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Generation of Recyclables by Rural Households

Paul M. Jakus, Kelly H. Tiller, and William M. Park

Rising landfill costs have forced solid waste managers to consider ways to reduce the waste stream. Using survey data, models explaining the weight of recyclables generated by households are estimated for paper and glass. Results indicate that households respond to the time cost of recycling paper but not glass. The waste generation models imply total monthly willingness to pay for recycling is $5.78 per household. Waste managers may increase the weight of recycled waste stream with programs which lower perceived time costs of nonrecyclers and improve the efficiency of recyclers.

Key words: generation of recyclables, recycling, willingness to pay

Introduction

Subtitle D regulations of the 1984 Resource Conservation and Recovery Act are raising the cost of traditional solid waste disposal methods. In response, many state and local governments have mandated reductions in solid waste requiring disposal and/or have established recycling programs. In some cases citizens have demanded the opportunity to recycle, which forced local decision makers to consider a wider range of alternative solid waste management plans (SWMP). Because of the significant economies of scale in collection, processing, and marketing of recyclables, a large volume of materials must be recovered if residential recycling is to be cost effective. Such economies of scale are difficult to achieve in rural areas unless a large proportion of eligible material is recycled.

Although information regarding potential recyclables generation is crucial in determining whether a recycling program can be an efficient component of a SWMP, there has been little research investigating the economic factors which influence household recycling generation. The few available studies focus on curbside collection of recyclables in urban areas, examining the effect on the quantity of material recycled in response to unit-based pricing for garbage disposal (Fullerton and Kinnaman; Hong, Adams, and Love; Morris and Holthausen). There has been no attempt to measure an own-cost effect for recycling or households' implied willingness to pay for recycling opportunities.

Our study fills this void by examining household recycling decisions in rural areas where low population density makes dropoff recycling the fiscally viable alternative. Using survey data, an implicit cost for recycling paper and glass is constructed and used to estimate "recyclables generation" models. The empirical models show that weight of paper recycled is responsive to the time cost of recycling, whereas the model results for glass are inconclusive. Finally, because these generation models are analogous to travel

Authors are assistant professor, graduate research assistant, and professor, respectively, in the Department of Agricultural Economics and Rural Sociology, The University of Tennessee.

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cost visitation models, we can obtain a measure of household willingness to pay (WTP) for recycling.

A Behavioral Model of Recycling

Theoretical Model

In this section, we present a model in which recycling is observed even in the absence of monetary incentives, a common occurrence in many communities. Recognizing that some individuals may wish to limit the amount of waste generated and sent to a landfill or incinerator, the utility function is given by

$$U[Z(x), G(S, x), L].$$

Z is the consumption commodity produced by the household using purchased inputs x, where x is an $n \times 1$ vector. G is the amount of garbage sent for disposal and is a function of inputs x and time spent separating recyclables, S. S is an $n \times 1$ vector of labor spent recycling some portion of the refuse generated by purchased inputs x. L is the amount of leisure consumed. The marginal product (Z_{x_j}) of any element j in x is positive, while the marginal utilities are assumed to be $U_z > 0$, $U_L > 0$, and $U_G \leq 0$. This last term is an inequality because garbage generation will impact the utility of some people negatively (those who would consider voluntary recycling), while it will not affect others (those who do not care about waste production).[1]

Use of inputs (x) generates trash (T) according to a function, $T(x)$, where $T_{x_j} > 0$. Trash may be separated into garbage or recyclable materials. Production of recyclables (R) is a function of the total time spent separating recyclables (S) and the amount of inputs x available for recycling:

$$R = R(S, x), \tag{1}$$

where R is increasing in both arguments. The amount of garbage is determined by total trash less recyclables, or

$$G(S, x) = T(x) - R(S, x). \tag{2}$$

Let the household's full income consist of wage and nonwage income, so that the budget constraint is

$$wH + V = p'x + fG(S, x),$$

where w is the wage rate, H is hours worked, V is nonlabor income, f is the unit cost of garbage disposal, and p is the $n \times 1$ price vector for x. A standard budget constraint is obtained if $f = 0$. The household's time is also constrained according to

$$D = H + L + i'S,$$

where D is total time available and i is an $n \times 1$ vector of ones. Substituting (1) and

[1] If the amount of material recycled also yields utility, the recently popular "altruistic" utility function may be specified as $U(Z, G, L, R)$, where R is the amount recycled and $U_R > 0$. Using this utility specification, the first-order conditions imply that even more waste will be recycled. Unfortunately, the model also implies that, given two inputs with equal amounts of product, the input with the greatest amount of packaging will be purchased because of the additional utility derived from recycling (Morris and Holthausen).

(2) directly into the utility function and budget constraint yields a consumer problem in which the variables of interest are x, S, and L. The constrained optimization problem is then given by (3):

$$\text{(3)} \quad \max \mathcal{L} = U[Z(x), T(x) - R(S, x), L] + \lambda\{wH + V - p'x - f[T(x) - R(S, x)]\} + \mu(D - H - L - i'S).$$

Where $j = 1, \ldots, n$, the conditions needed to optimize x, S, and L are given by (4a) through (4f):

$$\text{(4a)} \quad \partial\mathcal{L}/\partial x_j = U_Z Z_{xj} + U_G(T_{xj} - R_{xj}) - \lambda[p_j + f(T_{xj} - R_{xj})] \leq 0,$$

$$\text{(4b)} \quad (\partial\mathcal{L}/\partial x_j)x_j = 0,$$

$$\text{(4c)} \quad \partial\mathcal{L}/\partial S_j = -U_G R_{Sj} + \lambda(fR_{Sj}) - \mu \leq 0,$$

$$\text{(4d)} \quad (\partial\mathcal{L}/\partial S_j)S_j = 0,$$

$$\text{(4e)} \quad \partial\mathcal{L}/\partial L = U_L - \mu \leq 0, \text{ and,}$$

$$\text{(4f)} \quad (\partial\mathcal{L}/\partial L)L = 0,$$

where λ is the shadow value of income, μ is the shadow value of time, and Kuhn-Tucker conditions are needed because some consumers will not recycle. The derivatives with respect to H and the Lagrangian multipliers are suppressed.

Equation (4a) shows that the choice of optimal input level for x_j is affected by the "marginal utility product" of the input and the potential disutility of garbage produced (if $U_G < 0$), where $(T_{x_j} - R_{x_j})$ is the amount of garbage generated by the marginal unit of x_j. Condition (4a) reflects not only the market price of x_j but also its disposal cost, $f(T_{x_j} - R_{x_j})$. Condition (4b) is presented for completeness.

Equations (4c) and (4d) govern the optimal choice of S_j, the amount of time invested in recyclables preparation and separation for input x_j. If a consumer recycles, (4c) holds as an equality. Dividing by λ converts all terms to monetary values, so that the marginal benefit of time spent recycling is just balanced by the net marginal cost of recycling, $(\mu/\lambda - fR_{S_j})$, where μ/λ is the opportunity cost of time. If an individual's marginal cost of recycling exceeds the marginal benefit (for example, if $U_G = 0$ and $\mu/\lambda > fR_{S_j}$), then (4c) is negative and (4d) represents the appropriate marginal condition for a nonrecycler.

Conditions (4e) and (4f) deal with the optimal choice of leisure. At an interior solution, the marginal utility of leisure is equated with the shadow value of time. If the leisure activity is the next best alternative to recycling activities (for example, if work hours H cannot be adjusted by the individual), the opportunity cost of time in (4c) is not necessarily equal to the wage rate (W. D. Shaw).

The model explains how people can engage in a variety of waste reduction and recycling activities. Upon an increase in the marginal disposal fee f, consumers may choose products to decrease $T(x)$ or increase $R(S, x)$. Because f enters the budget constraint, consumers will "waste reduce" even if there is no disutility to garbage generation [condition (4a)]. Second, some consumers not currently recycling—those with $U_G < 0$, but whose marginal costs exceed the marginal benefits—would be more likely to recycle as the marginal cost of recycling declines [condition (4c)]. Finally, the model provides a rationale for the observation that some people recycle without monetary incentives. A flat-fee garbage disposal price implies the marginal disposal fee is zero. Purchases of input x_j would increase as its full cost (market price plus disposal cost) falls [condition (4a)]. Time spent in separation would decrease as the net marginal cost of recycling increases [condition (4c)]. The behavioral motivation to recycle remains, however, if the marginal benefit of recycling $(-U_G R_{S_j})$ is positive [condition (4c)].

Implementing the Model

Household production models require restrictive assumptions regarding the technology available to the household to make such models empirically tractable. Inputs to and outputs from each production process must be precisely identifiable and nonjoint. Production processes must have linear cost functions to yield a linear budget constraint. Further, the technical coefficients of the cost function must be exogenous to the consumer (Pollack and Wachter). As written, however, the model exhibits jointness in the purchased input vector x, where x is an input to the consumption, waste generation, and recycling production processes. Fortunately, some reasonable assumptions regarding the waste generation and recycling production technologies are sufficient to meet the conditions required for empirical estimation of the model.

Begin by noting that each input can be separated into "product" and "packaging." For example, a soft drink may contain 16 ounces of product (its net weight) and 1 ounce of plastic packaging. Thus, x_j is then allocatable across the production technologies, such that any unit of good x_j contains θ_j proportion of packaging and $(1 - \theta_j)$ of product. The packaging coefficient θ_j is exogenous and bounded by zero and one. Each good x_j has its own packaging coefficient, so that total trash production is $T(x) = \Sigma_j \theta_j x_j$. Consumers may reduce waste by selecting marketed goods with little packaging relative to the amount of product. The allocation of x establishes separability of $Z(x)$ and $G(S, x)$, which may be rewritten as $Z[(i - \theta)'x]$ and $G(S, \theta'x)$, where θ is an $n \times 1$ packaging coefficient vector.[2]

Each unit of trash also can be divided into its recyclable and nonrecyclable components. For refuse generated by input x_j, let γ_j be the proportion which is recyclable and $(1 - \gamma_j)$ be the proportion which is not recyclable, where γ_j is exogenous and bounded by zero and one. Further, let τ_j measure recyclables output produced using one unit of labor, so that $1/\tau_j$ units of labor are required to produce one unit of recycled material. Where S_j is total labor invested in recycling x_j, the production function for recyclables may be written as

$$R_j = \min[\tau_j S_j,\ \gamma_j(\theta_j x_j)],$$

where τ_j and γ_j are the technical coefficients of the Leontief production function. Assuming that x_j is purchased solely for its product, packaging available for disposal or recycling is costless. Noting that recycling requires little or no costs other than time, the unit cost function associated with recyclables production is

$$c_j = (\omega/\tau_j), \tag{5}$$

[2] For ease of exposition, an implicit assumption is that the consumption commodity $Z(x)$ and trash production $T(x)$ require zero time in production. The model can be extended to include time requirements in these technologies.

where ω is equal to the opportunity cost of time, μ/λ.[3] The τ_j and γ_j are exogenous to the consumer and the cost function is linear, satisfying the conditions outlined by Pollack and Wachter.

With these restrictions, the solution to (3) yields a function measuring the weight of recyclable material generated by the household. The function's arguments include all cost, price, and income terms, as well as the technology parameters:

$$r_j = r_j(\omega/\tau_j,\ \theta,\ \gamma, f,\ p,\ w,\ V), \tag{6}$$

where recycling of material j is assumed to be independent of the cost of recycling other materials, and $r_j(\cdot)$ is expected to be negatively influenced by the own cost of recycling and positively related to garbage disposal costs and income.[4] It is not clear a priori how $r_j(\cdot)$ will be impacted by p because changes in relative prices will result in substitution among products with different packaging and recycling coefficients.

Data Collection and Econometric Issues

Household recycling data were collected in Williamson County, Tennessee, in August and November of 1992. Located in middle Tennessee just south of Nashville, Williamson County has distinct suburban (northern) and rural (southern) regions. Most households in rural areas do not contract for house-to-house garbage collection. It is illegal to burn or bury waste, so the county has established a network of seven convenience (dropoff) centers in rural areas, where residents without house-to-house garbage collection can drop off their garbage. Residents are not required to separate trash into garbage and recyclables, but separated recyclables are accepted at all convenience centers. Most rural residents live less than five miles from the nearest convenience center, so delivery costs are negligible. Further, all but one person interviewed combined recyclables delivery with other activities (e.g., garbage delivery and a shopping trip). To allocate the travel costs between recycling and other activities would have been very difficult.

The survey was designed using a focus group and two pretests conducted at convenience centers in Knox County, Tennessee. Two hundred eighty-four individuals were interviewed as they entered convenience centers and asked if they would participate in the study.[5] Upon completion of one interview, enumerators attempted to interview the next person entering the convenience center. The response rate was 70.1%. Table 1 provides summary statistics of key variables. Respondents were presented with a number of statements regarding issues associated with household recycling and rural solid waste

[3] If consumers are willing to pay a premium to obtain packaging with particular characteristics, trash available for recycling is not costless. Assuming the price of x_j is evenly distributed across product and packaging, the cost function then would be $c_j = (\omega/\tau_j) + (\theta_j \rho_j)/\gamma_j$. The recycling technology also assumes an absence of other fixed or variable costs because recyclables require little capital investment and may be collected in paper or plastic bags in which groceries were once carried. Time costs remain the bulk of recycling costs.

[4] The recyclables generation function in (6) is analogous to the travel-cost, visitation equation derived from a household production model, where ω/τ is equivalent to the constructed opportunity cost of time portion of a travel-cost variable.

[5] Respondents were interviewed at three of the seven rural convenience centers. Interviews were conducted at convenience centers rather than at individual homes because the goal was to focus on those households with no trash hauling services. While this kept survey costs relatively low, the method introduces endogenous stratification into the sample, that is, interviews are more likely to occur with individuals who make frequent visits to convenience centers rather than with those who visit infrequently. To adjust for this problem, it would be necessary to know the relationship between the sampling method and the probabilities of visitation for each individual (D. Shaw). This was not possible given the data available.

Table 1. Summary Statistics for Key Variables

Variable	Mean or %	Std. Dev.	*n*
INCOME ($1,000s)	39.85	22.16	262
EDUCATION (years)	12.45	3.35	284
GENDER (% female)	27.10	0.45	284
HOMEOWNER (% owning)	85.56	0.35	284
HHMEMBER (no. of household members)	3.08	1.39	284
AGE (years)	44.38	14.89	283
FRIENDS: I have friends who recycle. (% yes)	74.32	0.44	257
Recycle Paper (% yes)	54.58	0.50	284
BROUGHT Paper (% yes)	23.24	0.42	284
INTERVAL Paper (days)	23.73	45.03	154
Recycle Glass (% yes)	39.79	0.49	284
BROUGHT Glass (% yes)	11.62	0.32	284
INTERVAL Glass (days)	15.17	10.96	113
Other variables:[a]			
TIME: It takes little time to recycle.	2.02	0.53	274
STORAGE: My home has adequate storage space for recyclables.	2.49	0.74	284
GENERATE: My household generates enough material to make recycling worthwhile.	2.14	0.69	281

[a] Measured on a four-point scale: 1 = strongly agree, 2 = agree, 3 = disagree, 4 = strongly disagree.

management and were asked to state the degree to which they agreed or disagreed with these statements. The statements and mean responses are also reported in table 1.

As each respondent was being questioned by one interviewer, his or her garbage and/or recyclables were being weighed by a second interviewer. Respondents were asked to estimate the number of days it had taken to accumulate the garbage and/or recyclables they had brought with them (the "accumulation interval"). Accumulation intervals were used to convert measured weights to monthly generation rates (pounds per month) for the materials accepted in the recycling program. Interviewers recorded the modal container size for glass, the weight of which was used as an estimate of $\gamma_j \theta_j x_j$. The average daily weight of the local newspaper was used as the estimate for paper. For the full sample, the mean monthly generation of paper was 10.55 pounds per household; mean monthly generation of glass per household was 2.38 pounds.[6]

The econometric approach used in the empirical analysis is driven by differences between self-reported recycling participation and observed participation. For paper, 54.6% of the sample reported recycling, yet only 23.2% showed up with recyclables in hand. Nearly 40% of the sample reported recycling glass, but only 11.6% were observed to recycle glass. It was not expected that all recyclers would bring all recyclables each time garbage is dropped off; however, the disparity between the percentages might require some explanation. For many people, the accumulation interval for recyclables is longer than that for garbage. This may be because recyclables "keep" better than garbage, or that storage capacity and household size combine to determine frequency of

[6] These figures fall within the range obtained in an EPA study of 16 dropoff recycling programs. Monthly household generation of paper ranged between 1.6 and 22.5 pounds (with a mean of 5.9 lbs.) while the range for glass was 0.1 to 5.25 pounds (mean 1.14 lbs.).

recyclables dropoff. Thus, an intercept survey method is more likely to interview a recycler on a "garbage-only" day rather than a day on which recyclables were included in the dropoff. Further, a household with relatively high recycling costs would accumulate recyclables at a slower rate than those households with lower costs.

The data support these hypotheses. Each household representative who claimed to recycle a material was asked how long, on average, it took to recycle one unit of the material (that is, one newspaper, one glass bottle). For both materials, the mean recycling time requirement reported by those who actually brought recyclable material that day was less than the mean time requirement reported by those who said they recycled the material but did not bring any. In addition, individuals with longer accumulation intervals tended to give higher estimates of recycling time.

The data thus contain two types of "zero-generation" observations: those who do not recycle and those who do recycle but brought no material to the dropoff center on the day of the interview. Pudney (p. 174) refers to this second category of zero as a "fortuitous" observation, where a household may consume goods (produce recyclables) in the long run, but is surveyed during a time period in which no "purchases" are made. Fortuitous observations should be retained since there exist valid reasons for observing zero generation.

Two selection criteria are in operation. First, does the household recycle this material, and second, was any material brought to the dropoff center. Catsiapis and Robinson were the first to empirically address this type of problem using ordinary least squares, with Lee (1983) providing a general econometric model. For our study, a probit selection model is used for the recycle/not recycle decision and is estimated simultaneously with a tobit model for recyclables generation, where the dependent variable for recyclers (weight of recyclables) is censored at zero (Greene, p. 572).[7]

Empirical Models

We provide an overview of the two-stage procedure used to estimate recyclables generation models. Two first-stage models are needed to construct a cost measure for recycling. The first is a model predicting household income, while the second estimates the unit time requirement for paper and glass recycling. These two first-stage models are used to construct the cost of recycling, where the income model is used to estimate the opportunity cost of time (ω_i) and the unit time requirement model is used to estimate $1/\tau_{ij}$. The constructed variable (*COST*) is the product of these two estimates and corresponds to the left-hand side of (5). At the second stage, models of household generation of recycled paper and glass are estimated. The second-stage models correspond to (6). A jackknife method is used at the second-stage because the constructed regressor (*COST*) is used in the generation model. In all models, people who claimed to be recyclers are coded as recyclers, regardless of whether they brought recyclables to the convenience center. Results are reported for paper and glass, which constitute 86% of the recyclables waste stream by weight.

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[7] A truncated generation model for just those bringing a positive amount of material would be inappropriate, since we do know something about nonrecyclers. Employing a standard Heckman two-step procedure would require us to drop the large number of "fortuitous" zero-generation observations.

Table 2. Models Predicting Household Income

	Paper	Glass
Intercept	−11.78	−9.78
	(−0.67)	(−0.54)
AGE	1.48*	1.28*
	(2.78)	(2.34)
AGE^2	−0.02*	−0.02*
	(−3.09)	(−2.60)
HOMEOWNER (1 = yes)	13.28*	13.88*
	(3.75)	(3.76)
GENDER (1 = female)	−2.88	−3.84
	(−1.04)	(−1.32)
RACE (1 = non-White)	−11.40	−11.57
	(−1.24)	(−1.20)
EDUCATION (years)	−2.45	−2.27
	(−1.08)	(−0.95)
EDUCATION^2	0.26*	0.26*
	(2.72)	(2.58)
σ	17.72*	18.56*
	(18.77)	(18.72)
n	215	217

Note: Numbers in parentheses represent the ratio of a coefficient to its asymptotic standard error. Asterisks denote significance at α = 0.05.

First-Stage Models

An Income Model. To minimize nonresponse to questions about household income, researchers often ask respondents to indicate a range within which their income falls. Because these data provide only upper and lower bounds on income, the midpoint of each range is used as an approximation of income. An alternative to this ad hoc method is a grouped data model (Stewart). The model adjusts for the doubly censored nature of the discrete data, converting the discrete variable into a continuous variable. Table 2 presents the results of the predicted income model used in this analysis, where income is a function of age, home ownership status, gender, race, and educational attainment of the respondent. All variables are consistent with expectations. Income predicted from this model (*INCOME*) is used to approximate opportunity cost of time. The predicted hourly wage rate (opportunity cost, ω_i) is obtained by dividing *INCOME* by 2,000 hours.[8]

Estimating the Cost Functions. Nonrecyclers were not asked how long it took to re-

[8] This is a common approximation for the opportunity cost of time, but the opportunity cost of time departs from the wage rate under a wide variety of conditions, that is, if the number of work hours is not freely chosen, if nonwage income is large relative to wage income, if work directly yields utility, if the marginal wage is nonlinear, and if taxes are nonzero (W. D. Shaw; McConnell and Strand; Bockstael, Strand, and Hanemann). The evidence suggests that nonwage income is not likely to be large relative to wage income. First, 75% of respondents reported incomes of less than $50,000, while 4% reported incomes in the lowest category (<$5,000). Thus, over 70% of the sample falls into income ranges where nonwage income is likely to be small relative to wage income ($5,000–$65,000). Second, the survey design attempted to intercept those who did not visit convenience centers at peak weekend times—those most likely to be unemployed or retired. One-third of the interviews were conducted midweek, so a grouped data income model was estimated using a dummy variable for weekend/nonweekend interview. The variable was insignificant, suggesting that incomes of those visiting at nonpeak times were not different from incomes of other visitors.

cycle a unit of material (the $1/\tau_{ij}$ for a newspaper or glass jar). To estimate time costs for nonrecyclers, we follow Lee (1976) by estimating maximum-likelihood Heckman selection models predicting the time requirements for paper and glass (table 3) for recyclers and nonrecyclers. Time requirements are positively related to *INTERVAL* and negatively related to *BROUGHT.* Homeowners have lower-stated time requirements, while time requirements are positively related to *TIME* (the four-point variable capturing the general notion of time needed to recycle). σ is the estimate of the unconditional sample variance of the time requirement, while ρ is the estimated error correlation between the selection and time requirement equations.

Predicted time requirements ($1/\tau_{ij}$) for recyclers are estimated by evaluating the model at observed values for all explanatory variables. The same is done for nonrecyclers except that *INTERVAL* was not observed. In this case, the mean *INTERVAL* for recyclers who did not bring recyclables to the center is substituted. Predicted per unit time requirements for each material are then converted to a per pound requirement. This is multiplied by the opportunity cost of time to obtain the recycling cost per pound of material (*COST*). The ranges for predicted unit time requirements and recycling costs are reported at the bottom of table 3. Variations in cost arise from differing opportunity costs of time (ω_i) and unit time requirements for each material ($1/\tau_{ij}$) for household i and material j.

Second-Stage Model: Household Generation

The generation models reported in table 4 are selection and generation equations estimated simultaneously using maximum likelihood. Due to the complex nature of the generated regressor problem associated with *COST,* jackknifed parameter estimates and t-ratios are reported. The jackknife method provides a robust estimate of the standard errors for the parameters (Gray and Schucany; Miller).[9] The dependent variable at the selection stage is a 0/1 variable indicating whether the household recycles the material. Dependent variables at the generation stage are measured at the household level (pounds per household per month) and at the per capita level (pounds per person per month). This second measure is obtained by dividing monthly household generation by the number of household members (*HHMEMBER*).

The selection stage models are similar for both materials. Households are more likely to recycle if the respondent knows someone else who recycles (*FRIENDS*). As storage space becomes a constraint (*STORAGE*), households are less likely to recycle. If the respondent feels that their household did not generate enough recyclables to warrant recycling (*GENERATE*), they are less likely to recycle. The older the respondent (*AGE*), the more likely the household is to recycle glass. Finally, as the time cost of recycling increases (*COST*), households are less likely to recycle.

Turning to the generation portion of the models, the model estimated for paper generation performs quite well. The recycling cost (*COST*) and income (*INCOME*) terms in the generation models have the expected signs and are statistically significant for paper

[9] The jackknife statistics were calculated using N groups of $N - 1$ observations each, where N is the total number of observations. The model is first estimated for the full sample (yielding parameters ξ_{all}). The model is then estimated many more times, first dropping, then replacing each observation i (e.g., $i = 1, \ldots, 215$) in sequence. Pseudo-values for each run were formed according to $P(\xi_{-i}) = N\xi_{all} - (N - 1)\xi_{-i}$, where ξ_{-i} denotes the vector of parameter estimates with observation i dropped. The jackknife estimator, $J(\xi)$, is the mean of the pseudo-values. The t-statistics were calculated as: $[J(\xi)/(S_\xi/\sqrt{N})] \times [(N - 1)/(2N - 1)]^{1/2}$, where S_ξ is the standard deviation of $J(\xi)$, and the second term represents a "conservative" adjustment for correlation among the pseudo-values (Gray and Schucany, pp. 165–66).

Table 3. Per Unit Time Requirement Functions for Paper and Glass Production

	Paper	Glass
Selection Equation[a]		
Intercept	2.31*	0.47
	(3.57)	(0.54)
FRIENDS	0.86*	1.41*
	(3.52)	(4.05)
STORAGE	−0.40*	−0.35*
	(−3.18)	(−2.28)
GENERATE	−0.52*	−0.49*
	(−3.12)	(−2.57)
AGE	0.02*	0.03*
	(2.08)	(4.07)
TIME	−0.65*	−0.64*
	(−3.65)	(−2.63)
n	215	217
Time Equation[b]		
Intercept	35.73	38.67
	(1.11)	(0.75)
INTERVAL (days)	0.42*	1.71*
	(3.17)	(3.36)
BROUGHT (1 = yes)	−9.32	−19.74
	(−0.72)	(−0.98)
STORAGE	−2.28	−2.24
	(−0.27)	(0.15)
HOMEOWNER (1 = yes)	−29.88*	−27.02
	(−2.76)	(−1.24)
TIME	13.02	5.94
	(0.79)	(0.31)
σ	48.94*	67.38*
	(19.35)	(13.96)
ρ	−0.09	−0.08
	(−0.19)	(−0.21)
n	125	93
Mean predicted time (seconds per unit) [range]	36.38 [3.67–102.4]	53.75 [6.64–154.1]
Mean predicted *COST* (per pound) [range]	$0.52 [$0.01–$1.68]	$0.77 [$0.10–$2.61]

Note: Numbers in parentheses represent the ratio of a coefficient to its asymptotic standard error. Asterisks denote significance at $\alpha = 0.05$.
[a] Dependent variable: 1 = do recycle material, 0 = do not recycle material.
[b] Dependent variable: seconds to recycle one unit of material.

($p < 0.05$). The generation model for recycled glass is not responsive to cost or income. In neither household generation model is the weight of recyclables sensitive to the number of people in the household (*HHMEMBER*). The lack of statistical significance in the paper model is reasonable because most households receive only one newspaper. The

Table 4. Generation of Recycled Paper and Glass

	Paper (n = 215)		Glass (n = 217)	
	Specif. 1 (HH)[a]	Specif. 2 (PC)[b]	Specif. 3 (HH)[a]	Specif. 4 (PC)[b]
Selection Equation[c]				
Intercept	2.35*	2.50*	−0.40	−0.48
	(2.21)	(2.30)	(−0.39)	(−0.49)
FRIENDS	0.94*	0.93*	1.39*	1.38*
	(3.50)	(2.48)	(3.48)	(3.44)
STORAGE	−0.56*	−0.59*	−0.40	−0.40
	(−2.42)	(−2.55)	(−1.82)	(−1.83)
GENERATE	−0.52*	−0.52*	−0.56*	−0.54*
	(−2.23)	(−2.26)	(−2.53)	(−2.45)
AGE	0.01	0.01	0.03*	0.04*
	(1.23)	(1.08)	(2.56)	(3.08)
COST	−1.59*	−1.58*	−0.08	−0.05
	(−2.56)	(−2.54)	(−0.21)	(−0.14)
Generation Equation[d]				
Intercept	16.88	9.18	−3.63	−7.85
	(0.38)	(0.64)	(−0.20)	(−0.84)
COST	−323.04*	−136.84*	−6.35	−2.25
	(−2.69)	(−2.66)	(−0.06)	(−0.05)
INCOME	2.91*	1.25*	0.42	0.18
	(2.80)	(2.74)	(0.36)	(0.38)
HHMEMBER	0.89		−4.97	
	(0.13)		(−1.00)	
σ	38.49*	17.64*	28.80*	12.27
	(3.14)	(4.74)	(2.03)	(2.39)
ρ	−0.01	−0.04	−0.54	−0.51
	(−0.02)	(−0.04)	(−0.93)	(−0.85)

Note: Reported parameters are means of jackknife statistics; t-ratios (in parentheses) are derived by using the standard deviation of the jackknife statistics. Asterisks denote significance at $\alpha = 0.05$.
[a] HH = household model.
[b] PC = per capita model.
[c] Dependent variable: 1 = do recycle material, 0 = do not recycle material.
[d] Dependent variable: weight (pounds per month) of recyclables brought to dropoff center.

inverse Mill's ratio calculated from the selection model is used in the generation model to obtain consistent estimates of the unconditional sample standard deviation (σ) of recyclables generation (the dependent variable) and error correlation (ρ). ρ is statistically insignificant, suggesting that the errors between the selection and generation equations are not correlated, so that selection effects do not appear to be present in our data.

The generation models provide an opportunity to estimate households' willingness to pay for recycling. This is done by integrating under the generation function, or "demand curve" for each material, a procedure equivalent to calculating consumer surplus using a travel-cost demand curve. The household generation model predicts a monthly WTP of $1.66 per household for paper and $4.12 per household for glass. Assuming independence of the generation models, the implied WTP to recycle these materials is $5.78 per household per month. Using the per capita models, WTP for paper recycling is $0.80

per capita and for glass it is $2.56 per capita, or $3.36 per capita monthly WTP for both paper and glass.

Concluding Comments

In this article, we developed a household production model describing recycling behavior. In contrast with some past research, this model does not explicitly rely on monetary incentives or altruistic arguments to motivate household recycling. Further, this study represents the first attempt to estimate the demand for recycling using generation models. While the empirical recyclables generation models met with somewhat mixed success, a number of insights have been gained. First, selection effects may be present and should be tested econometrically. This could take the form of a formal selection model (as presented here, where something is known about nonrecyclers) or a truncated model (if characteristics are unknown). Second, the models provide an initial estimate of the own-cost effects of recycling. The empirical models indicate that paper recycling is cost sensitive, while the results for glass do not suggest cost sensitivity. With households sensitive to the own cost of recycling, waste managers may encourage greater levels of recycling by providing information on ways to enhance time efficiency. Finally, we have presented WTP estimates based on observed recycling behavior. Such measures may be used in benefit cost analysis of proposed recycling programs.

The recycling own-cost variable, however, was a generated regressor and, therefore, has measurement error associated with it. Researchers cannot avoid using a constructed variable for *COST,* but future studies may minimize its associated error in at least two ways. First, one may follow W. D. Shaw's suggestions on how to measure the opportunity cost of time. Although we know of no study which has implemented these proposals, the central role of opportunity cost in all empirical household production models makes this a key line of research. Second, we did not ask nonrecyclers their *perceived* unit time requirements for recycling because presurvey investigation indicated that nonrecyclers had difficulty with this question. Yet perceived time requirements are clearly an important component in a generation model. Thus, we suggest that future research address the problem of *how* to ask the question such that nonresponse by those who do not recycle is minimized.

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