The Determinants of Household Recycling: A Material Specific Analysis of Recycling Program Features and Unit Pricing

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Abstract

This paper examines the impact of two popular solid waste programs on the percent recycled of several different materials found in the residential solid waste stream. We examine a unique, national, household-level data set containing information on the percent recycled of five different materials: glass bottles, plastic bottles, aluminum, newspaper, and yard waste. We find that access to curbside recycling has a significant and substantial positive effect on the percentage recycled of all five materials and that the level of this effect varies across different materials. The length of the recycling program's life has a significant and positive effect on two of the five materials and a mandatory recycling requirement does not affect any materials. The level of the unit price has an insignificant effect on all five materials.

Key Words: Solid Waste, Recycling, Unit Pricing, Incentives

JEL Classification Numbers: Q28, H31

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Introduction

The past 15 years have been a time of dramatic change for solid waste management. Beginning in the mid-1980s, with stricter EPA requirements for landfill construction on the horizon, landfill tipping fees increased dramatically and there was a widespread impression that landfill space was growing scarce and that a landfill "crisis" was inevitable.[2] Two clear national trends in solid waste management emerged during this period. Both were the result of local efforts to reduce the quantities of waste being landfilled. The most pervasive was the introduction of residential curbside recycling programs. In 1988, there were approximately 1,000 such programs in the US; in 1992, there were almost 5,000; by 1996 the number reached almost 9,000 (Goldstein, 1997). A second, less pervasive but still impressive, trend during this period was the introduction of volume-based pricing, or unit pricing, of solid waste disposal services wherein households are charged for garbage collection according to the number of containers they set out. Prior to the late 1980s there were perhaps a few dozen such programs (Skumatz, 1994). By 1996, there were over 3,800 programs, encompassing close to 10 percent of the US population (Miranda et al., 1998).

Though the nature of a curbside recycling program is quite different from a unit pricing program, both theoretically provide incentives for a redirection of waste quantities from disposal sites to recycling centers. A curbside program reduces a household's cost of recycling by making recycling more convenient and less time consuming. A unit pricing program charges households by the container for waste collection. [3] This increases a household's cost of discarding additional waste relative to its cost of recycling; i.e., not recycling leads to higher fees for waste collection services.

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[2] Most of the increase in tipping fees occurred during the middle and late 1980s. In 1985 the national average tipping fee in the US was approximately $11.20 per ton; in 1990, it was approximately $33.75. As of 1997, it remained close to $30.00. (All values are in 1997$.) (US EPA, 1997).

[3] Without unit pricing, most communities finance waste disposal via general tax revenues or flat fees. From the perspective of households, this places a marginal price of zero on waste disposal. This causes them to dispose

While both programs change a household's economic assessment of recycling, unit pricing is a "market-based" environmental policy whereas curbside recycling is not. This suggests possible differences in the outcomes of the two programs. Furthermore, unlike a curbside recycling program, unit pricing only gives an indirect incentive to recycle while its direct incentive is to reduce waste quantities. Another desirable outcome of unit pricing besides recycling is that households may adjust their purchasing habits to generate less solid waste. Thus, the two programs might very well have different effects on household recycling effort.

Not only might they have different effects on aggregate household recycling effort, economic principles suggest that the programs will have different impacts on different recyclable materials (Jenkins, 1993). One suggestion is that volume-based unit pricing will give households an incentive to recycle bulky items that take up lots of garbage container space – such as plastic milk jugs. On the other hand, because unit pricing affects recycling indirectly, rather than causing significant increases in recycling, it might encourage households to avoid generating bulky wastes in the first place. Households might alter their consumption bundles so that there is less trash to discard.

A curbside recycling program also might disproportionately affect certain materials. Curbside recycling reduces a specific set of costs which are more important for some materials than others. Compared to a household recycling without a local recycling program, a household with a curbside program will have a much easier time recycling materials that are difficult to transport, like glass bottles, which are bulky and can break.

Policy makers would benefit from a better understanding of the impact of the two programs and their features on different recyclable materials. To the municipalities that collect them, different recyclable materials have different costs of recycling as well as different values on the open market. Understanding which program features lead to greater recycling of high valued materials could improve the cost-effectiveness of a community's efforts to promote recycling. In other cases, in response to state objectives for aggregate recycling percentages, municipalities sometimes achieve very high recycling effort directed at a few materials and in order to get their aggregate percentage higher, must encourage households to recycle alternative materials. Understanding how to promote these alternative materials would be beneficial.

This study uses a large household-level data set to examine the impact of these two popular solid waste programs and their features on the percent recycled of several different materials found in the municipal solid waste stream. Many recent studies have examined the separate or combined impacts of these two popular programs on aggregate recycling.[4] However, none analyzes a data set with the multitude of desirable characteristics that ours presents. We examine a national, household level data set containing information on the percent recycled of five different materials: glass bottles, plastic bottles, aluminum, newspaper, and yard waste.

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of more than the socially efficient amount of waste. A unit pricing program imposes a non-zero marginal price on waste disposal that can potentially correct this problem.

[4] Please see Kinnaman and Fullerton (forthcoming) for a survey of this literature.

All communities in the data set offer curbside recycling of at least one of the five materials; although most offer it only for a *subset* of the five. However, the data set contains detailed information on the attributes of recycling options for all five specific materials. For example, the data indicate whether each material is collected at all through a local program and if so whether it is collected curbside or at a local drop-off facility. The data also indicate whether recycling the material is mandatory or voluntary, and so on. The data set contains rich household level socio-economic information. We augment the household-level data with community-level information on the prices charged for disposal under the unit-pricing program.

Literature Review

This paper makes two contributions to the existing economics literature on recycling. First it adds to the research on the effectiveness of curbside recycling and unit pricing at encouraging households to recycle. Several papers study various aspects of these programs, sometimes with unit pricing and curbside recycling operating together and sometimes with one program operating in isolation (Kinnaman and Fullerton, 1998; Nestor and Podolsky, 1998; Callan and Thomas, 1997; Fullerton and Kinnaman, 1996; Hong et al., 1993). However, ours is the first that analyzes data that is both national in scope and rests on a household-level unit of analysis.[5] Thus, this study is able to overcome many of the limitations that characterize previous studies. Second, this paper extends previous research by investigating whether and how the impact of these two popular programs differs for different recyclable materials. The few existing material-specific studies have lacked the rich amount of information about both recycling and unit pricing programs contained in our data set (Saltzman et al., 1993; Reschovsky and Stone, 1994). We also examine the effect of household socio-economic characteristics on recycling effort directed at different materials.

The only nationwide study of the determinants of recycling that we were able to locate is Kinnaman and Fullerton (1998). Using community-level data on aggregate recycling quantities and correcting for endogenous local policy choices, they find that a unit pricing program has an insignificant effect on recycling while a curbside recycling program has a positive significant effect. Other studies of the determinants of recycling are regional. For example, Van Houtven and Morris (1999) examine household-level data for Marietta, Georgia. They estimate the effectiveness of two types of unit pricing programs, a subscription can program and a bag program, first on the household's decision to participate in recycling and second on recycling quantities. They get mixed results. Both types of unit pricing programs significantly increase the probability of a household recycling. However, neither significantly affects the aggregate quantity recycled. This study included only an indicator variable for the presence of unit pricing and not the actual unit price. Unlike this study and the others that analyze aggregate recycling, we will analyze a national, household-level data set and investigate

[5] Several econometric studies analyze the impacts on recycling effort of one or both of these two popular programs by examining household-level data; in particular, Nestor and Podolsky (1998), Fullerton and Kinnaman (1996) and Hong et al. (1993). However, the data for all three of these studies are for a single region where curbside recycling and unit pricing co-exist. Several other studies are national in scope but rely on community-level data (Kinnaman and Fullerton (1998), Miranda et al. (1994) and U.S. EPA (1990)). (The latter two use the case study method of analysis.)

the significance of curbside recycling and the actual level of the unit price as well as various attributes of these programs.

Two papers examine the determinants of recycling specific materials. Both are regional. Reschovsky and Stone (1994) investigates the impact of unit pricing and curbside recycling on six recyclable materials -- glass, plastic, cardboard, food/yard waste, metal cans and newspaper. They find that the presence of a unit pricing program, separate from mandatory recycling or curbside collection, has a significant positive effect on only one material – food/yard waste. Because of insufficient relevant observations, they are not able to examine the significance of a curbside program operating in isolation. They do find that a mandatory curbside program and a combined curbside and unit pricing program are significant for the limited number of materials with sufficient data to permit reaching conclusions. The limitations of their data also restrict them to looking for *differences* in the impact of policy on only two materials – glass and newspaper. They find little difference. We will analyze the programs' impacts on five materials – glass bottles, plastic bottles, aluminum, newspaper, and yard waste.

A second material-specific study examines differences in the impact of socio-economic variables on the quantities of different materials households choose to recycle. Saltzman et al. (1993) analyzes the determinants of quantities recycled for newspaper and glass. Their primary finding is that the effect of changes in income on recycling differs across materials. Increases in income can lead to greater consumption and thus more waste available to be recycled and, at the same time, decreases in the amount of time devoted to recycling. Saltzman et al. suggest that for those materials for which substitutes are available the negative effect of a higher opportunity cost of time outweighs the positive impact from increased consumption. For example, they find income to have a significant positive effect on the quantity of newspaper recycled where there are no substitutes. On the other hand, income has a significant negative effect on the quantity of glass recycled since non-glass substitute containers are widely available.[6]

Table 1 summarizes the existing econometric literature that studies the effects of unit pricing and curbside recycling on household recycling effort. The first column identifies the study authors and year, the second column describes the dependent variable, the third and fourth columns describe the independent policy variables and finally, the fifth and sixth columns identify whether the data were national or regional and household-level or community-level.

In the remaining sections of this paper, we outline a conceptual framework, describe the data, present an empirical model, describe the results and discuss their relevance to policy.

[6] An alternative explanation for the finding that higher incomes are associated with less glass recycling is simply that households switch from recycling to disposing of glass.

Table 1. Econometric Studies of the Impact Of Unit Pricing and Curbside Recycling Programs On Recycling Effort

Author(s) (year)	*Dependent Variable*	*Independent Policy Variables*		*Data*	
	Aggregate or Material Specific Recycling Quantities	*Unit Price*	*Recycling Program Attributes*[a]	*National or Regional*	*Household Level*
Van Houtven and Morris (1999)	Aggregate (quantity is weight, not volume)	No, but dummy for presence of each of two types of unit pricing program	No	Regional – Marietta, Georgia	Yes
Hong and Adams (1999)	Aggregate	Yes	No	Regional – Portland, Oregon	Yes
Sterner and Bartelings (1999)	By Material (community proportion, not quantity recycled)	No	Yes	Regional – Southwest Sweden	No
Kinnaman and Fullerton (1998)	Aggregate	Yes	Yes	National	No
Nestor and Podolsky (1998)	Aggregate	Yes	No	Regional – Marietta, Georgia	Yes
Callan and Thomas (1997)	Aggregate (percent of total waste stream recycled)	No, but dummy for presence of unit pricing program	Yes	Regional – Massachusetts	No

[a] Two frequently studied recycling program attributes are whether it is curbside or drop-off and whether it is voluntary or mandatory.

Table 1. Econometric Studies of the Impact Of Unit Pricing and Curbside Recycling Programs On Recycling Effort (Continued)

Author(s) (year)	*Dependent Variable*	*Independent Policy Variables*		*Data*	
	Aggregate or Material Specific Recycling Quantities	*Unit Price*	*Recycling Program Attributes*[a]	*National or Regional*	*Household Level*
Rechovsky and Stone (1994)	By Material (proportion, not quantity, recycled)	No, but dummy for presence of unit pricing program	Yes	Regional – upstate NY	Yes
Hong et al. (1993)	Aggregate (recycling participation – yes/no)	Yes	No	Regional – Portland	Yes
Saltzman et al. (1993)	By Material	No	Yes	Regional – PA and NJ	No

Conceptual Framework

A number of papers have developed conceptual frameworks to study the impact of unit pricing (Fullerton and Kinnaman, 1995; Morris and Holthausen, 1994; Jenkins, 1993). Others, including Podolsky and Spiegel (1998) and Kinnaman and Fullerton (1995), describe the substitution possibilities between waste disposal and recycling as part of household waste management. These papers develop models in which households maximize utility subject to a budget that is constrained by a unit price for waste collection. The models are the basis for solid waste disposal and recycling demand equations.

On the right hand sides of these equations are three categories of exogenous variables: characteristics of the goods whose consumption generates waste; descriptions of the local waste management system; and socio-economic factors. The first category includes the price of consumption good i (P_i) and the amount of waste generated per unit of good i (β_i) where ($i = 1 \ldots n$). The second category

[a] Two frequently studied recycling program attributes are whether it is curbside or drop-off and whether it is voluntary or mandatory.

consists of the price per unit of waste disposal (P_W) and a vector of recycling program features (RP) including whether the collection occurs at the curb or at a drop-off facility, the length of life of a recycling program, and so on.[7] The third category is comprised of socio-economic characteristics (SE) such as household size, income and education.

Specifically, D and R are the optimal levels of household disposal and recycling,

$$D = f\,(\beta_1, \ldots, \beta_n, P_1, \ldots, P_n, P_W, RP, SE) \tag{1}$$

$$R_j = \gamma_j\,(\beta_1, \ldots, \beta_n, P_1, \ldots, P_n, P_W, RP, SE) \tag{2}$$

$$R = \Sigma\, R_{j.} \tag{3}$$

Unlike waste disposal, each recycled material, j, has unique characteristics that could affect the relationship between recycling and the exogenous variables. These characteristics include the ease with which a material can be recycled, its bulkiness or the availability of substitutes for the material. Thus, each material (R_j) has a unique recycling demand equation as specified in (2).

Consistent with (2), we analyze material-specific recycling behavior for each of five materials. However, since we do not have data on recycling quantities, we actually estimate the effects of the exogenous variables on the intensity of recycling for each material.

Data Description

The primary data source is a recycling survey mailed by Equifax, Inc. in 1992 – a year of increasing popularity for unit pricing and soaring popularity for curbside recycling.[8] The survey was mailed to 4,600 households residing in 20 US metropolitan areas (please see Table 2 for a list of the 20).[9] Sixty-five percent of questionnaires, 2,984, were returned. Households responded to questions about recycling participation, recycling program characteristics, household characteristics, and attitudes. Equifax supplemented the survey with its own data on age, income, education and other characteristics for each household.

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[7] The price per unit of waste disposal charged to households is usually a volume-based price. For example, households in communities employing a bag/sticker purchase official program bags or stickers, which they affix to garbage bags of the mandated size. Alternatively, households in communities using a subscription can program specify a level of waste disposal per period of time in advance and are charged according to this level.

[8] During 1992, the number of curbside recycling programs in the US increased by 10 percent, from just under 4,000 to 5,404 (Steuteville and Goldstein, 1993).

[9] These 4600 households were selected using a stratified sampling method from Equifax's 250,000 member Home Testing Institute Panel. For this panel of homes, Equifax has extensive data on socio-economic household characteristics such as income and education. The 4600 households were selected to provide a mix of ages and household income levels representative of the population at large of the included metropolitan statistical areas.

From the Equifax data set, we selected only households that reported their communities had an ongoing recycling program (N=1939). We then appended unit pricing data from three sources. The first is a 1997 report (Miranda and LaPalme, 1997) that identifies which US communities had a unit pricing program for solid waste collection in 1992. The second is an EPA survey (1993), which collected information regarding the actual unit prices charged in 1992 by many of the unit pricing communities that were then in existence. For those communities not included in the EPA survey, we conducted our own telephone survey of community solid waste officials to solicit information on unit prices and other characteristics of the unit pricing program.

Table 2. Metropolitan Statistical Areas Sampled

Boston/Hartford Corridor
Detroit
New York Metro (New Jersey side)
Philadelphia
Minneapolis/St. Paul
Atlanta
San Francisco
Phoenix
Houston
Tampa
New York City Metro (New York and Connecticut)
Portland
Camden, New Jersey
Chicago
Seattle
St. Louis
Los Angeles
Dallas-Fort Worth
Miami
Denver

Following our telephone survey, we eliminated 123 additional observations for various reasons. The most common is that we were unable to contact a knowledgeable respondent. Other reasons include, for example, that the community had multiple trash haulers and thus multiple solid waste user fees. In these cases, we lacked information to connect a particular household to one or the other of the possible fees. In addition, we deleted several observations due to missing values. Finally, to eliminate any potential bias that would result from respondents, particularly non recycling respondents, failing to report the existence of a neighborhood drop-off recycling program, we retained only those households that reported curbside collection of at least one of the five materials. Our final data set consists of 1,049 observations.

Of the final 1,049, 116 are households facing a positive unit price for solid waste collection. Table 3 identifies the metropolitan areas that contain communities with unit pricing programs and the number of respondents residing in each. The majority of these respondents live in western states. Of the 116 households, 104 live in communities with subscription programs where households subscribe to collection of a pre-specified number of containers. Households can change that number but must incur transaction costs to do so. The remaining 12 households live in communities with bag/tag/sticker programs where households place their garbage in specially marked plastic bags, or place specially marked tags or stickers on regular garbage containers, and pay a price for the specially marked items that includes the cost of collection. In these communities, households can more easily alter the number of containers discarded.

Table 3. Unit Pricing Programs

MSA	**Number of Observations**	**Program Type**
Los Angeles	1	Subscription
San Francisco	20	Subscription
Chicago	10	Bag/Tag/Sticker
Detroit	1	Bag/Tag/Sticker
Minneapolis/St. Paul	2	Subscription
Portland	46	Subscription
Philadelphia	2	Bag/Tag/Sticker
Seattle	34	Subscription

We define the marginal price of solid waste collection as the price of the second container of waste. The reason is that households virtually always generate some solid waste, so paying for collection of the first container is difficult to avoid. Not paying for the second container is more likely and can be achieved by increased recycling.[10] Households in communities with no unit pricing face a zero marginal price for solid waste collection.

Table 4 gives the mean values and standard deviations of the independent variables used in our ordered probit analysis. The first row gives the mean marginal price of solid waste collection, $1.91 per 32-gallons, faced by the 116 households in communities with unit pricing programs. This marginal price applies to all five of the different materials, except for the two communities that have a different price structure for yard waste. Thus, the second row of Table 4 gives the mean marginal price of yard waste collection. Note that while the variables are different, the mean values are almost the same[11] as are the standard deviations of 86 cents.

[10] Perhaps less easily, households also can avoid paying for the second container by generating less garbage in the first place.

[11] The solid waste and yard waste price variables in the probit equations are in dollars per gallon (instead of per 32-gallons). The difference in the sample mean values of the two variables begins at the fifth significant digit.

Table 4. Mean Values of Independent Variables

Variable	*Mean Value (N=1049 unless otherwise noted)*	*Standard Deviation (N=1049 unless otherwise noted)*
Policy Variables		
1. Marginal price of solid waste collection ($ per 32-gallons)[a]	$1.91[b]	$0.86[b]
2. Marginal price of yard waste collection ($ per 32-gallons)[a]	$1.90[b]	$0.86[b]
3. Indicator variable for curbside collection of newspaper	.916[c]	.278[c]
4. Indicator variable for curbside collection of glass bottles	.886[c]	.318[c]
5. Indicator variable for curbside collection of aluminum	.853[c]	.355[c]
6. Indicator variable for curbside collection of plastic bottles	.775[c]	.417[c]
7. Indicator variable for curbside collection of yard waste	.528[c]	.500[c]
8. Number of materials collected curbside	3.9	1.2
9. Indicator variable for drop-off collection of newspaper	.056[c]	.229[c]
10. Indicator variable for drop-off collection of glass bottles	.071[c]	.256[c]
11. Indicator variable for drop-off collection of aluminum	.104[c]	.305[c]
12. Indicator variable for drop-off collection of plastic bottles	.127[c]	.333[c]
13. Indicator variable for drop-off collection of yard waste	.057[c]	.232[c]
14. Indicator variable for a mandatory recycling program	.349	.477
15. Indicator variable for a recycling program that was between one and two years old	.407	.492

[a] In the probit equations, this variable is in dollars per gallon.

[b] Mean is for the 116 households living in communities with unit pricing programs.

[c] Mean is for the observations included in each different material's probit analysis: N=1,042 for the newspaper equation; N=1,033 for the glass bottles equation; N=1,012 for the aluminum equation; N=1,014 for the plastic bottles equation; N=963 for the yard waste equation.

Table 4. Mean Values of Independent Variables (Continued)

Variable	*Mean Value (N=1049 unless otherwise noted)*	*Standard Deviation (N=1049 unless otherwise noted)*
16. Indicator variable for a recycling program that was older than two years	.327	.469
Socio-Economic Variables		
17. Population density (thousands of persons per square mile)	5.820	5.923
18. Indicator variable for household income between $10,000 and $14,999	.068	.251
19. Indicator variable for household income between $15,000 and $24,999	.133	.339
20. Indicator variable for household income between $25,000 and $34,999	.135	.342
21. Indicator variable for household income between $35,000 and $49,999	.208	.406
22. Indicator variable for household income between $50,000 and $74,999	.258	.438
23. Indicator variable for household income of $75,000 or higher	.140	.347
24. Household size	2.7	1.4
25. Age of household head	47.9	15.9
26. Indicator variable for a detached house	.726	.446
27. Indicator variable for home ownership	.793	.405
28. Indicator variable for highest level of education is high school graduate	.511	.500
29. Indicator variable for highest level of education is college graduate	.247	.431
30. Indicator variable for highest level of education is beyond college	.195	.397

As mentioned, all of the observations in our data set represent households with curbside recycling of at least one material. However, the number and type of materials collected by a curbside recycling program vary. Table 4 gives the proportions of households that live in communities with curbside recycling programs that collect each of the five different materials. The highest proportion is of households in communities that collect newspapers at the curb, over 90 percent. The lowest proportion is of households in communities that collect yard waste at the curb, approximately 50 percent. These proportions are also the means of the five variables that indicate the presence of curbside recycling for each material. Overall, of the five materials in this study, the mean number eligible to be picked up by a community's curbside recycling program is 3.9.

The percent of households whose only option for recycling a material is at a drop-off center is much lower than the percent with curbside collection. Approximately 5 percent of households have only drop-off recycling for newspapers and yard waste; approximately 7 percent for glass bottles; 10 percent for aluminum and 13 percent for plastic bottles.

Thirty-five percent of respondents report that participation in their recycling program is mandatory. Recall that all respondents have curbside collection of at least one material. We assume that the mandatory requirement applied to all of the materials collected at the curb.

As expected, many of the recycling programs represented by our data set are new. Twenty-five percent of respondents indicated that their recycling program was under a year old and 41 percent indicated it was between one and two years old. Thirty-three percent indicated it was older than two years.

The data set includes one socio-economic variable that describes the communities where respondents reside – population density. These data are from the 1990 census. We collected information for the specific community when possible and for the county otherwise. Table 4 gives the mean population density: 5,820 persons per square mile with a rather high standard deviation of 5,923. The data set also includes a series of dummy variables that indicate the metropolitan statistical area (MSA) where each household is located. This variable is used in the regressions to control for unobserved regional effects such as weather and cultural differences.

The data set includes information from Equifax for five socio-economic characteristics of respondents' households with sample statistics reported in Table 4. The first is household income. Table 4 gives the percentage of respondents living in households within each of six different income ranges. (In the table these percentages appear as the means of the six variables that indicate the household's income category.) A high proportion is from upper income categories. The second household characteristic is household size with a sample average of 2.7 persons per household. The third is the average age of the female and male heads of the household. The sample average is 48. The fourth is whether the respondent lives in a detached house. Seventy-three percent do. The fifth is whether the respondent and/or another household member own(s) the house. Seventy-nine percent do. Finally, the sixth is the level of education of the most educated household member. As expected, given the income distribution, there is a high proportion of respondents in the high education categories.

As mentioned, the survey asked respondents about recycling participation. Specifically, respondents were asked what proportion of the following materials they recycled through all available recycling programs: steel sided cans, glass bottles, plastic bottles, newspaper, magazines, aluminum, other plastics, yard waste and other. As noted already, we chose to study five of these materials. Thus, we define a dependent variable for each of the five. The survey asked whether recycling percentages fell into one of seven possible categories: 0 to 10 percent; 11 to 25 percent; 26 to 50 percent; 51 to 74 percent; 75 to 84 percent; 85 to 95 percent or over 95 percent. We aggregate the data into three categories of "proportion of the material recycled" – 0 to 10 percent, 11 to 95 percent, and over 95 percent. Table 5 gives the percent of respondents falling into the three categories for each of the five materials. Except for yard waste, the majority of respondents recycled over 95 percent of each material. Table 5 also gives the number of respondents falling into each category and the number of missing observations for each of the five probit equations.

Table 5. Proportions of Materials Recycled

Material	*Percentage and Number of Respondents Recycling 0 to 10 Percent*	*Percentage and Number of Respondents Recycling 11 to 95 Percent*	*Percentage and Number of Respondents Recycling Over 95 Percent*	*Total*	*Number Missing*
Newspaper	8.8 % 92	16.6 % 173	74.6 % 777	100 % 1,042	7
Glass bottles	11.3 % 117	22.2 % 229	66.5 % 687	100 % 1,033	16
Aluminum	15.0 % 152	21.8 % 221	63.2 % 639	100 % 1,012	37
Plastic bottles	17.8 % 180	28.0 % 284	54.2 % 550	100 % 1,014	35
Yard waste	43.3 % 417	22.8 % 220	33.9 % 326	100 % 963	86

Model Specification

The model that we estimate seeks to identify which policy and socio-economic factors influence the level of recycling effort households expend on each recyclable material.[12] We use a latent regression model for ordered data as the framework for estimation. As noted above, for each material type, we define three ordered categories: category 0 for 0 to10 percent recycled, category 1 for 11 to 95 percent recycled and category 2 for over 95 percent recycled. For each material type, j, we consider the relationship

$$y_{ji}^{*} = \beta_j^{'} x_i + \varepsilon_{ji}$$

where *y** is unobserved level of recycling effort (percentage of material j recycled) and *i* is an index of households. The vector x_i contains the marginal price, recycling program attributes, and socio-economic features for each household. β is a vector of coefficients to be estimated by maximum likelihood estimation (MLE) in an ordered probit model. Assuming ε_{ji} is distributed standard normal, the probability that we observe household *i* in category *k*, where *k*=0,1 or 2, for material *j* is given by

[12] Ideally we would account for potential systematic differences between households that received the questionnaire and returned it and those that didn't return it. However, the data required for such an analysis were not available.

$$\Pr\left(y_{ji}=0\right)=\Phi\left(-\beta_j{}'x_{ji}\right);$$
$$\Pr\left(y_{ji}=1\right)=\Phi\left(\mu-\beta_j{}'x_{ji}\right)-\Phi\left(-\beta_j{}'x_{ji}\right);$$
$$\Pr\left(y_{ji}=2\right)=1-\Phi\left(\mu-\beta_j{}'x_{ji}\right)$$

where Φ is the standard normal cdf.[13]

Results

The intensity of household recycling activities by material is modeled as a function of several socio-economic variables and several policy variables representing the characteristics of the recycling program and the unit pricing program. These variables are described in Section 4. The regression for each material was estimated using the same set of independent variables, except that the values for the curbside and drop-off indicator variables varied across materials depending on the type of collection available for the specific material. In addition, the marginal disposal price was different for yard waste.

The diverse nature of the communities and households represented in our data set led us to question the appropriateness of the standard assumption that all of the disturbance terms in the underlying model have a common variance. In particular, we suspected that the disturbance terms surrounding the propensity to recycle could be a function of the presence of curbside recycling and the length of time that the recycling program had been in existence. We hypothesize that the regression disturbance terms are likely to be different across households that have curbside recycling for the relevant material and those that do not. By eliminating the need to transport recyclables to drop-off points at varying distances from the household, curbside recycling tends to even out the time required to recycle across households. Likewise, we expect households with greater potential experience with recycling to have different disturbance terms than those with less experience with recycling. Greater experience with recycling allows households to develop a recycling habit, which will lead to less variation in the error terms.

Using these variables as determinants in a multiplicative model of heteroskedasticity of the form $\varepsilon_{ji}=\exp(\gamma z_i)$ where the z vector includes the three potential contributors to heteroskedasticity, we tested the ordered probit model for each material for the presence of heteroskedasticity.[14] We found that for two materials, glass and plastic bottles, we could reject the null hypothesis of homoskedasticity, and therefore, we report the results of the heteroskedasticity-corrected model for those two materials.

[13] See Greene (1993) p. 672 for more information.

[14] There are three potential contributors because the amount of time a recycling program has been in place is represented by two categorical indicator variables (see Section 3).

The results of this analysis are presented in two forms. First, the results of the econometric estimation of the ordered probit regression for each material are presented in Table 6.

Table 6. Econometrics Results for Ordered Probit Model

	Newspaper	***Glass Bottles***	***Aluminum***	***Plastic Bottles***	***Yard Waste***
Variable Name					
Constant	-2.0060*** (.4354)	-1.4056*** (.3798)	-1.0295** (.4037)	-1.8395*** (.4131)	-1.5560*** (.3791)
Policy Variables					
Drop-off	.4420 (.2767)	.9489*** (.2492)	.5149** (.2239)	1.2930*** (.2270)	.6387*** (.1954)
Curbside	.6586*** (.2493)	1.3379*** (.2805)	1.0470 *** (.2172)	1.7989*** (.2516)	.7856*** (.1124)
Mandatory and Curbside	.1125 (.1187)	-.0329 (.0683)	.1198 (.1070)	.1486 (.1028)	.0637 (.1228)
Total Materials Curbside	.0821* (.0442)	-.0597 (.0390)	-.0746 (.0539)	-.0556 (.0501)	.0517 (.0388)
Recycling Program is between 1 and 2 years old	.3521*** (.1115)	.1205 (.0893)	.0742 (.1029)	.2121** (.1056)	.1788* (.1078)
Recycling Program is over 2 years old	.3121** (.1213)	.1086 (.1007)	.1158 (.1140)	.0736 (.1119)	.2819** (.1188)
Disposal Price	-5.3332 (4.2400)	.0850 (2.1136)	-2.5147 (3.4457)	.4924 (3.1474)	-1.8378 (3.0377)
Number of observations	1042	1033	1012	1014	963
Log Likelihood	-691.977	-779.600	-850.909	-865.872	-851.217
Chi squared statistic	139.946***	200.879***	134.617***	286.387***	351.441***
MSA controls	Yes	Yes	Yes	Yes	Yes
Heteroskedasticity corrected	No	Yes	No	Yes	No

Table 6. Econometrics Results for Ordered Probit Model (Continued)

	Newspaper	*Glass Bottles*	*Aluminum*	*Plastic Bottles*	*Yard Waste*
Variable Name					
Socio-Economic Variables					
Population Density	.0011 (.0104)	.0003 (.0069)	-.0056 (.0091)	-.0024 (.0089)	-.0309*** (.0106)
Household Income between $10,000 and $14,999	.5913** (.2442)	.3070* (.1744)	.5681** (.2424)	.7427*** (.2215)	-.2200 (.2533)
Household Income between $15,000 and $24,999	.2722 (.2074)	-.0342 (.1305)	-.0423 (.2042)	.1148 (.1774)	-.0898 (.2157)
Household Income between $25,000 and $34,999	.3775* (.2156)	.0147 (.1299)	.0165 (.2086)	.3644** (.1800)	-.1646 (.2224)
Household Income between $35,000 and $49,999	.4932** (.2127)	-.0152 (.1278)	.0446 (.1974)	.2647 (.1743)	-.2682 (.2180)
Household Income between $50,000 and $74,999	.6411*** (.2216)	.0745 (.1365)	.0339 (.2063)	.2881 (.1858)	-.0928 (.2237)
Household Income over $75,000	.7300*** (.2520)	.0500 (.1500)	.0784 (.2295)	.3072 (.2044)	-.2023 (.2451)
Household size	.0166 (.0379)	.0567** (.0257)	.0017 (.0322)	.0479 (.0313)	.0603* (.0332)
Age of hh head	.0113*** (.0035)	.0033 (.0022)	.0058* (.0032)	.0062** (.0031)	.0074** (.0033)
Single family	-.0093 (.1205)	.0588 (.0725)	.0995 (.1086)	.2599** (.1071)	.4105*** (.1095)
Owner occupied	.1169 (.1252)	.2343** (.0928)	.2202* (.1187)	.1967* (.1188)	.2093 (.1275)
Highest education level is high school graduate	.7014*** (.1939)	.3370** (.1385)	.6316*** (.1863)	.0879 (.1681)	-.1928 (.2128)
Highest education level is college graduate	.7827*** (.2171)	.3316** (.1499)	.6535*** (.2062)	.0746 (.1814)	-.2271 (.2335)
Highest education level is beyond college	.7698*** (.2247)	.3785** (.1596)	.5770*** (.2117)	.1884 (.1933)	-.1400 (.2362)

Standard error reported in ( ).

* = significant at 90% level of confidence

** = significant at 95% level of confidence

*** = significant at 99% level of confidence

These results indicate which variables have a statistically significant effect and the direction of that effect on the propensity to recycle different materials. However, because of the non-linear estimation procedure employed, the regression results do not provide a good indicator of the magnitude of the effect. To determine magnitudes, we use the estimated probit model coefficients to calculate the marginal effects of different independent variables on the probability that a typical household will fall into each of three levels of recycling intensity: 0 to 10 percent of the material recycled, 11 to 95 percent recycled or over 95 percent recycled.[15] For the significant policy variables, these marginal effects are reported in Table 7.

The next three sub-sections of the paper discuss the results for three categories of independent variables respectively: recycling program policy variables, unit pricing program policy variables and socio-economic variables. In addition to the independent variables discussed below, all of the regressions include MSA indicator variables that were found as a group to be statistically significant determinants of recycling intensity for each material.[16]

Recycling Program Features

This analysis identifies several features of recycling programs that have a significant effect on intensity of household recycling effort. Two features that are almost always significant are availability of local drop-off recycling and existence of curbside recycling. Increasing the number of total materials included in the curbside recycling program has a positive effect on recycling effort for newspaper only. Length of program life is also an important determinant of the intensity of recycling effort for newspaper and yard waste. The effects of individual program features are discussed in greater detail in the following paragraphs.

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[15] The equation that predicts the probability that an observation will fall into each of the three categories is non-linear in the independent variables. Therefore, the equation that defines the marginal effects of each independent variable on that probability is a function of all of the independent variables. The marginal effect of each significant continuous independent variable is calculated using the average value for all of the independent variables except where noted in Table 7. The marginal effect of each significant discrete independent variable is calculated by solving the probability equation once with that variable set to one and all other independent variables set at their sample mean values (except where noted), again with that variable set to zero and other values unchanged and then taking the difference between the two solutions.

[16] We used a likelihood ratio test of the joint significance of the MSA indicator variables. We find that they are significant as a group at the 99% level for all materials except plastic bottles. For plastic bottles, the MSA dummies are significant at the 95% level.

Table 7. Marginal Effects of Significant Policy Variables

	Newspaper	*Glass Bottles*	*Aluminum*	*Plastic Bottles*	*Yard Waste*
Continuous Policy Variables					
Total Materials Curbside					
Recycle 0 – 10%	-.0104				
Recycle 11 – 95%	-.0146				
Recycle over 95%	.0250				
Indicator Policy Variables					
Drop-off					
Recycle 0 – 10%		-.5178	-.1867	-.5015	-.2503
Recycle 11 – 95%		.0975	-.0041	.1618	.0538
Recycle over 95%		.4203	.1908	.3397	.1965
Curbside (not mandatory)					
Recycle 0 – 10%	-.1315	-.6311	-.3231	-.6299	-.3034
Recycle 11 – 95%	-.1073	-.0118	-.0747	.0810	.0512
Recycle over 95%	.2388	.6429	.3978	.5489	.2522
Drop-off to Curbside					
Recycle 0 – 10%		-.1133	-.1363	-.1284	-.0532
Recycle 11 – 95%		-.1093	-.0707	-.0808	-.0025
Recycle over 95%		.2226	.2070	.2092	.0557
Program length over 2 years					
Recycle 0 – 10%	.0044				-.0398
Recycle 11 – 95%	.0070				.0035
Recycle over 95%	-.0114				.0363

Note: For disposal price, the marginal effect is calculated for a 1 cent per gallon increase in the price of disposal both with and without curbside recycling. For total materials curbside, the marginal effect is calculated assuming a one-unit increase in the total number of materials recycled curbside. For binary indicator variables, marginal effects are calculated by solving the model once with the significant indicator variable of interest set at one and all other variables set at their mean value, solving again with the indicator variable of interest set at zero and all other variables set at their means, and then taking the difference. The marginal effect for drop-off (curbside) is calculated with the curbside (drop-off) dummy variable set at zero. The "drop-off to curbside" marginal effect is defined as the difference between the marginal effect of curbside and the marginal effect of drop-off. For program length, the marginal effect gives the difference between having a program in place between one and two years and having a program for more than two years.

The two most commonly significant recycling program policy variables, the drop-off and curbside program indicators, serve as proxy measures of the convenience of recycling. Introducing a local drop-off program for recycling of a particular material decreases the time and storage costs associated with other modes of recycling such as accumulating materials to haul to more distant recycling centers or participating in infrequent recycling drives for charity. Instituting a curbside recycling program makes recycling even more convenient thus its effect on recycling effort should be bigger than the effect of a drop-off program. Curbside collection lowers the time and out-of-pocket costs of recycling by completely eliminating the need to transport recyclables to collection points or to store them for long periods of time. The results reported in Tables 6 and 7 conform to these expectations.

Our results show that for all materials except newspaper, instituting a local drop-off program has a positive and significant impact on intensity of recycling effort. Table 7 shows that the magnitude of the effect of the drop-off program variable varies dramatically across materials. Introducing a local drop-off program increases the probability that over 95 percent of all glass bottles used in the household are recycled by 42 percent; for plastic bottles the marginal effect is 34 percent and for aluminum it is 19 percent. One interpretation of these results is that introducing a local recycling option has a greater impact on those materials whose transportation and storage would be most difficult for households. Unlike aluminum (after it has been crushed), glass and plastic bottles are bulky and therefore difficult to store and transport. Adding a drop-off recycling program is likely to have a bigger impact on those materials. In addition, for newspaper and aluminum, households may recycle much of this material outside of the home. Newspaper carried to (or even purchased at) work may be recycled at work and beverage cans used outside the home may be recycled away from the home as well. Adding a local drop-off program is likely to have little impact on this type of recycling behavior.

Introducing a local drop-off option for yard waste increases the probability that over 95 percent of it will be recycled by 19 percentage points – the same increase as for aluminum. While this effect appears small relative to other materials, it represents a large increase relative to the percent of households in the sample that recycled over 95%. Table 5 shows that only 34 percent of respondents recycle over 95 percent of yard waste while between 54 and 75 percent recycle over 95 percent of the other materials. Thus, an increase of 19 percent in the probability that a household will recycle over 95 percent of yard waste is, relatively speaking, a larger increase than the same percentage increase for aluminum or the other materials. This suggests that drop-off recycling has a larger effect on yard waste (a bulky material) than appears at first glance.

As expected, the presence of curbside recycling has a positive and significant effect on intensity of recycling activity for all five materials. The magnitude of the effect of curbside recycling on intensity of recycling effort varies substantially across materials, just as the magnitude of the drop-off option did. Table 7 shows that introducing a curbside recycling program increases the probability that the average household recycles over 95 percent of glass and plastic bottles by more than 50 percent; aluminum by more than 39 percent; and yard waste and newspaper by around 25 percent. The interpretation of the differences across materials is similar to that offered for the drop-off program variable. Bulky and potentially messy materials such as glass and plastic bottles are difficult to transport and thus more responsive to the introduction of curbside than are other materials. The exception is yard waste for the reasons outlined above.

Table 7 also shows the marginal effects of replacing an existing drop-off recycling program with a curbside recycling program.[17] Also as expected, its effect on each material is bigger than the effect of the drop-off option. The size of the difference is fairly consistent across materials. Replacing a drop-off program with a curbside program leads to roughly a 20 percent increase in the probability of recycling over 95% of all materials except yard waste. For yard waste, replacing a drop-off program with a curbside program increases the probability of recycling over 95% by just over 5 percent.

Experience with a recycling program has a positive effect on recycling effort for both newspaper and yard waste. Table 7 reports the marginal effect of having a program in place for more than two years versus having it in place between one and two years. The magnitudes are quite small. For yard waste, greater experience with recycling programs increases the probability that over 95 percent of it is recycled by 3.6 percent. In the case of newspaper, program length also has a positive effect on recycling effort. However, the coefficient on the indicator variable for a program of over two years in length is smaller than the coefficient on the indicator variable for a program of between one and two years in length. This means that the marginal effect of going from a program of 1 to 2 years in length to a program of over 2 years in length is actually negative, but only slightly so. The finding that recycling effort increases with experience is consistent with Reschovsky and Stone (1994) which finds that the probability of participating in recycling rises for newspaper, glass, plastic, cardboard, metal and composting when households feel knowledgeable about the recycling program.

Our findings on the effects of other features of curbside recycling programs are mixed. The total number of materials collected curbside also has a small significant and positive effect on the intensity of newspaper recycling. Increasing the number of materials collected curbside by 1 leads to a 2.5 percent increase in the probability that a typical household will recycle over 95 percent of its newspaper waste. Making a curbside recycling program mandatory has no statistically discernable effect on intensity of recycling effort for any of the materials. Unfortunately, we lack any information on enforcement of the mandatory feature. One possibility is that mandatory features are not enforced to a degree that would affect household behavior.

Unit Pricing Policy Variables[18]

The econometric results reported in Table 6 indicate that the price of disposal is not a significant determinant of intensity of household recycling effort for any of the materials.[19] This finding

[17]For newspaper, the drop-off program variable is insignificant, so the marginal effect of moving from a drop-off program to a curbside program is identical to the marginal effect of implementing curbside.

[18] Initially this analysis set out to identify the effects of the level of the disposal price as well as other unit pricing program characteristics such as program type (bag/tag/sticker, subscription can) on the propensity to recycle. However, due to the small number of observations for bag/tag/sticker communities, we were unable to identify the effects of the type of unit-pricing program on the intensity of household recycling efforts. (See Table 3.)

[19] We did run some regressions where we excluded the MSA dummies for each of the materials. When the MSA dummies are excluded, disposal price has a significant and positive effect on the intensity of recycling effort for newspaper, but not for any of the other materials.

suggests that increasing the price of disposal does not increase the intensity of recycling effort. There are several possible explanations why the data reveal no effect.

One is that the average price of disposal for the unit-pricing communities in our sample is simply too low to create a response from our relatively high-income households. The sample's median household income is approximately $40,000 per year, which equates to an hourly wage of roughly $20. At that wage level, if the amount of time associated with recycling 32 gallons of trash is more than 5.75 minutes then the household will have time costs of recycling that exceed the avoided $1.91 average disposal charge. Thus, as an incentive to recycle, unit pricing is ineffective.

Another reason for such ineffectiveness is that a disposal price provides only an indirect signal to increase recycling, whereas it provides a direct signal to reduce trash. When faced with the prospect of paying a unit price for trash disposal, households may respond by changing their purchasing habits or making other changes in behavior that have a more direct impact on waste disposal. We return to this point in the conclusion of the paper.

Finally, most of the unit pricing programs included in our sample are subscription can programs. These programs provide a discontinuous signal to reduce disposal and therefore may provide only a weak incentive to households to recycle instead of disposing of solid waste (Nestor and Podolsky 1998).

Our finding of no effect of disposal price on recycling efforts is consistent with the findings of earlier studies by Kinnaman and Fullerton (1998), Fullerton and Kinnaman (1996) and Reschovsky and Stone (1994) which find that unit pricing does not significantly affect the level of recycling or the probability of participation in recycling programs. However, our findings differ from those of Callan and Thomas (1997) and Hong et al. (1993). Callan and Thomas (1997) finds that the presence of unit pricing increases the recycling rate by approximately 6.5 percent. Hong et al. (1993) indicates that unit pricing increases the probability that households will participate more often in recycling. Van Houtven and Morris (1999) finds that the presence of unit pricing positively affects the probability that a household will participate in recycling but has no effect on the quantity of recyclables set out for collection.

Socio-economic factors

The econometric models also include a number of socio-economic variables describing various characteristics of the households. The statistical significance and size of the effects of these different variables on intensity of recycling effort vary substantially across materials. Below we discuss those variables that have a statistically significant effect.

Household income has a significant and positive effect on intensity of recycling effort for newspaper only.[20] Due to the format of the original survey, income and several other theoretically continuous variables, such as years of education, are represented by a set of categorical variables spanning the

[20] This finding is in harmony with the theoretical results reported by Saltzman et al (1993) that the impact of income on recycled newspaper should always be positive while the impact of income on other recyclable materials might not be and can even be negative.

range of potential values.[21] This categorical representation of the data limits our ability to look at marginal effects of dollar changes in income. However, we can calculate the "marginal" effects of moving from one income category to the next highest income category. For example, we calculate the marginal effects on intensity of newspaper recycling effort for a typical household of moving from the "income between $35,000 and $49,999" category to the "income between $50,000 and $74,999" category. We find that such a change in category of income leads to a 4.3 percent increase in the probability of recycling over 95 percent of all newspaper waste generated by the typical household.

The level of education attained by the most highly educated person in the household has a significant effect on intensity of recycling effort for all materials except plastic bottles and yard waste. The marginal effects for a typical household of moving from the "high school graduate" category to the "college graduate" category is to increase the probability of recycling over 95 percent of aluminum and newspaper by 1 and 2.5 percent respectively. Curiously, for glass bottles, the level of education has a small negative effect on intensity of recycling effort.

A number of other socio-economic variables also influence the intensity of yard waste recycling efforts. For example, population density has a negative and significant effect on yard waste recycling. Increasing population density by 1000 persons per square mile leads to a less than 1 percent increase in the probability that a typical household recycles 10 percent or less of its yard waste. A likely reason is a growing scarcity of appropriate outdoor storage space as population becomes more dense. However, the effect is quite small in magnitude.

Another important socio-economic variable is whether a dwelling is single- or multi-family. Residents of single-family dwellings are substantially more likely to recycle larger quantities of their yard waste than residents of multi-family dwellings. As with population density and yard waste, the reason might be a lack of outdoor storage space or of storage space period.

Household size and the average age of the female and male heads of the household also have significant effects on intensity of recycling effort for some of the materials. Age has a positive, but small, impact on intensity of recycling for all materials except glass bottles. Household size has a significant and positive effect on recycling efforts for glass bottles and yard waste. Increasing the number of occupants of the average household by 1 person leads to a 3 percent increase in the probability that the household will recycle over 95 percent of its glass bottle waste. This finding may be due to the fact that glass bottle recycling is time intensive because the bottles must be cleaned. As the number of occupants rises, the amount of time required from each occupant decreases thereby reducing the implicit cost on any one individual. A similar argument explains the 2 percent increase in the probability that a household will recycle most of its yard waste associated with a 1 person increase in household size.

[21] See Table 4 for definitions of these discrete categories for the income and education variables.

Conclusion and Policy Implications

This study uses a national, household-level data set to examine the effect of two popular solid waste programs, curbside recycling and unit pricing on the percent recycled of five different materials found in the municipal solid waste stream: glass bottles, plastic bottles, aluminum, newspaper, and yard waste. The study also assesses the impact of other attributes of recycling programs (e.g. mandatory or voluntary) along with socio-economic characteristics of households. Taken together, the results presented here provide new insights that could help policy makers to improve the cost-effectiveness of a community's recycling program and to design a program to achieve mandated recycling rate goals. Consistent with expectations, a curbside recycling program increases households' intensity of recycling and the results differ across recyclable materials. The effect of a unit pricing program, on the other hand, is less clear.

The analysis indicates that drop-off and curbside recycling programs increase households' intensity of recycling for the five materials. The magnitude of the effect of these programs varies dramatically across materials with the largest impact on glass and plastic bottles. The size of the impact on yard waste recycling effort is also large relative to the average intensity of recycling effort observed in the sample. One interpretation of these results is that recycling programs have a greater impact on materials whose transportation and storage would be most difficult for households. Unlike aluminum and newspaper, glass and plastic bottles and yard waste are bulky and potentially messy. In addition, households might recycle aluminum and newspaper at work or at other locations besides home. Thus, neighborhood recycling programs do not have as large an impact on these materials. Local governments should take this into consideration when selecting which materials to include in a recycling program. For example, our results indicate that curbside collection of yard waste could lead to substantial diversion from the landfill of this major component of municipal solid waste.

Curbside recycling programs have a bigger effect on behavior than drop-off programs. For almost every material, a curbside program increases the probability that the average household recycles over 95 percent by approximately 20 percent more than the increase generated by a drop-off program. Local governments could compare the benefits of such an increase to the incremental costs of implementing curbside as opposed to drop-off recycling.

The impact of unit pricing on the intensity of recycling effort for specific materials is less clear. Unit pricing gives a direct incentive to decrease waste quantities. In response to such a program, households might adjust their consumption choices towards goods that generate easy-to-recycle wastes, likely those wastes eligible for collection by a local recycling program. These easy-to-recycle wastes increase in quantity; however, the *percentage* of that quantity that is recycled might not change. If unit pricing does increase recycling quantities by shifting consumption toward materials that are collected by a community's recycling program, its impact on recycling will not be detected by examining the percent of a material a household recycles.

Another interpretation of our findings is that the added convenience created by a recycling program creates a stronger incentive to recycle than having to pay at the margin for trash disposal. This interpretation suggests that collecting more materials at curbside will produce greater waste diversion than will implementing unit-pricing. However, if the costs of adding a particular material to a curbside program exceed the waste diversion and recycling revenue benefits of doing so, then adding materials may not be worthwhile.[22]

Our findings also suggest that a drop-off recycling program is effective at increasing recycling. In fact, with the exception of newspaper, the marginal effect on a material of initiating a drop-off program in a community with no program is larger than the marginal effect of initiating curbside recycling in a community with a drop-off program. This suggests that a budget-constrained community with no recycling program at all could see measurable waste diversion with the introduction of a less expensive drop-off alternative.

Recycling programs appear to become more effective over time. Our findings indicate that greater experience with a recycling program leads to greater recycling effort directed at newspapers and yard waste. However, the magnitudes of these effects are quite small. Of interest to policy-makers perhaps is that this effect is not negative; that is, households do not appear to become less enthusiastic over time about participating in recycling.

Of course, which materials to include in a recycling program also depends on the market prices of recyclable materials and on collection and processing costs. For example, our findings suggest that introducing curbside recycling has a big effect on the recycling of plastic bottles, one of the highest valued materials of those we studied.[23] However, collection and transport costs are also high for plastic bottles due to their low density. Policy makers can combine the insights from this study with information on the material composition of their local waste stream, local collection and transport costs and current market prices for recyclable plastic to decide if curbside recycling is a cost-effective means of managing plastic waste.

The study suggests several issues for future research. First, due to a lack of variation in our data, we were unable to analyze the differences in responses to the two main approaches to implementing unit pricing for solid waste disposal services: bag/tag/sticker versus subscription can. Van Houtven and Morris (1999) and Nestor and Podolsky (1998) analyze data from Marietta, Georgia and find that there are differences. For example, Van Houtven and Morris find that a bag program causes larger reductions in waste quantities than a subscription can program – 36 percent versus 14 percent. Future research could explore if the different program types affect recycling of different materials in different ways. Second, the nature of our data set has limited us to focusing on recycling intensity (percentage of each material type generated by the household that is recycled). However, policy makers and solid waste planners ultimately need more information about how recycling program characteristics and unit prices affect material-specific quantities of both recycling and waste disposal

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[22] One consideration that might change this calculation is if consumers are willing to pay a positive price for curbside recycling programs because of associated reductions in environmental impacts upstream or other perceived environmental benefits. Kinnaman (1999) finds that the households included in his survey do exhibit a positive willingness to pay for recycling programs.

[23] The following are average prices recyclers were paying for materials in late January or early February, 2000 in 8 urban centers across the country: Aluminum cans –$750 per ton; Natural HDPE (a type of plastic container) -- $300 per ton; Newspaper number 8 -- $70 per ton; Amber glass -- $27 per ton (Truini 2000).

by households. Providing such information requires national household-level data on quantities of materials recycled and discarded. Acquiring such data is resource-intensive, but would allow for an unprecedented analysis that would lend particular insight into the indirect impacts of unit pricing. Third, research into the costs of implementing curbside recycling programs with different scopes compared to the costs of implementing a drop-off program as well as a unit pricing program would be useful to policy makers seeking to design effective and efficient waste management strategies.

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