Curbside Recycling:
Waste Resource or Waste of Resources?

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Abstract: In this paper, we estimate the social net benefits of curbside recycling. Benefits are estimated using survey data on household willingness to pay (WTP) from over 4,000 households across 40 western U.S. cities. We calibrate WTP for hypothetical bias using an experimental design that contrasts stated and revealed preferences. Cost estimates are compiled from previous studies by the U.S. Environmental Protection Agency, the Institute for Local Self Reliance, as well as from in-depth interviews with recycling coordinators in our sampled cities. Remarkably, we find that the estimated mean social net benefit of curbside recycling is almost exactly zero. Therefore, the decision of whether to implement or maintain a curbside recycling program (CRP) must be done on a city-by-city basis.

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1. Introduction

One of society's greatest challenges is determining optimal allocations for environmental goods, such as old-growth forests, wetlands, spotted owls, wolf habitat, clean air, etc. The primary difficulty with this type of problem is measuring the social benefits accruing from the provision of these goods. Unlike private goods, environmental goods have a large public-good component that encourages free-riding behavior. Furthermore, their prices are not determined in well-developed markets. As a consequence, it is often necessary to estimate the benefits from environmental goods through non-market valuation methods, such as contingent valuation.

In this paper, we focus on one such environmental good – curbside recycling. Recycling is typically thought to benefit the environment by diverting solid waste from landfills, which can pollute groundwater, produce airborne pollutants, and compete for open space (U.S. EPA, 1992). At the same time, however, recycling programs are costly. They require households to clean, sort, store and deliver recyclables. Furthermore, curbside recycling programs (CRPs) divert resources from other societal programs and services such as public education, highway maintenance, welfare programs, etc. Our goal in this paper is to provide a comprehensive measure of the social net benefits of curbside recycling, in order to help answer the often contentious question: "Should we be recycling?"

We have witnessed a renewed national debate regarding the efficacy of recycling in the wake of New York City's recent decision to suspend collection of plastics and glass.[1] Mayor Bloomberg's and the city council's decision appears to be based primarily on claims that the recycling of glass and plastics is cost ineffective (Johnson, 2002). Cost effectiveness is an understandable criterion given the absence of reliable estimates of the social benefits of recycling. However, by failing to assess both the social costs *and* benefits of New York City's recycling program, we are left to wonder whether the mayor and city council made the correct decision.

This paper represents a first attempt at establishing an economic basis for making such decisions. On the benefit side, we use contingent valuation methods (CVM) and responses from over 4,000 households located in 40 metropolitan areas throughout the Western U.S. to estimate willingness-to-pay (WTP) for CRPs.[2] To detect potential hypothetical bias in our WTP data (due to the hypothetical nature of the payment vehicle for recycling services), we contrast stated-preference information from CVM with revealed-preference information from actual decisions made by households in communities with voluntary recycling programs. As a result, we are able to detect hypothetical bias in the stated-preference data and calibrate the corresponding estimates to the decisions made by households in a real market setting.

On the cost side, we employ a wide distribution of cost data acquired from communities in our population to obtain an estimated economic cost of providing curbside recycling services. In calculating the costs of curbside recycling, both explicit variable and fixed costs are included, as well as the opportunity costs associated with diverting public resources away from their next most productive use.

The next section presents a simple theoretical framework that describes the management of solid waste at both the household and community levels. This framework guides our ensuing empirical analysis. In section three, we introduce the data sources used in developing measures of economic costs and benefits. In section four, we present our econometric model for

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[1] New York City is not alone among large cities that are reevaluating the efficacy of their recycling programs. For example, Denver, CO is considering a drastic scaling back its curbside recycling program (Brovsky and Larson, 2003).

[2] Due to budget limitations, our population does not include the eastern U.S.

estimating WTP, including the methods used to mitigate hypothetical bias, and discuss our empirical results. In section five, we discuss the policy implications of our empirical findings and suggest some possible avenues for future research.

2. Theoretical Model

Our model involves an equilibrium relationship between households and a community planner, whereby households make utility-maximizing decisions in response to the planner's policies and the planner sets policy to maximize the well-being of the households. We begin with the household's problem.[3]

2.1. Households

Given the policy decisions of the community planner, household *i*, i = 1,…,n, is assumed to maximize utility by choosing recycling effort, e_i, and the composite good, z_i, subject to its budget constraint. Household solid waste, w_i, is generated as a function of consumption according to $w_i = \lambda z_i$, where $0 < \lambda < 1$. Furthermore, household solid waste cannot be entirely recycled, so that $r_i \in [0, r_i^{max} < w_i]$, where r_i is the amount of private recyclables generated per month and r_i^{max} is the maximum amount of recyclables that can be generated for a given w_i. Preferences are given by

$$u_i = u_i(z_i, l_i, r_i, R) \qquad (1)$$

where l_i is the fraction of non-market time spent in leisure and $R = \Sigma_i r_i$ is the total amount of recyclables generated in the community. There is a tradeoff between leisure and the effort required to clean, sort, store and deliver the recyclables (either to the curb or to a centralized dropoff site). We assume the tradeoff is given by $l_i = 1 - e_i$, where maximum leisure is normalized to unity. We assume that u_i is strictly increasing in z_i and l_i, but only weakly increasing in r_i and *R*.[4] Commensurate with Andreoni's (1990) impure-altruism model, households may receive private non-pecuniary (e.g., "warm glow") benefits derived from helping to divert municipal waste from the landfills (measured at the margin by $u_{r,i}$), as well as public benefits associated with the community's aggregate level of recycling, measured by $u_{R,i}$. This creates a possible external effect since households have no apparent incentive to internalize the effect of their private recycling activity on the welfare of the other households. The assumption of impurely altruistic households is based on our survey results showing that the primary motivation behind the decision to recycle for approximately 90% of the sampled households is "an ethical duty to help the environment". We discuss this issue further in Section 5.

We further assume that recycling effort translates into recyclables according to

$$r_i = \begin{cases} g(e_i) & \text{curbside recycling} \\ \max\left(0, g(e_i) - c_i\right) & \text{dropoff recycling} \end{cases} \tag{2}$$

where g is strictly increasing, concave and g(0) = 0. The functions in (2) are capped from above by r_i^{max}, which corresponds to a maximum amount of curbside effort $e_i^{max}(\text{curb}) = g^{-1}(r_i^{max})$ or dropoff effort $e_i^{max}(\text{drop}) = g^{-1}(r_i^{max} + c_i)$. The positive constant c_i represents the additional effort, primarily in terms of transportation costs, required for dropoff recycling. Figure 1 depicts a stylized example of the functional relationship between e_i and r_i.

The household budget constraint is represented by $y_i \geq pz_i + \tau_i \phi_i$, where y_i is household income, p is z_i's corresponding price index, $\tau_i = t - s_i$ is the recycling fee, t, net of any savings,

[3] See Fullerton and Wu (1998) and Kinnaman and Fullerton (2000) for alternative general equilibrium models of recycling and other "green policies" at the household level.

s_i, associated with reduced garbage expense in communities with a variable-pricing scheme, and ϕ_i is a binary variable equal to one if household *i* voluntarily signs up for a CRP (or is automatically signed up by virtue of a community mandate) and zero otherwise.[5]

The household recycling choice results in either an interior solution or one of two possible corner solutions. Begin by assuming an interior solution. The household supplies optimal recycling effort, e_i^*, up to the point where its marginal recycling benefits are equal to its marginal disutility of foregone leisure, i.e., $(u_{r,i} + u_{R,i})g_e = u_{l,i}$. Because the curbside fee and the additional effort required for dropoff are fixed for a given household, this condition characterizes an interior solution for both dropoff and (mandatory or voluntary) curbside recycling.

The conditions for corner solutions (i.e., where the household either recycles nothing or recycles everything possible), however, depend on which of the three program types is offered.[6] When only dropoff recycling is available, the household chooses not to recycle if $(u_{r,i} + u_{R,i})g_e < u_{l,i}$ at $e_i = c_i$ and recycles everything possible if $(u_{r,i} + u_{R,i})g_e \geq u_{l,i}$ at $e_i = e_i^{max}(drop)$. With mandatory curbside recycling, the household chooses not to recycle if $(u_{r,i} + u_{R,i})g_e < u_{l,i}$ at $e_i = 0$ and recycles at the maximum possible level if $(u_{r,i} + u_{R,i})g_e > u_{l,i}$ at $e_i = e_i^{max}(curb)$.[7] When voluntary curbside recycling becomes available, a household not currently using dropoff recycling will sign up for the CRP if the gain in utility from participating

[4] We further assume that conditions on u_i are such that sufficient second-order conditions for utility maximization hold, ensuring a well-defined solution.

[5] To keep the model simple, we abstract from the possibility that households receive revenue from the sale of dropoff recyclables (e.g., selling aluminum cans or newspapers). We note, however, that the revenue from dropoff recycling could be incorporated into the budget constraint in a straightforward manner.

[6] We assume that policymakers always offer dropoff recycling, which is motivated by the empirical observation that the great majority of communities in our sample offer dropoff services.

[7] When we refer to *mandatory* curbside recycling we mean that the household is required to pay the effective fee τ_i for the service, not that they are required to use it. Based on our own survey of recycling coordinators, few communities appear to enforce the use of their curbside recycling service. Note from Figure 1 that if the CRP is mandatory, the household will never choose to use dropoff recycling for any $e_i > 0$.

in the CRP is greater than the loss in utility associated with foregone leisure and income. A household that currently uses dropoff recycling will sign up for the CRP if the gain in utility associated with the increase in leisure outweighs the loss in utility associated with foregone income attributable to paying the curbside recycling fee. Once a household signs up for a voluntary CRP, they will either recycle at effort levels e_i^* or $e_i^{max}(curb)$. Figures 2 and 3 depict the various possible household-level solutions for mandatory curbside and dropoff recycling, respectively. In Figure 3, the discontinuity depicted in the marginal benefit curve for dropoff recycling ($u_{r,i}g_e$) reflects the additional fixed cost per household associated with dropoff recycling as compared to curbside recycling.

Next, we link the utility specification in (1) to the household's WTP for curbside recycling. Begin by considering the indirect utility function $v_i = v_i(p, \tau_i, y_i, R)$ resulting from constrained maximization of (1). Assuming v_i is strictly increasing in y_i, one can invert any reference v_i with respect to y_i to produce the household's expenditure function, $m_i = m_i(p, \tau_i, R, v_i)$. In this case, we set the reference v_i equal to the maximum utility given that the household does not participate in a CRP, v_i^0. WTP for curbside recycling is then derived by subtracting the household's minimum expenditure when it participates in the CRP, $m_i^1 = m_i(p, \tau_i, R, v_i^0 \mid \phi_i = 1)$, from its minimum expenditure given that it does not participate $m_i^0 = m_i(p, \tau_i, R, v_i^0 \mid \phi_i = 0)$. In other words, WTP for household *i* is defined by the amount of income the household would willingly forego so as to participate in a CRP and maintain the original utility level v_i^0. The household's WTP for curbside recycling may be negative if the disutility of foregone leisure is sufficiently large relative to the utility gained from recycling.

2.2. Community Planner

The community planner is responsible for managing municipal solid waste $W = \Sigma_i w_i$ by (a) selecting a type of CRP indexed by $j \in \{N,M,V\}$, where N, M and V refer to no, mandatory and voluntary curbside recycling respectively; (b) selecting a garbage pricing scheme; and (c) selecting the household curbside recycling fee, t. The aggregate solid waste that is not recycled, W – R, is disposed of in landfills or incinerated and enters household preferences indirectly through R. The planner also faces a balanced-budget constraint,[8]

$$\sum_{i=1}^{n_j} \tau_i = C(n_j, j) \tag{3}$$

where n_j represents the number of participants for CRP type *j* and C is the total economic cost of providing curbside recycling.[9] The number of participants are given by $n_N = 0$, $n_M = n$ is the number of households participating in the mandatory CRP, and $n_V = n^*$ is defined by the number of households that satisfy $WTP_i \geq \tau_i$ under a voluntary program. C includes both explicit fixed and variable components, as well as the implicit costs associated with the foregone use of resources allocated toward a CRP (further discussion of these costs is provided in the next section). We also assume that marginal cost is positive and non-decreasing in n_j. Thus, the average total cost (ATC) curve has the usual u-shape, falling over some initial range until the point of minimum efficient scale and rising thereafter.

The community planner then uses this benefit and cost information, along with budget-balance condition (3), to simultaneously determine whether to establish a CRP, and if so, which

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[8] Although the revenues from household fees and sales of recyclable materials do not always cover the total costs of the municipal CRPs, the resulting cost overruns are funded out of general tax revenues. In these cases, the balanced-budget constraint is therefore implicitly satisfied.

[9] τ_i rather than t is used in (3) under the assumption that in communities with a variable-pricing scheme, the community planner can estimate the savings per household associated with usage of smaller garbage containers.

type and at what effective household fee level. We begin by stating the condition required for the community planner to offer a CRP of either type M or V.

CRP Condition I. Given (3), the community planner will offer a CRP of either type M or V, if and only if $\sum_{i=1}^{n} WTP_i \geq C(n, M)$ or $\sum_{i=1}^{n^*} WTP_i \geq C(n^*, V)$.

Figure 4 depicts the case where CRP Condition I is not satisfied for either a mandatory or a voluntary program. For this diagram, we make the simplifying assumption that when she decides to offer a variable-pricing scheme jointly with a CRP, the community planner predicts that each household will select the smallest possible garbage container size. As a result, each household faces the same effective recycling fee, namely τ. The aggregate marginal surplus (AMS) curve, drawn linear for simplification, depicts the change in aggregate WTP as the number of households increases, beginning with the household with the largest WTP and ending with the household whose WTP is lowest (in the case of Figure 4, the lowest household WTP is negative). The mandatory program fails because the aggregate WTP at τ (area A + B + C under the AMS curve) is less than rectangular area B + C + D = $\tau \times n$ defining total costs. The voluntary program also fails because the ATC curve lies everywhere above the AMS curve, implying that the budget-balance condition (3) fails for any τ and corresponding n*.

If CRP Condition I is satisfied, the community planner then determines which type of program to offer. The following condition gives the condition required for choosing a voluntary or mandatory CRP.

CRP Condition II. Assume CRP Condition I is satisfied. The community planner chooses a voluntary (mandatory) CRP if $\sum_{i=1}^{n^*} WTP_i - C(n^*, V)$ is greater (less) than $\sum_{i=1}^{n} WTP_i - C(n, M)$ with corresponding household fee t_V (t_M) and garbage-pricing scheme satisfying (3).

In other words, a voluntary program is chosen over a mandatory program whenever the associated household fees and participation levels for the two programs are such that the net community surplus from the voluntary program is greater than that from the mandatory program.[10]

Figure 5 depicts the geometry associated with CRP Condition II. The effective household fee for the voluntary program, τ_V, is determined by budget balance at the intersection between the AMS and ATC curves, which also determines the number of participating households, n*, and the total net community surplus, area A. A mandatory program charges a household fee of τ_M, which by the budget-balance condition is consistent with *n* participating households. Moving from a voluntary to a mandatory CRP, n* households obtain a net surplus increase of area B, while n – n* households obtain a change in net surplus of area C – E. Therefore, if area B + C – E > 0, a mandatory program is chosen under CRP Condition II with effective fee τ_M; otherwise a voluntary program is chosen with effective fee τ_V. As can be seen from Figure 5, the probability that a voluntary program is chosen increases as the ATC curve becomes flatter, ceteris paribus. In the limit (i.e. for a horizontal ATC curve between n^* and n), a voluntary program will always be selected under CRP Condition II.

[10] CRP Condition II is therefore consistent with the Hicks-Kaldor compensation principle.

In closing, our joint household-community planner model makes clear predictions about the social efficiency of various recycling options and enables us to predict which types of recycling programs should be observed in the different communities included in our sample. Before making these predictions, however, we first introduce the data sources used to estimate the costs and benefits of the various CRPs sampled from our population.

3. Cost and Benefit Data

3.1. Cost Data

Our CRP cost data was obtained from two sources: (a) from in-depth interviews with community recycling coordinators and private contractors, and (b) from published studies by the Institute for Local Self-Reliance (ILSR) (1991) and Franklin Associates, Ltd (1997). The ILSR study provides detailed cost information for Seattle, WA and West Linn, OR, while the Franklin Associates study provides information for Olathe, KS. From the recycling coordinators and private contractors, we obtained cost information for eight cities – seven communities in our sample and Portland, OR.[11] This information is shown in Table 1.

The costs are based on explicit fixed and variable expenses for collection and processing incurred during the most recent year available. They are reported on a per-household per-month basis in order to be directly comparable with our benefit information.[12] The costs have also been adjusted for cost-of-living differences across communities (MSN, 2003), and in the case of

[11] Cost information was unavailable for many of our sampled communities because it does not exist, cannot be extracted from overall waste-disposal cost information, or is proprietary.

[12] Costs are reported as an average cost over the lifetime of the program. This reflects the fact that recycling coordinators and contractors are generally required to report on an annual basis and that CRPs are generally associated with relatively long planning horizons (e.g., 10-20 years) over which up-front capital costs are spread. As a result, we do not attempt to calculate net present value estimates based on the specific periods in which the costs are incurred. Rather, we presume that the monthly cost estimates provided by the recycling coordinators accurately reflect what a community can expect to incur during any given month of any given year.

Seattle, West Linn, and Olathe appropriate adjustments for inflation have been made using the consumer price index (Bureau of Labor Statistics, 2003). In addition to the CRP costs, Table 1 also includes information on the number of participating households per year, percentage of the community's population participating, as well as indicators for whether the CRP is mandatory and whether household sorting of recyclables is required.

Several observations can be made from the information provided in Table 1. To begin with, the estimated mean monthly cost per household across the eleven communities equals $2.93, with a coefficient of variation of 33%, implying a fairly tight distribution of cost estimates around the mean. Second, because each CRP in our sample is different in terms of the items collected, collection frequency, whether it is a mandatory or voluntary program, degree of sorting required, etc., we are unable to identify a single underlying ATC curve. As a result, the numbers from Table 1 are more likely to represent distinct points along several different ATC curves, rather than points along a single curve. Lastly, there seems to be a weak relationship between costs and whether the CRP is mandatory or voluntary. Five of the six most cost-efficient CRPs are voluntary. However, we refrain from attaching an interpretation to this result as it is not a perfect ordering (e.g., the mandatory CRP in Tempe, AZ is the lowest cost CRP in our sample).

3.2. Survey Data and Design

Turning to the benefit data, we conducted a random-digit dialed telephone survey regarding recycling behavior during the winter of 2002 to over 4,000 households in 40 western U.S. cities with populations over 50,000.[13] We chose an approximately even three-way split between communities with a voluntary, a mandatory and no CRP. We purposefully over-sampled households in communities with voluntary CRPs to allow for the detection of any hypothetical bias in the data. To supplement the household data, we also conducted a telephone survey of the recycling coordinators in each of the 40 cities in order to provide specific information on the attributes and history of recycling in their respective communities.

4. Econometric Methodology and WTP Estimates

In this section, we discuss (a) the double-bounded dichotomous-choice (DBDC) model used to obtain our welfare estimates, (b) the estimation results for overall WTP, (c) the identification and estimation of hypothetical bias across the different program types (i.e., M, V, and N), and (d) the calibration of the mean WTP estimates for a select group of cities.

4.1. Econometric Model

Our econometric approach follows Cameron and James (1987). WTP questions are set in the DBDC format in order to elicit a household's WTP through a sequence of dichotomous-choice (i.e., yes or no) valuation questions. The first question is: "Would you be willing to pay $\$\tau$ for the service?" The opening bid τ is chosen randomly from a set of predetermined values.[14] Based on her response to the opening bid, the respondent is then asked a similar follow-up question, but with a larger bid value, $\tau_H = 2\tau$, if she answered "yes" (i.e., she is willing to pay at

[13] The survey was administered by the survey research laboratory at Washington State University. The response and cooperation rates were 27% and 49%, respectively. The survey instrument and a list of the 40 cities in our sample are available at www.uwyo.edu/aadland/research/recycle/datareport.pdf.

[14] The opening bids are chosen with equal probabilities from the set of integers two through 10. This set encompasses the range of household fees charged by the communities in our sample.

least τ for the service) or a smaller bid $\tau_L = 0.5\tau$ if she answered "no" (i.e., she is unwilling to pay τ for the service).

Based on the responses to the opening bid and follow-up questions, the respondent's latent WTP may be placed in one of four regions: $(-\infty,\tau_L)$, (τ_L,τ), (τ,τ_H) or (τ_H, ∞). Unlike other CVM studies, we follow up with a third valuation question for those who respond "no" to the first two valuation questions: "Would you be willing to use the service if it were free of charge?" Previous experience with household recycling surveys suggests that some households have negative WTP values, or in other words need to be paid to participate in a CRP (Haab and McConnell, 1997; Aadland and Caplan, 2003a). As a result, our survey generates five rather than four valuation regions with $(-\infty, \tau_L)$ being replaced by $(-\infty, 0)$ and $(0, \tau_L)$.[15]

Turning to our econometric model, we specify a reduced-form relationship between WTP_i and a number of household- and community-specific characteristics, which are represented by the vector X_i. A stochastic error term ε_i is added to capture the portion of WTP_i unexplained by X_i, implying

$$WTP_i = X_i\beta + \varepsilon_i \, , \tag{4}$$

where β is a vector of coefficients. The variance of the error terms is assumed to follow

$$\sigma_i^2 = \exp(Z_i\gamma) \, , \tag{5}$$

where Z_i is a vector of variables (possibly intersecting with X_i) and γ is a vector of parameters.

[15] Some respondents answered "Don't Know" to one or more of the valuation questions. For these households, their unknown WTP does not fit into one of the five categories, but instead overlaps one or more of the intervals. For example, if a respondent answered "Don't Know" to whether they would be willing to pay $\$\tau$ and "Yes" to whether they would be willing to pay $\$\tau_L$, we assume that their unknown WTP falls in the region (τ_L, ∞). The likelihood function is adjusted accordingly.

We further assume that the error terms are mutually independent and normally distributed. Letting $P_{j,i}$ indicate the probability that household *i*'s true WTP falls in the j^{th} region, the (log) likelihood function conditional on (4), (5), and the observed data is

$$\ln(L) = \sum_{i=1}^{n}\sum_{j=1}^{5}\theta_{j,i}\ln(P_{j,i}), \qquad (6)$$

where $\theta_{j,i} = 1$ if the stated WTP value falls in the j^{th} region and 0 otherwise. The definitions of the explanatory variables used in equations (4) and (5) are provided in Table 2.

4.2. Econometric Results

In columns two and three of Table 3, we report our DBDC estimates from maximizing (6) across all (N = 4012) households in our sample. First, note that the overall mean estimated WTP is approximately $5.35 per month.[16] This estimate is larger than those reported in Lake et al. (1996); approximately the same as in Caplan and Grijalva (2003); but smaller than those in Aadland and Caplan (2003a) and Caplan et al. (2003).

Second, we find several individual- and community-specific characteristics that are significantly related to WTP for curbside recycling. To highlight a few, those willing to pay the most are (a) young; (b) female; (c) highly educated; (d) motivated to recycle because of an ethical duty to help the environment; (e) members of an environmental organization; (f) rated their current CRP as good or excellent; and (g) not needing to sort their recyclables. Many of these effects are similar to those found in Aadland and Caplan (2003a). The likelihood ratio statistic used to test for overall goodness of fit is 883.27 with a 1% critical value equal to 156.65.

[16]We have also tested for possible incentive incompatibility and starting-point bias using an approach originally suggested by Whitehead (2002) and later modified by Aadland and Caplan (2004). We find evidence of starting-point bias but no incentive incompatibility. The mean WTP estimates for the two models (one controlling for starting-point bias and incentive incompatibility and one not) are very similar. As a result, we report the results from the latter model. The results from the former model are available from the authors upon request.

Therefore, we reject the null hypothesis in favor of a significant amount of the variation in WTP being explained by household, community, and program attributes.

Third, we test for heteroscedasticity using (5). By construction of the bid design, BID is systematically related to the variance of the latent WTP errors. Recall that the opening bids are even integers between two and 10, with subsequent bids equal to either half or twice the opening amount. Therefore, the bid design generates larger WTP intervals (and thus more uncertainty regarding the true WTP) for higher opening bids. As expected, the coefficient on BID is positive and statistically significant at the 1% level. Furthermore, the likelihood ratio statistic used to test the null hypothesis that $\gamma = 0$ in (5) is 510.75 with a 1% critical value equal to 6.63. Therefore, we reject the null hypothesis in favor of heteroscedastic errors.

4.3. Calibrating WTP for Hypothetical Bias

The potential for hypothetical bias arises whenever people are asked to provide a maximum amount they are willing to pay for a good or service, even though they will not have to actually pay for it (cf., Arrow et al. 1993; Hanemann, 1994; Diamond and Hausman, 1994). We estimate the magnitude of the bias in each of our community types – voluntary, mandatory and no CRP – and calibrate the mean WTP estimates accordingly. In CVM it is typically not possible to estimate the magnitude of hypothetical bias (although Aadland and Caplan (2003a) establish its presence in a related curbside recycling study). Estimation of hypothetical bias requires two similar groups of households valuing the same good – one making actual (revealed) decisions, the other making hypothetical (stated) decisions. Unfortunately, this is rarely possible in CVM because the good under question is not typically traded in an established market. Even if the good is traded in an established market, one needs sufficient variation in the price of both the hypothetical and actual goods. With this in mind, our experiment was designed to satisfy both criteria. Our sample includes two different groups (one making stated decisions and the other making revealed decisions) and price variation across both hypothetical and actual CRPs. This feature of our data enables us to estimate the magnitude of hypothetical bias for each of our community types. We begin with voluntary CRP communities.

4.3.1. Estimating Hypothetical Bias: Communities with Voluntary CRPs

We first extract two non-overlapping subsamples of households from the dataset: (a) households residing in communities with voluntary CRPs that made a *hypothetical* decision about whether to participate in their existing CRP at a randomly assigned, initial bid level and (b) households residing in communities with voluntary CRPs that have made an *actual* decision about whether to participate in their existing CRP. Households in the second subsample (N = 538) have revealed their preferences for curbside recycling, while households in the first subsample (N = 630) are simply stating their preferences for curbside recycling. The subsample of stated-preference households was restricted to those whose initial (cost-of-living adjusted) bids were between \$1.30 and \$4.94 per month in order to be directly comparable with the existing fees faced by the revealed-preference households.

Next, we pool these two groups together and estimate a simple (random-threshold) probit model for the decision of whether to participate in a voluntary CRP, controlling for a host of household, program, and community attributes. We also allow the error variances to differ according to whether households are stating or revealing their preferences (Adamowicz et al., 1994). Our null hypothesis of no hypothetical bias is tested by observing the statistical significance of the coefficient on the dummy variable for whether the participation decision is hypothetical or real. If this coefficient is positive and statistically significant, we conclude that the typical household in a community with a voluntary CRP will, all else equal, tend to overstate their WTP for curbside recycling by the value of the coefficient. The estimation results for this model, shown in columns four and five of Table 3, indicate that hypothetical bias for households in voluntary CRP communities is nearly $2 per month.

4.3.2. Estimating Hypothetical Bias: Communities with a Mandatory or No CRP

Next, we estimate hypothetical bias for households residing in communities with either a mandatory CRP or no CRP, using methods similar to those described above. In this case, the revealed-preference group includes all households that reside in voluntary CRP communities with existing (cost-of-living adjusted) fees between $1.30 and $4.94 per month and that are aware of the program's existence, irrespective of the initial hypothetical bid that they received (N = 994).[17]

There are two stated-preference groups in this case – those making hypothetical decisions about their mandatory CRP (N = 332) and those in communities without a CRP who are making make decisions about a hypothetical CRP described in the survey (N = 788). We then pool all three groups – the revealed-preference voluntary CRP group, the mandatory CRP group, and the hypothetical CRP group – and estimate a (random-threshold) probit model to predict whether a household participates in a CRP. As before, we control for a wide variety of household, program and community attributes, and we allow the error variances to differ by CRP type and whether the households are stating or revealing their preferences. The two variables of most interest are the binary ones for whether the stated-preference households are located in a community with

[17] We estimate hypothetical bias for the mandatory and no CRP households separately from the bias in the voluntary CRP households because the revealed-preference group in this section is larger than that in Section 4.3.1.

either a mandatory or no CRP. If the coefficients on these two dummy variables are positive and statistically significant, we interpret this as evidence in favor of positive hypothetical bias. In other words, when faced with the decision of whether to sign up for a CRP, all else equal, households located in a mandatory or no CRP community that are making a hypothetical decision are more likely to do so (and consequently have a higher latent WTP) than those making an actual decision.

The results from this experiment, shown in columns six and seven of Table 3, indicate that hypothetical bias among households in mandatory and no CRP communities is $2.65 and $2.77 per month, respectively. As anticipated, the bias estimate for the typical household in a mandatory CRP community is lower (albeit slightly) than that for the no-CRP community, and both of these estimates are higher than that for the typical household in a voluntary CRP community. This ordering suggests that the experience associated with voluntarily signing up for and/or using a CRP enables households to more accurately determine their true WTP.

4.3.3. Calibrated WTP

Using the hypothetical bias estimates from the previous two sections, we can adjust the mean WTP estimates, conditional on whether the household resides in a voluntary, mandatory, or no CRP community. Also, using city-level U.S. Census Bureau data (2000) we are able to adjust the estimates to better represent population demographics. Making adjustments for hypothetical bias and sampling error, we find that the average calibrated WTP value across the 40 communities in our sample is $2.92 (see bottom of Table 3). Table 4 provides additional details on the calibration process for the nine cities in our sample with available cost data and three randomly selected non-CRP cities. In terms of estimated WTP, these 12 cities are both representative of our sample of 40 cities and highlight the diversity across communities. It is interesting to note that the estimated average monthly benefits per household from curbside recycling range from a high of nearly \$5 in Tempe, AZ to a low of slightly more than \$1 in Palo Alto, CA.

5. Policy Analysis and Conclusions

Remarkably, by comparing our mean calibrated WTP and cost estimates, we conclude that the social net benefits of curbside recycling are almost exactly zero. As a result, to determine whether it is an efficient use of society's resources, we need to evaluate curbside recycling on a city-by-city basis.

In Table 5, we take a closer look at the 12 communities included in Table 4. Calibrated WTP values from Table 4 and per-household costs from Table 1 are provided in columns 2 and 3. Column 4 presents the corresponding social net benefits of curbside recycling, which vary greatly across the 12 communities. For example, monthly net benefits in Tempe, AZ are \$3.27 per household, while in Palo Alto, CA they are -\$3.08. At their current populations and rates of CRP participation, this amounts to annualized net benefits of \$1.5 million in Tempe and nearly -\$1.0 million in Palo Alto.

The last three columns of Table 5 indicate which cities have satisfied CRP Conditions I and II from Section 2. Under the column titled "CRP Condition I Prediction," we combine CRP Condition I with our empirical estimates to predict whether a given community should in fact have a CRP. Of the 12 communities, five satisfy CRP Condition I (i.e., social net benefits of curbside recycling are positive), while seven do not. Of the seven communities that we predict should not have a CRP, three (Abilene, Peoria and Inglewood) represent correct predictions and four (Escondido, Olathe, Newport Beach and Palo Alto) do not. The most probable explanation for why Escondido, Newport Beach, and Palo Alto have chosen mandatory CRPs (when our estimates suggest that their social net benefits are clearly negative) is that California has implemented a state-mandated recycling goal. Recall that we have not incorporated mandatory recycling goals into our theoretical model.

The last two columns in Table 5 show that the two mandatory CRP communities (Tempe, AZ and Longmont, CO) are inconsistent with CRP Condition II, which predicts they should be voluntary CRP communities. This result is premised on the assumption (mentioned in Section 2) of a constant per-household cost of delivering curbside recycling services in both cities. Therefore, the closer these two communities are to having constant per-household costs, the more accurate are the corresponding predictions based on CRP Condition II. Taking the results from CRP Conditions I and II together, the results in the last column of Table 5 indicate that exactly half of our sampled cities are behaving as theory (absent the California mandatory recycling goals) predicts they should. Interestingly, all three of the randomly selected cities in Table 5 that have decided not to implement a CRP are, at least with respect to our theory, making the right decision.

Next, we highlight the main shortcomings of our approach, beginning with the reasons why our estimates may in fact understate social net benefits. First, our final mean WTP estimate may understate the social benefit of recycling if survey respondents are not fully internalizing the public benefits associated with recycling. As mentioned in Section 2, we have assumed that households are "impurely altruistic", in the sense that although they are motivated to recycle out of an "ethical responsibility to help the environment," they may not be fully internalizing the effects of their recycling effort on the welfare of other households located in their community.[18] To the extent that each household values increased aggregate recycling, this may cause us to understate the social net benefit of recycling.

Second, we may be overestimating the costs associated with operating a curbside recycling program. For example, of the 11 communities included in Table 1 only three – Portland, West Linn, and Seattle – are among the thirty communities acknowledged by the U.S. Environmental Protection Agency (EPA) for their "high materials recovery rates [or] model waste reduction initiatives" (U.S. EPA, 1994). It is possible, therefore, that our sample is not representative of the more progressive and efficient recycling programs currently operating throughout the U.S.[19]

On the other hand, it is possible that we may be overstating the net benefits of curbside recycling. The issue of how to account for implicit opportunity costs through discounting is hotly debated (Hanley and Spash, 1993). We have tacitly assumed that the opportunity cost associated with diverting resources toward curbside recycling is the foregone interest income at the market interest rate, which in turn is assumed to equal the social discount rate. As a result, discounting completely offsets any accumulated opportunity costs. To the degree that the market interest rate exceeds the social discount rate, the social net benefit of recycling will diminish, possibly becoming negative. In other words, the explicit costs reported in Table 1 are assumed to be the full economic costs associated with curbside recycling.

In sum, despite the shortcomings mentioned above, this is the most comprehensive study to-date of the social efficiency of curbside recycling. The study covers approximately 20 western U.S. states, surveying over 4,000 households and recycling coordinators in 40 different

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[18] Note that the first-best (community planner's) solution for the i^{th} household is $(u_{r,i} + \sum_{i=1}^{n} u_{R,i})g_e = u_{l,i}$.

communities. The benefit measure generated from the household survey is carefully calibrated for hypothetical bias by contrasting with the actual decisions of households residing in communities with voluntary CRPs. The economic cost of providing curbside recycling services is estimated from direct interviews with the recycling coordinators from cities within our sample and from previous research compiled by the U.S. EPA and ISLR. Remarkably, we find that, on average, the benefits and costs per household are almost exactly identical.

Although this finding lends scientific credibility to an often contentious national recycling debate, it does little to guide national policy regarding municipal recycling programs. At a local level, however, our research suggests that the public policy choices are often much more clear. Some cities with positive net social benefits should clearly be supporting curbside recycling programs and other cities with negative net social benefits should consider other waste management options. Toward that end, our research provides local policymakers within our population of western U.S. states the additional tools necessary to decide whether to implement or maintain a CRP. A natural next step would be to extend our research to the eastern U.S. where the constraints on landfill space are more binding, and to obtain more precise CRP cost data across a wider variety of communities. To accomplish this, more case studies of existing CRPs are required (along the lines of ILSR, 1991; USEPA, 1994; Franklin Associates, Ltd., 1997; and Kinnaman, 2000). This would enable us to more accurately estimate the average total costs for curbside recycling and identify the most cost-effective programs.

[19] There could be several reasons for why our sample does not appear to be representative of the more efficient recycling programs across the country, such as differences in cost-accounting procedures, access to recycling markets, the role of state and local government subsidies, etc.

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Figure 1. Curbside and Dropoff Recycling Effort Functions.

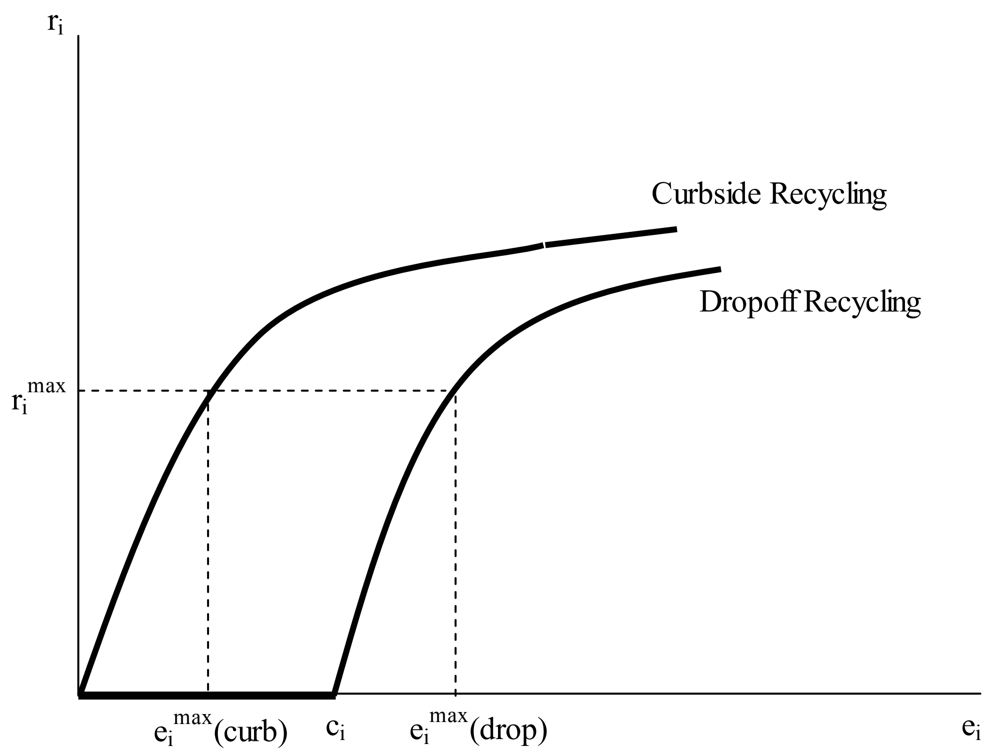
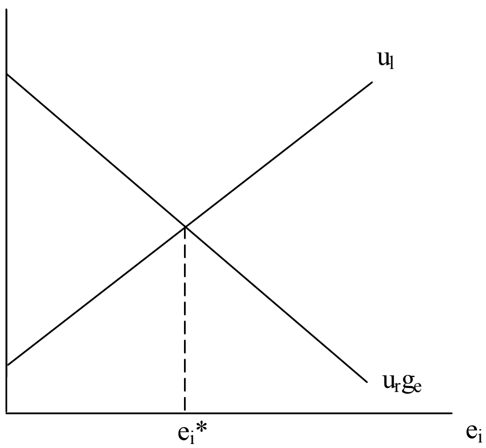
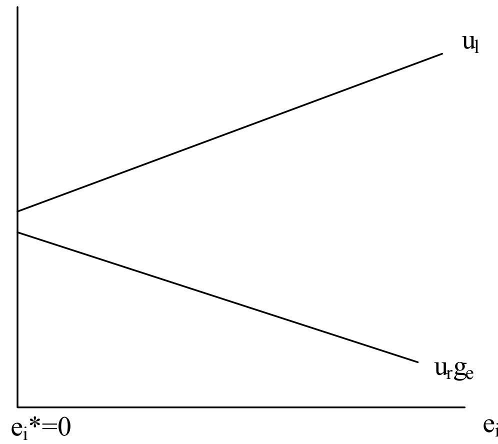


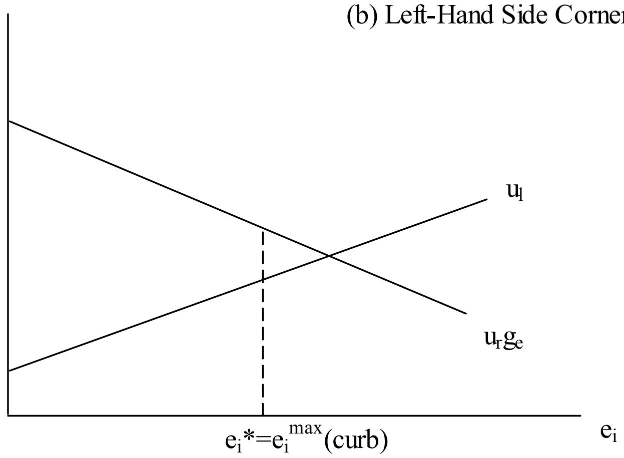
Figure 2. Possible Household Choices with Mandatory Curbside Recycling.



(a) Interior Solution

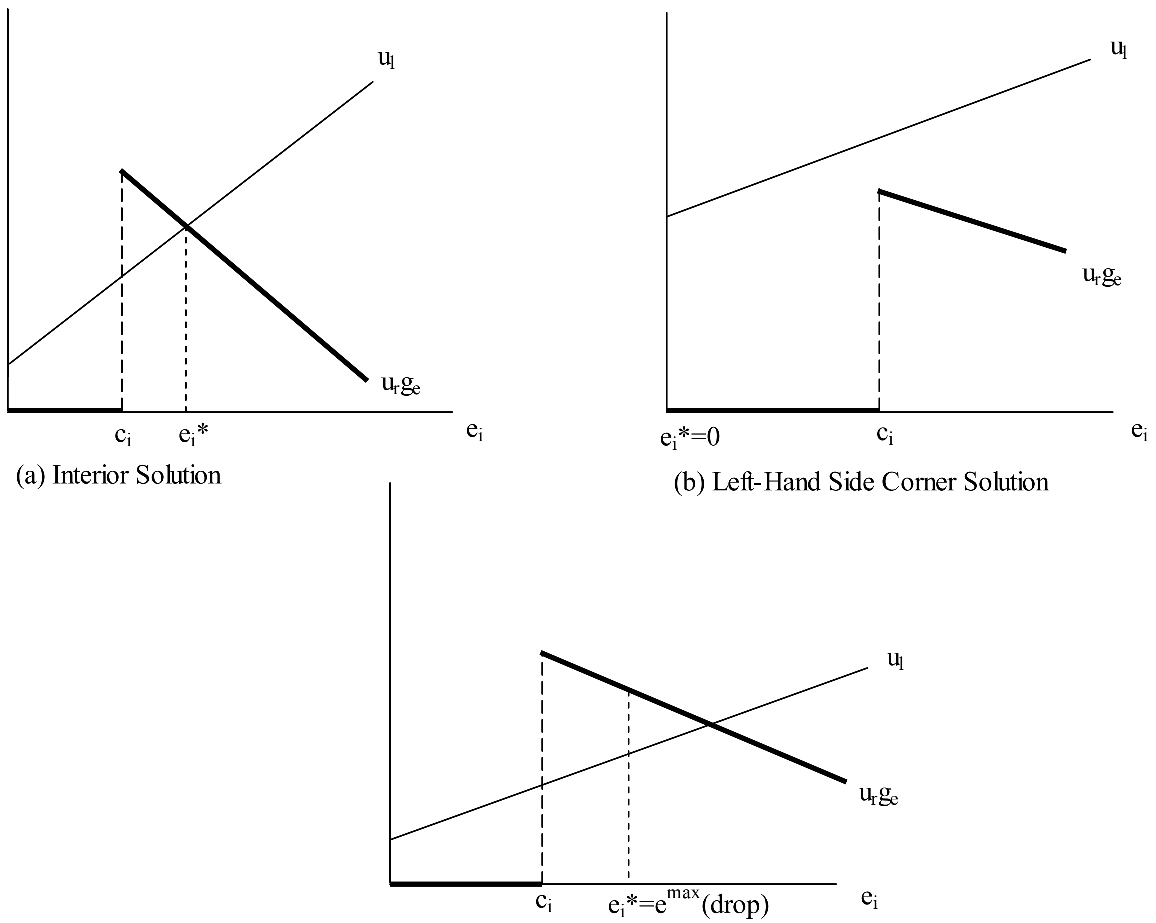


(b) Left-Hand Side Corner Solution



(c) Right-Hand Side Corner Solution

Figure 3. Possible Household Choices with Dropoff Recycling.



(a) Interior Solution

(b) Left-Hand Side Corner Solution

(c) Right-Hand Side Corner Solution

Figure 4. CRP Condition I.

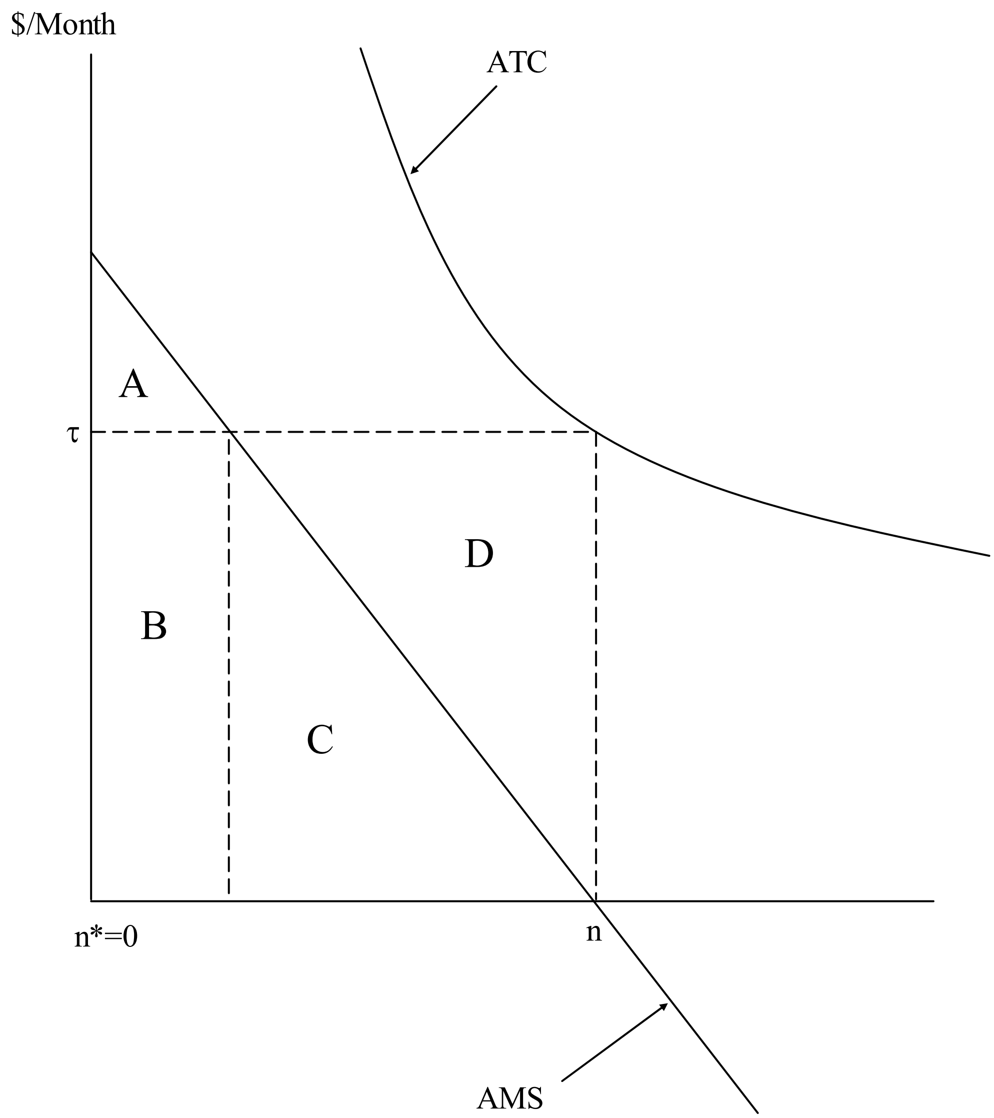


Figure 5. CRP Condition II.

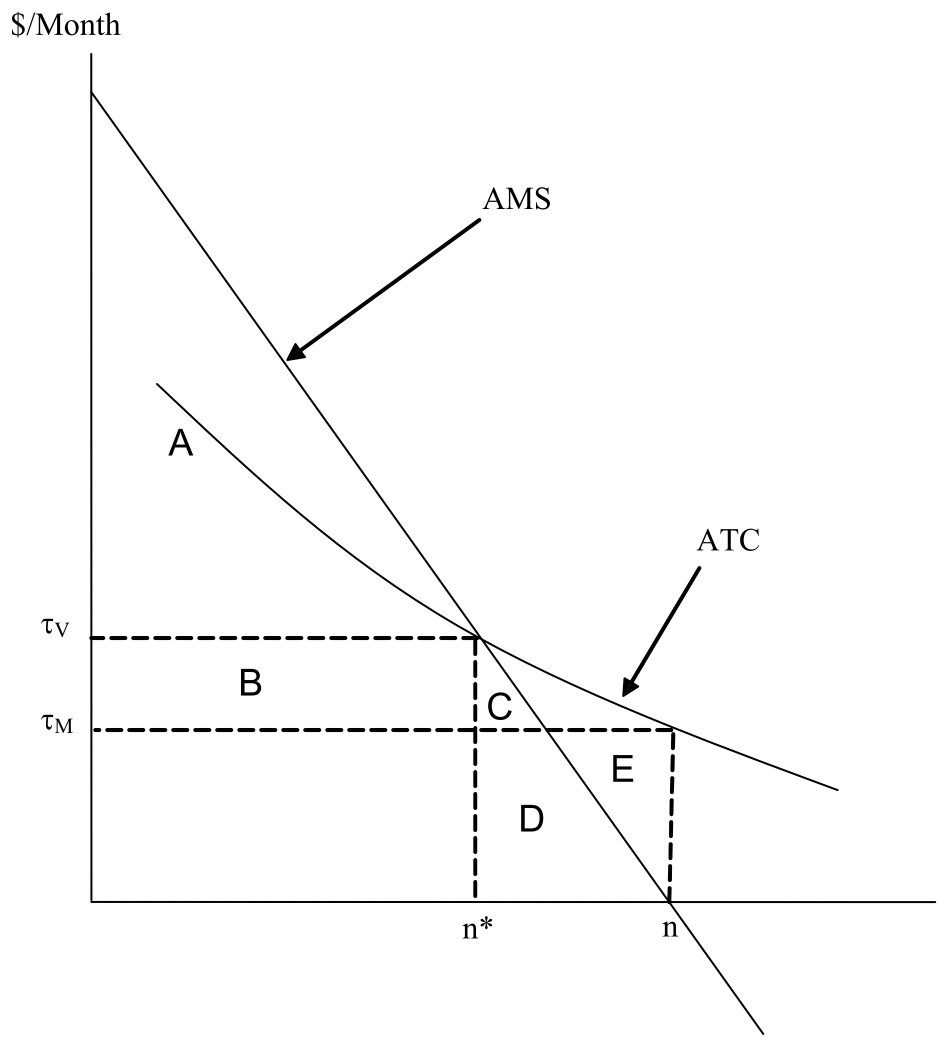


Table 1. Costs per Household and Other Characteristics for CRPs

City	Cost ($) per Household per Month	Number of Households Participating	Percent of Households Participating	Mandatory Program?	Household Sorting Required?
Tempe, AZ	1.62	38,000	60	Yes	Yes
Seattle, WA[e]	1.71	113,484	44	No	No[f]
West Linn, OR[e]	2.21	4,956	61	No	Yes
Fargo, ND	2.68	1,452	4	No	Yes
Orem, UT	2.78[b]	5,400	23	No	No
Portland, OR[c]	2.89	139,431	62	Yes	Yes
Longmont, CO	3.03[g]	22,950	86	Yes	Yes
Escondido, CA	3.16[b]	NA	NA	Yes	Yes
Newport Beach, CA	3.42	27,700	84	Yes	Yes
Olathe, KS[a]	3.58[b]	30,000	93	No	Yes
Palo Alto, CA	5.10[d]	25,216	100	Yes	No
Mean	2.93	40,859	61.7	---	---
Coefficient of Var.	0.33	1.15	0.50	---	---

Notes. [a]Based on figures provided by Franklin Associates, Ltd., "Solid Waste Management at the Crossroads," December 1997. [b]Since the revenues from the sale of recyclable materials were unavailable, we used the average revenue (adjusted for location) across communities that reported revenue sales. This amounted to $0.44 per household per month. [c]Based on figures provided by Neal Johnson, Recycling Coordinator, December 2002. [d]Includes once-a-month curbside collection of household hazardous waste and green waste. [e]Based on figures provided by ILSR (1991). [f]Approximately 56 percent of households (those located in the "north section" of the city) participate a commingled program, while the remaining 44 percent (located in the "south section") participate in a non-sorting program. [g]Processing costs are inferred using Franklin Associates, Ltd. (1997) at $1.53 per household per month (after adjusting for location and inflation). NA means "not available".

Table 2. Variable Definitions

Variables	Description
Ethical Duty	Do you feel an ethical duty to recycle to help the environment? 1 = yes, 0 = no.
Monetary	Are you motivated to recycle in order to save money? 1= yes, 0 = no.
Primarily Ethics	Which most encourages your household to recycle? 1 = ethical duty, 0 = save money.
Dropoff Distance	Distance in miles to the nearest dropoff site.
Dropoff User	In the past 12 months has your household used dropoff recycling? 1 = yes, 0 = no.
Young	1 if 18<Age<35, 0 otherwise.
Old	1 if 65<Age, 0 otherwise.
Male	1 = male, 0 = female.
High School	Highest level of education in household? 1 = high school graduate, 0 = otherwise
Associates	1 = associates degree, 0 = otherwise
Bachelors	1 = bachelors degree, 0 = otherwise
Masters	1 = masters degree, 0 = otherwise
Ph.D.	1 = Ph.D. or equivalent professional degree, 0 = otherwise
Household Size	Number of adults in household, other than the respondent.
Environmental Org.	Anyone in your household belong to an environmental organization? 1 = yes, 0 = no.
Med Income	1 if \$35K/yr<Household Income<\$75K/yr, 0 otherwise
High Income	1 if \$75K/yr<Household Income, 0 otherwise
Employed	Adult with the highest income currently employed? 1 = yes, 0 = no.
Retired	Adult with the highest income currently retired? 1 = yes, 0 = no.
Short Cheap Talk	1 = received short cheap-talk statement, 0 otherwise.
Longer Cheap Talk	1 = received longer cheap-talk statement, 0 otherwise.
Sorting Required	1 = CRP requires some sorting of recyclable materials, 0 otherwise.
Polite	1 if polite refusal for first call attempt, 0 otherwise.
Angry	1 if angry refusal for first call attempt, 0 otherwise.
Landfill Visit	Has anyone in your household visited your community's landfill? 1 = yes, 0 = no.
Landfill Distance	Distance to nearest landfill in miles.
Landfill Distance > 2 mi.	Distance above and beyond 2 miles to nearest landfill, 0 otherwise.
Hypothetical	1 = respondent valued a hypothetical CRP, 0 = otherwise.
Precision	On a scale of 0-100, how certain are you of the answers to your WTP questions?
English	Is English your first language? 1 = yes, 0 = no
Employer Recycle	Do you recycle at work? 1 = yes, 0 = no
Caucasian	What racial group best describes you? 1 = White or Caucasian, 0 otherwise
Hispanic	What racial group best describes you? 1 = Hispanic, 0 otherwise
African American	What racial group best describes you? 1 = Black or African American, 0 otherwise
Generation Link	Were you (or other adults in your house) raised in recycling households? 1 =yes, 0 = no
Neighbor Recycle	Do most of your neighbors currently recycle?
Years in Community	How many years have you lived in your community?
Number of Children	How many children under the age of 18 currently live in your home?
Attempt 1	Respondent available for survey after first dialing attempt.
Attempt 2	Respondent available for survey after second dialing attempt.
Fee Known	Respondent offer answer to how much household pays for current CRP? 1 = yes, 0 = no
Fee Difference	Stated CRP fee minus actual CRP fee.
CRP Performance	Job performance of your current CRP? 1 = excellent or good, 0 = fair or poor

Notes. The description does not always exactly match the wording in the survey instrument. To see the exact wording, please refer to www.uwyo.edu/aadland/research/recycle/datareport.pdf.

Table 3. Estimation Results for WTP and Participation Models

Explanatory Variables	DBDC WTP Estimates		Voluntary CRP Participation Probit Estimates		Mandatory/No CRP Participation Probit Estimates	
	Coefficient	P –Value	Coefficient	P –Value	Coefficient	P –Value
Ethical Duty	2.839***	0.000	3.299***	0.001	4.725***	0.000
Monetary	0.289	0.244	0.797	0.200	-0.626	0.264
Primarily Ethics	1.167***	0.000	0.924**	0.023	1.414***	0.003
Dropoff Distance	0.022	0.194	0.049	0.114	0.067	0.101
Dropoff User	-0.056	0.398	-0.203	0.289	-0.422	0.178
Young	1.507***	0.000	-0.681**	0.032	0.266	0.271
Old	-0.246	0.194	-0.464	0.184	-0.822*	0.096
Male	-0.557***	0.000	-0.238	0.171	-0.002	0.497
High School	0.512	0.138	0.044	0.484	1.150	0.160
Some College	0.643*	0.087	-0.254	0.407	1.196	0.150
Associates	0.276	0.291	0.243	0.413	1.542*	0.100
Bachelors	0.822**	0.039	0.522	0.313	1.803*	0.060
Masters	0.858**	0.039	0.969	0.193	2.199**	0.034
Ph.D.	1.518***	0.002	0.431	0.353	2.039*	0.053
Household Size	0.093	0.127	-0.026	0.424	0.026	0.438
Environmental Organization	1.319***	0.000	0.802**	0.039	1.567***	0.003
Med Income	-0.011	0.478	0.043	0.454	0.139	0.377
High Income	0.165	0.241	-0.060	0.440	0.484	0.159
Employed	3.732**	0.024	1.273**	0.041	0.246	0.364
Retired	0.161	0.331	1.381**	0.039	1.334*	0.054
English	0.777*	0.079	-1.111	0.230	-1.711	0.118
Caucasian	0.681***	0.005	-0.135	0.376	-0.645	0.116
Hispanic	0.215	0.278	-0.379	0.279	-0.919	0.124
African American	0.071	0.442	1.129	0.117	-0.071	0.473
Generational Link	0.181	0.120	0.238	0.186	0.547**	0.050
Neighbors Recycle	-0.220	0.155	---	---	---	---
Number of Children	-0.049	0.200	0.106	0.119	-0.048	0.327
Call Attempt #1	-0.182	0.183	0.492*	0.070	0.810**	0.024
Call Attempt #2	-0.477**	0.028	0.350	0.193	0.706*	0.080
Years in Community	-0.020***	0.000	-0.008	0.199	-0.007	0.267
Employer Recycle	0.005	0.490	0.186	0.281	0.884**	0.018
Polite	-0.698***	0.002	-0.487*	0.086	-0.895**	0.026
Angry	-0.394	0.323	-0.075	0.481	1.270	0.233
Precision	-0.013***	0.000	-0.003	0.301	-0.009	0.104

Table 3. Estimation Results for WTP and Participation Models (continued)

Fee Known		-0.455**	0.015	1.094***	0.003	---	---
Fee Overstated		0.069***	0.000	-0.013	0.235	---	---
CRP Performance		2.027***	0.000	---	---	---	---
Sorting Required		-0.261*	0.076	---	---	-1.140***	0.004
Landfill Visit		0.029	0.435	0.132	0.325	0.089	0.402
Landfill Distance		-1.731	0.117	0.211	0.147	0.570***	0.010
Landfill Distance > 2 mi.		1.747	0.115	-0.234	0.136	-0.674***	0.005
Short Cheap Talk		0.351**	0.021	1.301*	0.075	1.362**	0.031
Longer Cheap Talk		0.694***	0.000	1.839**	0.024	2.307***	0.002
CRP Community		-1.021***	0.000				
Voluntary CRP Hypothetical Bias				1.967***	0.003		
Mandatory CRP Hypothetical Bias						2.645**	0.017
No CRP Hypothetical Bias						2.765***	0.000
Hetero.	Constant	1.798***	0.000	2.359***	0.000	2.828***	0.000
	Bid	0.190***	0.000	0.220*	0.058	0.158*	0.073
	Voluntary SP			2.428***	0.000		
	Mandatory SP					1.277**	0.013
	No CRP SP					1.050***	0.005
Sample Size		4012		1168		2114	
Mean WTP		5.368		---		---	
Calibrated Mean WTP		2.922		---		---	

Notes. (***), (**), and (*) refer to statistical significance at the 1, 5 and 10 percent levels respectively. The estimates for the constant terms, community dummy variables, as well as the dummy variables for “don’t know” and “missing responses” are not shown.

Table 4. Calibrated WTP for Select Cities

City	CRP Type	Raw WTP Estimate	Hypothetical bias correction	Sample vs. population correction	Calibrated WTP Estimate
Tempe, AZ	M	7.57	-2.65	-0.03	4.89
Longmont, CO	M	7.21	-2.65	-0.02	4.54
Orem, UT	V	5.75	-1.97	+0.05	3.83
Wichita, KS	V	5.16	-1.97	+0.15	3.34
Fargo, ND	V	4.86	-1.97	+0.07	2.96
Abilene, TX	N	4.97	-2.77	+0.06	2.26
Palo Alto, CA	M	5.03	-2.65	-0.36	2.02
Olathe, KS	V	4.06	-1.97	-0.07	2.02
Peoria, AZ	N	4.81	-2.77	-0.02	2.02
Escondido, CA	M	4.58	-2.65	+0.04	1.97
Inglewood, CA	N	4.06	-2.77	+0.36	1.65
Newport Beach, CA	M	4.09	-2.65	-0.30	1.14

Notes: Mandatory and voluntary CRP cities were selected due to the availability of cost data. Three representative non-CRP cities were chosen at random. The correction for differences between the sample and population demographics includes the variables: gender, age, education, household size, income, primary language and race.

Table 5. City Comparisons of Net Benefits and Theoretical Predictions for CRP Type

City	WTP	Cost	Net Benefit (WTP-Cost)	CRP Type	CRP Cond.I Prediction	CRP Cond.II Prediction[b]	Correct Prediction?
Tempe, AZ	4.89	1.62	3.27	M	CRP	V	No
Longmont, CO	4.54	3.03	1.51	M	CRP	V	No
Orem, UT	3.83	2.78	1.05	V	CRP	V	Yes
Wichita, KS	3.34	2.93[a]	0.41	V	CRP	V	Yes
Fargo, ND	2.96	2.68	0.28	V	CRP	V	Yes
Abilene, TX	2.26	2.93[a]	-0.67	N	No CRP	---	Yes
Peoria, AZ	2.02	2.93[a]	-0.91	N	No CRP	---	Yes
Escondido, CA	1.97	3.16	-1.19	M	No CRP	---	No[c]
Inglewood, CA	1.65	2.93[a]	-1.28	N	No CRP	---	Yes
Olathe, KS	2.02	3.58	-1.56	V	No CRP	---	No
Newport Beach, CA	1.14	3.42	-2.28	M	No CRP	---	No[c]
Palo Alto, CA	2.02	5.10	-3.08	M	No CRP	---	No[c]

Notes: (a) The overall mean cost estimate from Table 1. (b) Prediction made under the assumption of constant ATC (c) Theoretical prediction does not account for state-mandated recycling goals.