier and sloppy with decisions that are not binding.

Bounds that are based on responses to hypothetical offers are assumed to be noisy; that is, a true bound lies in a finite interval around the suggested bound.<sup>18</sup> Specifically,

---

14 We assume that individuals have the ability to determine with certainty whether their WTA is below a specific amount, that the individual has the incentive to use all of this ability when the offer is actual, but the individual does use all of this ability when the offer is hypothetical.

15 Given the offer is nonnegotiable and binding, such behavior is incentive compatible.

16 The average vehicle year of the solicited vehicles was 1977, and the average suggested bluebook value was \$2,159.

17 Allocating time to a specific decision is costly (Shugan (1980)), so when the offer is hypothetical, the individual have an incentive to allocate less time than is needed to determine with certainty whether WTA is less than the amount offered. That is, the process an individual uses to make a decision differs depending on the consequences of the decision.

18 There is literature that assumes individuals do not have the ability to determine with certainty which choices are optimal, so individuals use simple myopic rules to make decisions. See, for example, DePalma et al. (1994), Herstein (1991), March (1978), and Newell and Simon (1972). Quoting DePalma et al.,

Thus, within our framework, individual choice behavior can only be determined up to a probability

(continued...)

$$(2) \quad SWTA_{Li} = WTA_{Li} + \mu_i$$

where  $\mu_i = 0$  if  $SWTA_{Li} = \$30$  or  $\$1000$ ; otherwise  $\mu_i$  has a discrete uniform distribution over  $-\$99/m, -\$66/m, -\$33/m, 0, \$33/m, \$66/m, \$99/m$ ;  $m \in \mathbb{N}$ . The distributional assumption on  $\mu$  is a simple discrete approximation to a continuous uniform distribution from  $-\$99/m$  to  $\$99/m$ , where  $m$  is an estimated parameter. And,

$$(3) \quad SWTA_{Hi} = WTA_{Hi} + \eta_i$$

where  $\eta_i = 0$  if  $SWTA_{Li} = \$1000$  or  $\$10,000$ ; otherwise  $\eta_i$  has a discrete uniform distribution over  $-\$99/m, -\$66/m, -\$33/m, 0, \$33/m, \$66/m, \$99/m$ ;  $m \in \mathbb{N}$ . Each of the  $(\mu_i, \eta_i)$  pairs occurs with probability  $\frac{1}{49}$ .

Noise is greatest when  $m = 1$  and approaches zero (distinct bounds) as  $m \rightarrow \infty$ . An important issue is the range on the  $\mu_i$  and  $\eta_i$ . Allowing a true but unknown bound to be no more than plus or minus  $\$99$  of the suggested bound greatly simplifies the model; given that a number of the suggested intervals are  $\$200$ , a range of greater than plus or minus  $\$99$  would admit the probabilistic irrationality that  $WTA_{Li} > WTA_{Hi}$ . The assumption that noise has a uniform distribution is obviously a simplifying assumption. It is a place to start the investigation of the distribution of hypothetical noise.<sup>19</sup>

The probability of observing a  $\{SWTA_{Li}, SWTA_{Hi}\}$  pair; conditional on  $\mu_i, \eta_i$ , and  $E(LnWTA_i)$  is

---

18 (...continued)

distribution which serves as a "black box" to summarize complex behavioral aspects of the individual.

Such ambiguity in choice predictions is deeply rooted in the real world. It arises because individuals may not know their preferences perfectly well...

Adopting an assumption that individuals use suboptimal decision processes, but can adopt decision processes that require more or less ability depending on the consequences of the decision that needs to be made, would imply a model where all of the bounds are noisy, but bounds based on the responses to hypothetical offers are more noisy.

19 Alternatively one might assume a nonuniform distribution such as a triangular distribution with zero mean.

(4)  $Prob(SWTA_{Li} \text{ and } SWTA_{Hi} \in [\mu_i, \mu_i + a\beta X_i])$

$$= F\left(\frac{\ln(SWTA_{Hi} \text{ and } \mu_i) - E(\ln WTA_i)}{S_{\ln WTA}}\right) - F\left(\frac{\ln(SWTA_{Li} \text{ and } \mu_i) - E(\ln WTA_i)}{S_{\ln WTA}}\right)$$

where  $F$  is the standard normal CDF. The log of the likelihood function for the sample of 480 individuals is therefore:

(5)

$$\log L = \sum_{i=1}^{480} \sum_{k=1}^7 \sum_{\mu_i=1}^7 \ln\left(\frac{1}{49} \left[ F\left(\frac{\ln(SWTA_{Hi} \text{ and } \mu_i) - E(\ln WTA_i)}{S_{\ln WTA}}\right) - F\left(\frac{\ln(SWTA_{Li} \text{ and } \mu_i) - E(\ln WTA_i)}{S_{\ln WTA}}\right) \right]\right)$$

where  $\mu_1 = 0 \text{ or } 1$  if  $SWTA_{Li} = \$30$  or  $\$1000$ ; otherwise  $\mu_1 = -99/m$ ,  $\mu_2 = -66/m$ ,  $\mu_3 = -33/m$ ,  $\mu_4 = 0$ ,  $\mu_5 = 33/m$ ,  $\mu_6 = 66/m$ ,  $\mu_7 = 99/m$ ; and  $\mu_k = 0 \text{ or } k$  if  $SWTA_{Hi} = \$1000$  or  $\$10,000$ ; otherwise  $\mu_1 = -99/m$ ,  $\mu_2 = -66/m$ ,  $\mu_3 = -33/m$ ,  $\mu_4 = 0$ ,  $\mu_5 = 33/m$ ,  $\mu_6 = 66/m$ ,  $\mu_7 = 99/m$ ;  $m = \$1$ . The parameters are  $a$ ,  $\beta$ , and  $m$ .

The estimated  $\beta$  parameters (asymptotic  $t$  statistics in parentheses) are

$$\begin{aligned} E[\ln(WTA_i)] = & 7.479 + .0001644*BLUE_i - .3284*MAINTAIN_i - .1335*WAIV_i \\ & (37.42) \quad (2.11) \quad \quad \quad (-4.92) \quad \quad \quad (-2.65) \\ & - .1069*COND_i - .0840*POLLUTE_i - .0210*MILES_i + .001247*TOTMIL_i \\ & (2.53) \quad \quad \quad (-3.67) \quad \quad \quad (-1.23) \quad \quad \quad (1.51) \\ & + .0002120*BLUE/COND - .00000002070*(BLUE)^2 + .0370*(MAINTAIN)^2 \\ & (3.19) \quad \quad \quad (-1.75) \quad \quad \quad (4.11) \\ & - .000002620*(TOTMIL)^2. \\ & (-1.85) \end{aligned}$$

The variables were defined in Table 1. Recollect that  $BLUE$  is the Blue book value,  $MAINTAIN$  is the cost of maintaining the vehicle for one more year,  $WAIV$  equals one if it is a waived vehicle,  $COND$  is the condition of the vehicle (levels 1-5),  $POLLUTE$  is the owners perception of how much the vehicle pollutes,  $MILES$  is the number of miles driven last year, and  $TOTMIL$  is

work miles, Likelihood ratio tests indicate that WAIV, MILES, TOTMIL, COND, POLLUTE, MAINTAIN, and BLUE are the significant determinants of WTA. None of the other collected variables were found to be significant.

The estimate of  $m$  is one, implying the maximum allowable range of plus or minus \$99 on the noisy bound. That estimation wants to allow for a larger range suggests that the way noise is specified is overly restrictive. Rationality on the part of the individual - he already knows whether his WTA is less than or greater than \$1000 - dictates a limited range, but the distributions are not necessarily uniform or have the same range.

For a vehicle of average condition (2.45), WTA is increasing in BLUE for BLUE up to \$6,061 and then decreasing, so WTA is increasing in BLUE over the relevant range. That it is eventually decreasing is an artifact of the simple functional form. WTA is decreasing in WAIV, COND and MILES; and decreasing in MAINTAIN for levels 1-4 and increasing for levels 5 and 6. (Mean MAINTAIN=3.3). WAIV, COND, and MILES are inversely related to the market value of the vehicle. WTA is increasing in TOTMIL up to 238 miles, and then decreasing - mean TOTMIL = 30. We did not have strong a priori expectations about the signs of the parameters on MILES and TOTMIL, which capture two offsetting influences. Both variables capture some of the owner's need for the vehicle in that driving more miles indicates a greater need for transportation services. Ceteris paribus, this factor should increase WTA. However, both MILES and TOTMIL are likely correlated with how many miles are on the vehicle, and, ceteris paribus, vehicles with more miles have lower market value. This factor should decrease WTA. We could not identify a variable that measured need, was independent of market value, and statistically significant.

How much one thinks their car pollutes relative to other vehicles has a significant negative influence on WTA. In fact, the two variables that have the largest impact on the probability of accepting the \$1000 offer, in terms of elasticities, are BLUE and POLLUTE. Any

dissemination of information that leads the owner to increase his estimate of how much his vehicle pollutes relative to other vehicles could reduce WTA and decrease the cost of the AVRP.<sup>20</sup>

Because WTP for reduced pollution is, in general, increasing in income, we hypothesized that this negative impact of POLLUTE on WTA is increasing in household income, but the influence of income is not significant.

Interestingly, WTA is, with the possible exception of POLLUTE, only a function of factors that influence the market price of the vehicle; that is, what one would expect in a perfect market, and not a function of socioeconomic characteristics of the owner such as income and education. This surprised us.

The model correctly predicts acceptance or rejection of the \$1000 offer for 77.3% of the sample, predicting acceptance for 189 of the 271 individuals who accepted the offer, and predicting rejection for 182 of the 209 individuals who rejected the offer.<sup>21</sup> The estimated  $s_{WTA}$  range from \$151 to \$4,249, increasing as a function of  $E(\ln WTA_i) + \alpha \% \beta X_i$ .

The estimated WTA range from \$227 to \$6,376, average \$1209, and 36% of the estimated WTA are in the suggested intervals. For comparison, ADPRICE is, on average, \$123 less. The AVRP eliminates the hassles associated with advertising and selling one's car. In addition, the AVRP solicitation letter is likely to increase an owner's awareness of pollution and their car's contribution to it, and selling the AVRP eliminates the vehicle's potential to pollute.

---

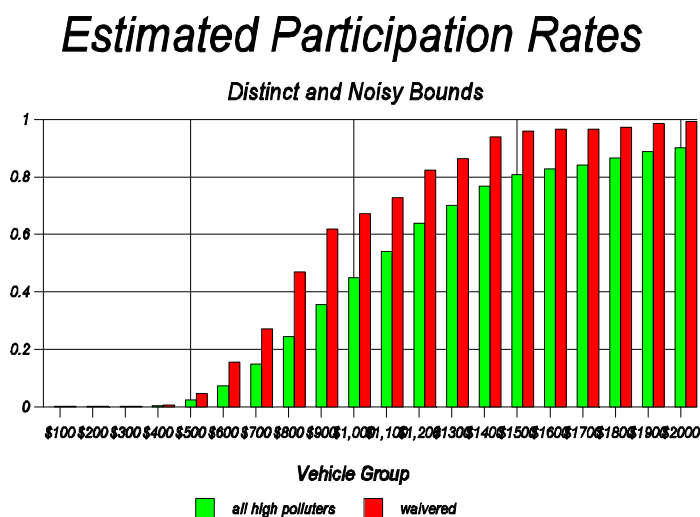
20 Extrapolating this result to the sale of cars and other vehicles suggests that the composition of new vehicles in terms of the amount they pollute per mile might be impacted by requiring dealers to specify how much the vehicle pollutes relative to other vehicles. Recently, the relative sales of low mileage, high polluting vehicles has soared.

21 Note that  $E(WTA_i) = e^{(E(\ln(WTA_i)) + (s_{\ln WTA}^2/2))}$  where  $s_{\ln WTA} = .43386820$  and the standard deviation of  $WTA_i$  is

$$s_{wtp_i} = [e^{2E(\ln(WTP_i))} e^{s_{\ln WTA}^2} (e^{s_{\ln WTA}^2} + 1)]^{1/2}.$$

Figures 1 shows

estimated participation rates as function of the offer price. The model predicts that 45% of contacted high-polluting vehicles would accept the \$1000 offer (56.5% accepted), and predicted that 67.4% of contacted waived vehicles



would accept (67% accepted). At a \$500 offer, estimated participation is 2.5% for high polluters and 4.8% for waived vehicles. After a point, the offer price is increasing faster in percentage terms than the increase in acceptances.

In contrast, Alberini et al. (1995) estimated that at an offer price of \$1000, 37% of waived vehicles in Delaware would be purchased, and 30% of pre-1980 vehicles; and at \$500, 7.5% of waived vehicles and 3% of pre-1980 vehicles. When comparing, keep in mind that the Colorado program was not restricted to pre-1980 vehicles, that the population of high-polluting vehicles includes post-1980 vehicles, that the population of pre-1980 vehicles includes low polluters, and that the waived vehicles solicited in Colorado includes post-1980 vehicles.

On the basis of a likelihood ratio test, the null hypothesis that  $m = 4$  (no noise on the bounds generated by hypothetical responses) is rejected. However, the differences across the two models are not dramatic: average estimated WTA is \$7.28 larger in the no-noise model, the no-noise model predicts two fewer correct responses to the \$1000 offer and one fewer WTA estimate in the suggested interval, the ranges on WTA and  $s_{WTA}$  are slightly different, and the predicted participation rates are very similar. That the distinct/noisy model predicts slightly better

than the all-bounds distinct model provides some support to those who criticize the informational content of answers to hypothetical questions. However, since the practical intent of the models is to predict participation rates by vehicle type at different offer prices, and, in this case, these predictions are almost the same, so little is lost here by ignoring the lesser amount of information generated by the hypothetical questions. However, the comparison between the two models is limited because all of the actual offers were \$1000 and all of the hypothetical offers were not \$1000. If at every offer price there were both actual and hypothetical offers, a significant difference between the predictive power of the two models would more strongly indicate a distinction between the informational content of answers to the hypothetical versus actual offers.

Estimation with only the revealed preference data, ignoring the data generated by the responses to the hypothetical offers, generates significantly different predictions. If one discards the hypothetical data as too suspect, those who accepted the \$1000 offer have  $SWTA_{Li} = \$30$  and  $SWTA_{Hi} = \$1000$ , and those that rejected the \$1000 offer have  $SWTA_{Li} = \$1000$  and  $SWTA_{Hi} = \$10,000$ . Not surprisingly, estimation with only the revealed preference data does a better job of predicting the responses to the \$1000 offer; predicting 384 versus 371 correct responses. In explanation, this model only needs to predict whether WTA is above or below the \$1000 offer, whereas the distinct/noisy model is equally concerned with predicting how much above or below.

The predicted participation rates are significantly higher than those predicted by the distinct/noisy model. Estimating with only the revealed preference data, the model predicts that 3.5% of high polluters contacted (7.5% of waived vehicles) would have accepted a \$500 offer price.<sup>22</sup> In comparison, the distinct/noisy model that estimates using both the stated and revealed

---

<sup>22</sup> Interestingly, these estimates are quite similar to the Alberini (1995) predicted participation rates.

## Estimated Participation Rates



preference data predicts and 2.5% of the high polluting vehicles would have accepted the \$500 offer (4.8% for waived vehicles). Utilizing the stated preference data (with or without noise) significantly changes the estimated participation rates.

## II. Investigating the Possibility of Hypothetical Bias: A Hypothetical-Bias Ordered Probit Model of WTA?

A great deal of additional data was obtained at low cost in both the Delaware and Colorado AVRPs by making hypothetical offers after an actual offer was accepted or rejected. Including such hypothetical data but assuming that responses to the hypothetical offers are noisy significantly improves the explanatory power of the model. However, the distinct/noisy model continues to assume that the responses to the hypothetical offers are not systematically biased. We now turn to an investigation of that issue.

Continue to assume each individual has a WTA, but an individual does not walk around with her WTA at her cognitive fingertips. Assume

$$(6) \quad WTA_i = E(WTA_i) + e_i = a + \beta X_i + e_i \quad i=1,2,\dots,N.,$$

where each  $e_i$  is independently drawn from a normal distribution with mean zero and standard deviation  $s$ , and as before,  $a$  is a scalar,  $\beta$  is a vector, and  $X_i$  is a vector of the relevant characteristics of individual  $i$  and her vehicle. Note that we are now assuming WTA has a normal

rather than a lognormal distribution. Continue to assume that if the offer is an actual offer the individual cogitates long enough, but only long enough, to determine with certainty whether  $WTA_i \neq P_i$ . The individual's response to the \$1000 offer correctly identifies whether the individual's WTA is in the interval  $\neq \$1000$ , or in the interval  $> \$1000$ . Given that WTA is assumed normally distributed, no lower or upper limit is placed on the range of WTA.

When offers are hypothetical, it is not necessarily in the owner's interests to reveal what she knows about her WTA. This is particularly true when bargaining, and, while the AVRPP hypothetical offers were not part of any bargaining over the final price, the owners might have "knee-jerk" reacted to the hypothetical offers as if they part of a bargaining process. We now incorporate this possibility.

Denote the highest hypothetical offer an individual rejected "Suggested" Willingness to Accept Low ( $SWTA_{Li}$ ), and denote the lowest hypothetical offer an individual accepted "Suggested" Willingness to Accept High ( $SWTA_{Hi}$ ). Interpret  $SWTA_{Li}$  and  $SWTA_{Hi}$  as  $WTA_{Li}$  and  $WTA_{Hi}$  influenced by hypothetical response bias resulting from three factors: a perceived incentive to behave strategically if the offer is hypothetical, a lack of incentive to cogitate long enough to know for sure whether  $WTA_i \neq P_i$ , and how an individual responds to hypothetical risk.

Specifically assume

$$(7) \quad SWTA_{Li} = SWTA_{Li} + \beta \quad \text{and} \quad (8) \quad SWTA_{Hi} = SWTA_{Hi} + \beta$$

where  $\beta = 0$  if  $WTA_{Li} = \$1,000$  or  $WTA_{Hi} = \$1,000$ ; otherwise  $-\$200 \leq \beta \leq \$200$ . The restrictions ( $\beta = 0$  if  $WTA_{Li} = \$1,000$  or  $WTA_{Hi} = \$1,000$ ) and ( $-\$200 \leq \beta \leq \$200$ ) preclude  $SWTA_{Li}$  from being less than \$1000 if the individual rejected the \$1000 offer and preclude  $SWTA_{Hi}$  from being greater than \$1000 if the individual accepted the \$1000 offer. Both are necessary preclusions given that when the hypothetical offers are made each individual has already

cogitated sufficiently to determine whether his or her WTA is above or below \$1000. The parameter  $\beta$  indicates the degree and direction of hypothetical response bias. If one assumes  $\beta = 0$ , the model simplifies to one with no hypothetical bias or noise.

If  $\beta < 0$ ,  $WTA_i$  can be less than  $SWTA_{Li}$ , specifically  $WTA_i$  can be as much as  $|\beta|$  less than  $SWTA_{Li}$ , and estimating WTA assuming that  $\beta = 0$  will lead to estimates of WTA that are biased upward. If  $\beta > 0$ ,  $WTA_i$  can be greater than  $SWTA_{Hi}$ , specifically  $WTA_i$  can be as much as  $\beta$  greater than  $SWTA_{Hi}$ , and estimating WTA assuming that  $\beta = 0$  will lead to estimates of WTA that are biased downward.

To elaborate, acknowledging a nonzero  $\beta$  admits seven offer regions in relation to  $WTA_{Li}$ ,  $WTA_{Hi}$ ,  $SWTA_{Li}$ , and  $SWTA_{Hi}$ :

region a: if  $P_i \leq WTA_{Hi}$  and  $P_i \leq SWTA_{Hi}$ , individual accepts the offer whether it is actual or hypothetical.

region b: if  $P_i < WTA_{Li}$  and  $P_i < SWTA_{Li}$ , individual rejects the offer whether it is actual or hypothetical.

region c: if  $SWTA_{Hi} > P_i \geq WTA_{Hi}$ , individual accepts if actual but might not accept hypothetical.

region d: if  $WTA_{Hi} > P_i \geq SWTA_{Hi}$ , individual accepts if hypothetical but might not accept if actual.

region e: if  $SWTA_{Li} < P_i < WTA_{Li}$ , individual rejects if actual but might not reject if hypothetical.

region f: if  $WTA_{Li} < P_i < SWTA_{Li}$ , individual rejects if hypothetical but might not reject if actual.

region g: if  $WTA_{Li} < P_i \neq WTA_{Hi}$  and  $SWTA_{Li} < P_i \neq SWTA_{Hi}$  don't know what an individual will do with either an actual or a hypothetical offer.

If  $\beta < 0$ , there is not a (d) or (e) region but always a (c) and (f) region; that is, the individual possibly rejects hypothetical offers that he would accept if they were actual offers. If  $\beta > 0$ , there is not a (c) or (f) region but always a (d) and (e) region; that is, the individual possibly accepts hypothetical offers that he would reject if they were actual offers.

Given equations (6), (7) and (8) the conditional probability  $WTA_i$  lies between  $WTA_{Li}$  and  $WTA_{Hi}$  when  $E(WTA_i) = a + \beta X_i$  is:

$$(9) \text{ Prob}(WTA_{Li} < WTA_i \sim WTA_{Hi} \mid E(WTA_i) = a + \beta X_i)$$

$$\begin{aligned}
 & \cdot \text{Prob}(WTA_i \sim WTA_{Hi}) \& \text{Prob}(WTA_i \sim WTA_{Li}) \\
 & \cdot \text{Prob}(WTA_i \sim SWTA_{Hi} \% ?) \& \text{Prob}(WTA_i \sim SWTA_{Li} \% \text{etas}) \\
 & \cdot F\left(\frac{SWTA_{Hi} \% ? \& E(WTA_i)}{s}\right) \& F\left(\frac{SWTA_{Li} \% ? \& E(WTA_i)}{s}\right)
 \end{aligned}$$

where F is the standard normal CDF. The log of the likelihood function for the sample of 480 individuals is

$$(10) \quad \text{Log } L = \sum_{i=1}^{480} \log\left[F\left(\frac{SWTA_{Hi} \% ? \& E(WTA_i)}{s_i}\right) \& F\left(\frac{SWTA_{Li} \% ? \& E(WTA_i)}{s_i}\right)\right]$$

The parameter estimates (t statistics in parentheses) are

$$\begin{aligned}
 E(WTA_i) = & 1271 + .0226*BLUE_i - 53.35*MAINTAIN_i - 139.5*WAIV_i - 70.36*COND_i \\
 & (10.13) \quad (.66) \quad \quad \quad (-4.28) \quad \quad \quad (-2.98) \quad \quad \quad (-1.81) \\
 & -75.52*POLLUTE_i + -18.67*MILES_i - .3029*TOTMIL_i + .2478*BLUE_i/COND_i \\
 & (-3.52) \quad \quad \quad (-1.18) \quad \quad \quad (-.987) \quad \quad \quad (3.83)
 \end{aligned}$$

Likelihood ratio tests indicate that WAIV, MILES, TOTMIL, COND, POLLUTE, MAINTAIN, BLUE, and (BLUE/COND) are the significant determinants of WTA. On the basis of a likelihood ratio test, one rejects the null hypothesis that  $\beta = 0$ . The estimated standard deviation on WTA is  $s = 416.74$  (21.64), and  $\beta = -\$125.65$  (-2.90).

This model correctly predicts the sample participation rate at the \$1000 offer for 57% of the sample. It correctly predicts the response to the \$1000 offer for 79% of the sample, predicting acceptance for 222 of the 271 individuals who accepted the offer, and predicting rejection for 157 of the 209 individuals who rejected the offer. It places estimated  $WTA_i$  in the suggested interval 181 times. All of these prediction rates better the rates predicted by the restricted model with no hypothetical bias ( $\beta = 0$  @ i).

The estimated hypothetical bias model suggests that assuming that the responses to the hypothetical offers identify true bounds on  $WTA_i$  is incorrect and leads to estimates of  $WTA_i$  that are biased upward. That the estimated  $\beta$  is negative and significantly different from zero indicates individuals reject some hypothetical offers that they would accept if the offers were actual. Specifically, for those individual who have neither  $SWTA_{Li}$  or  $SWTA_{Hi} = 1000$ , offers in the range  $SWTA_{Hi} - \$125 \leq \text{offer} < SWTA_{Hi}$  (i.e. region c) will be accepted if actual but might not be accepted if hypothetical, and offers in the range  $SWTA_{Li} - \$125 \leq \text{offer} < SWTA_{Li}$  (i.e. region f) will be rejected if hypothetical but might not be rejected if actual.

The prediction that individuals are more likely reject a hypothetical offer than an actual offer has intuitive appeal in that it is what one would expect if individuals react to an AVRPP hypothetical offer as they might to the question from a potential buyer in the marketplace, "Would you sell me your car for \$X?" The owner will likely say no even though she might accept an actual offer for the same amount because she does not want to play her hand or waste time cogitating until she has a commitment to buy at that price.

### **However!!!!**

The big effect on estimated participation rates resulting from allowing hypothetical responses to contain different information than the responses to actual offers highlights the importance of investigating the informational content of responses to hypothetical offers versus actual offers. Estimation of the hypothetical bias model is a step in that investigation.

However, investigation of the estimated likelihood function for the hypothetical bias model indicates that with the Denver AVRPP data, the estimate of  $\beta$  is not so much determined by whether the response is to an actual offer or a hypothetical offer, but rather more determined by the number of owners in the sample who rejected all offers ( $SWTA > \$1400$  or  $SWTA > \$1600$ ) relative to the number of individuals who accepted all offers ( $SWTA < \$400$  or  $SWTA < \$600$ ). A large proportion of the sample is in one of these two categories: 25% rejected all offers and

11% accepted all offers. For that subset of the sample with suggested intervals not bounded by \$1000, 41% rejected all offers and 19% accepted all offers.

Examining the log of the likelihood function individual by individual,  $\gamma$  only significantly impacts the probability of the responses for those individuals with SWTA that is unbounded from either above or below.<sup>23</sup> Such individuals tend to be those individuals whose responses place them, relatively speaking, furthest from the  $E(WTA)$  predicted by their vehicle and owner characteristics.

The parameter  $\gamma$  only affects the length of the WTA intervals that are unbounded from either above or below.<sup>24</sup> If  $\gamma$  is positive, the intervals  $SWTA > \$1400$  and  $SWTA > \$1600$  remain unbounded from above but get shortened in length by the amount  $\gamma$ .<sup>25</sup> Intervals of  $SWTA < \$400$  and  $SWTA < \$600$  remain unbounded from below but get lengthened by the amount  $\gamma$ .<sup>26</sup> Therefore, a positive  $\gamma$  decreases the probability of observing individuals who rejected all offers because their WTA intervals are now shorter and further from the  $E(WTA)$  for individuals with their same vehicle and owner characteristics. Alternatively, a positive  $\gamma$  increases the probability of observing individuals who accepted all offers because their WTA intervals are now longer and nearer the  $E(WTA)$  for individuals with their same vehicle and owner characteristics.

If  $\gamma$  is negative, the intervals  $SWTA > \$1400$  and  $SWTA > \$1600$  remain unbounded from above but get lengthened by  $\gamma$ .<sup>27</sup> Intervals of  $SWTA < \$400$  and  $SWTA < \$600$  remain

---

23 Recollect,  $\gamma$  does not affect the probability of the responses for those individuals with either  $SWTA_{Li}$  or  $SWTA_{Hi}$  equal to \$1000. Examination of the estimated likelihood function shows that the parameter  $\gamma$  only marginally affects the probabilities of the responses for those individuals who do not have bounds of -4, +4 or \$1000.

24 Length /  $WTA_{Hi} - WTA_{Li} = (SWTA_{Hi} + \gamma) - (SWTA_{Li} + \gamma)$ . A  $SWTA_{Hi}$  ( $SWTA_{Li}$ ) of 4 (-4) is not affected by  $\gamma$  ( $\gamma \neq 200$ ).

25 For example, if  $SWTA > \$1600$  and  $\gamma = 100$ ,  $WTA > \$1700$ .

26 For example, if  $SWTA < \$400$  and  $\gamma = 100$ ,  $WTA < \$500$ .

27 For example, if  $SWTA > \$1600$  and  $\gamma = -100$ ,  $WTA > \$1500$ .

unbounded from below but get shortened in length by  $\beta$ .<sup>28</sup> Therefore, a negative  $\beta$  increases the probability of observing individuals who rejected all offers because their WTA intervals are now longer and nearer the  $E(WTA)$  for individuals with their same vehicle and owner characteristics. Alternatively, a negative  $\beta$  decreases the probability of the responses for those individuals who accepted all offers because for them their WTA intervals are now shorter and further from the  $E(WTA)$  for individuals with their same vehicle and owner characteristics.

Therefore, the estimate of  $\beta$  is negative predominately because twice as many individual rejected all offers as accepted all offers, and probably not, given our data, because individuals are more likely to reject hypothetical offers to sell their vehicle than they are to reject actual offers. They might be, but one cannot tell from the Denver AVRPs data. The negative estimate of  $\beta$  is making it easier for the model to explain the significant number of owners who rejected all offers.

The problem is with the data, not the Hypothetical Bias Model. All of the actual offers were \$1000 and all of the hypothetical offers were at other amounts. In addition, the range of the offers did not go low enough to include amounts that most owners who accepted the \$1000 offer would reject, nor high enough to include amounts that most owners who rejected the \$1000 would accept. For the estimate of  $\beta$  to reflect the degree of hypothetical response bias, actual and hypothetical offers each need to be made over a wide range, including high offers that most owners would accept and low offers that most owners would reject. Otherwise, it will be difficult to use offer response data to isolate the effect of hypothetical response bias.

### **III. Concluding Thoughts**

Our experiences with the Colorado AVRPs suggest some recommendations and some cautions with respect to future AVRPs; a number of AVRPs are in the planning stage. The

---

<sup>28</sup> For example, if  $SWTA < \$400$  and  $\beta = -100$ ,  $WTA < \$300$ .

Colorado AVRP and the Delaware AVRP estimate quite different participation rates as a function of the offer price, indicating caution in using participation rates from one program to predict participation rates for other programs. But accurately estimating participating rates is crucial to determining whether an AVRP is a cost-effective way to reduce pollution. Therefore, AVRPs should have two purchasing phases: a small initial phase to estimate participation rates at different offer prices, and a program phase where offers are made on the basis of the estimated participation rates from the first phase. The first phase should make both actual and hypothetical offers at every one of a number of offer prices. Inferences from both the Delaware and Colorado AVRP are limited because all actual offers were made at the same price (\$1000 in Colorado and \$500 in Delaware) and all hypothetical offers were at other prices.

A great deal of additional data was obtained at low cost in both the Delaware and Colorado AVRP by making hypothetical offers after the an actual offer was accepted or rejected. Including such hypothetical data is warranted but one must be cognizant of the possibility that the response to the hypothetical offers contain less information about preferences than do the responses to actual offers, or possibly biased information. To investigate the first possibility, we developed and estimated a simple extension of the probit model that assumes bounds generated by responses to actual offers are distinct, but bounds generated by responses to hypothetical offers are noisy. Recollect that the model that used only the data from the actual offers generates significantly different participation rates than the general model which uses both the actual and hypothetical data. The results suggest that the responses to the hypothetical offers are noisy. To investigate, the issue of hypothetical bias, we developed a hypothetical bias model that is capable of addressing the issue of bias, but after much investigation, determined that there was not enough variation in the actual offers to address the issue. Possible extensions include: a more general specification for the range on the noisy bounds, distributions of noise than are symmetric but nonuniform, integration of noise and bias, and more complicated forms of bias, including bias

that varies across respondents. Because of the limited variation in the actual offers in the Denver AVR data set, we decided not to pursue such extensions, but hope to do so with a richer data set.

#### IV. References

- Alberini, Anna, Winston Harrington, and Virginia McConnell, "Determinants of Participation in Accelerated Vehicle Retirement Programs," *Rand Journal of Economics*, 26 (Spring 1995), 93 -112.
- Alberini, Anna, Harrington, Winston, McConnell, Virginia, "Estimating an Emissions Supply Function From Accelerated Vehicle Retirement Programs," *Review of Economics and Statistics*, (1996), 71-85.
- Cameron, Trudy, and Don Huppert, "OLS versus ML Estimation of Non-market Values with Payment Card Interval Data," *Journal of Environmental Economics and Management*, 17 (1989), 230-246.
- Green, W.H., *Econometric Analysis*, second edition, MacMillan Publishing Company, New York, 1993.
- DePalma, A., G.M. Meyers and Y.Y. Papageorgiou, "Rational Choice Under and Imperfect Ability to Choose," *American Economic Review*, 84 (1994), 419-440.
- Green, W.H., *Econometric Analysis*, second edition, MacMillan Publishing Company, New York, 1993.
- Herstein, R.J., "Experiments on Stable Suboptimality in Individual Behavior," *American Economic Review: Papers and Proceedings*, 81 (May 1991), 360-364.
- March, James, "Bounded Rationality, Ambiguity and the Engineering of Choice," *Bell Journal of Economics*, 9 (Autumn 1978), 587-608.

Newell, Allen, and Herbert Simon, *Human Problem Solving*, Prentice Hall, Englewood Cliffs, NJ, 1972,

Shugan, S.M., "The Cost of Thinking," *Journal of Consumer Research*, 7 (1980), 99-111.

Zavoina, R., and W.McElvey, "A Statistical Model for the Analysis of Ordinal Level Dependent Variables." *Journal of Mathematical Sociology*, (Summer 1975), 103-120.