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GARBAGE AND RECYCLING IN COMMUNITIES WITH CURBSIDE RECYCLING AND UNIT-BASED PRICING

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ABSTRACT

This paper estimates the impact of a user fee and a curbside recycling program on garbage and recycling amounts, allowing for the possibility of endogenous policy choices. Previous estimates of the effects of these policies could be biased if unobserved variables such as local preference for the environment jointly impact the probability of implementing these policies and the levels of garbage and recycling collected in the community. A simple sequential model of local policymaking is estimated using original data gathered from a large cross-section of communities with user fees, combined with an even larger cross-section of towns without user fees but with and without curbside recycling programs. The combined data set is larger and more comprehensive than any used in previous studies. Without correction for endogenous policy, the price per unit of garbage collection has a negative effect on garbage and a positive cross-price effect on recycling. When we correct for endogenous policy, then the effect of the user fee on garbage increases, and the significance of the cross-price effect on recycling disappears.

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I. INTRODUCTION

Most communities in the United States pay for municipal solid waste services using general revenues or monthly fees that do not vary per unit of garbage collected at the curb. Thus households think that more garbage is free. This public provision might be warranted if the service were nonrival, but the marginal cost of collecting and disposing of another unit of garbage is decidedly nonzero. The community must pay for additional labor, truck space, and tipping fees at area landfills or incinerators. Similarly, free public provision might be warranted if the service were nonexcludable, but providers can indeed extract a price per unit of garbage collected. An increasing number of communities have begun to sell special stickers or tags that must be attached to any bag of garbage at the curb -- or else it will not be collected.

This local policy innovation can have several beneficial effects. The price per bag of garbage can help reduce household generation of garbage that must be put in a landfill, help raise revenue, alleviate budget problems, and allow property tax reductions. It provides incentives for recycling, composting, and even for source reduction -- demanding less packaging at stores. Unfortunately, these policies also have costs. The new programs must be advertised, promoted, administered, and enforced. And the price per bag of garbage might induce households to litter, burn their garbage, or dump it in vacant lots or commercial dumpsters.

Additional towns have adopted curbside recycling programs to help deal with their solid waste problems. A curbside recycling program can be expensive to operate, but saves costs at the landfill and could produce revenue if collected materials are sold.

Many other communities are currently considering the adoption of curbside recycling and a user fee (price per bag), and economic analysis can be very useful in their decisions. Because these programs are still new, however, very little is known about them. The U.S. EPA (1990) describes case studies of 17 communities with pricing programs, and Jenkins (1991, 1992) uses a panel of 14 communities to initiate a growing econometric literature that estimates the demand for garbage collection as a function of the price per bag, the presence of a free curbside recycling program, and household demographic characteristics.

Our paper makes four major contributions to this empirical literature. First, we collect original data from a significantly larger set of communities. We found 148 communities that have implemented curbside recycling and charge a price per bag. We called them on the phone, and over a hundred provided adequate data for our model. We combine this original data with similar information for over 800 communities with and without curbside recycling, and without a user fee. We use U.S. Census data for demographic characteristics of all these communities and data published by *Biocycle* magazine's annual survey for tipping fees and any state mandates expected to affect garbage and recycling.

Second, we estimate both the demand for garbage collection and the demand for recycling collection. We thus provide the cross-price effect of the garbage price on the recycling quantity. Third, our model allows for three methods of disposal: regular garbage, recycling, and illegal burning or dumping. We do not have data to estimate dumping behavior, but we do have proxies for the cost to the household of dumping. The price of this third option can affect observed amounts of garbage and recycling. Also, with three options, garbage and recycling are not constrained to be substitutes.

Fourth, and most important, we account for the possible endogeneity in the two local policy variables. For example, the environmental awareness of the community is unobserved to the econometrician and may jointly affect (1) the probability of implementing a user fee, if a user fee is considered a "green" policy, and (2) the observed amount of garbage and recycling, if environmentally-aware citizens recycle more. Previous estimates of the effect of price are biased if they leave in the error term these unobserved characteristics that are correlated with price.

To account for possible endogeneity, we specify a sequential process for local government decisions about curbside recycling, whether to charge a price, and what price to charge. These choices are estimated as functions of observable variables such as the tipping fee, population density, and demographic characteristics. We then use predicted values for these policy variables in the garbage and recycling demand equations. Relative to the results obtained from treating these policies as exogenous, this correction increases the impact of a user fee in the garbage equation, and increases the effect of a curbside recycling program, but decreases the effect of a user fee in the recycling equation. When we correct for endogeneity, the effect of the garbage price in the recycling equation becomes insignificant.

II. OVERVIEW OF THE DATA AND MODEL

We estimate demands for garbage and recycling collection using data from communities with and without curbside recycling programs and user fee programs. The model requires data for each community's garbage tonnage, recycling tonnage, the user fee program characteristics, curbside recycling program characteristics, demographic characteristics, tipping fees, state mandates, and other variables. We combine data from four sources in a sequential model of decision-making by communities and by households. This section clarifies our four main contributions relative to existing literature.

A. Original Data for More Communities

No existing econometric study uses data with more than 12 communities that have a user fee.[1] In this study, we use data from four sources to create a cross-section of 959 towns, 148 of which employ a user fee. The first and most important source of information is an original data set we have collected from over 100 communities that have implemented programs to charge a price per unit of garbage collected at the curb. We started with a list of 32 communities with user fee programs (EPA, 1990) updated by a more recent list of 109 communities (EPA, 1993). We called each of these communities on the phone to find the appropriate solid waste official and to ask about the pricing program, the recycling program, actual tonnage of garbage and recycling, and whether they know of any other communities that charge a price per unit of garbage at the curb. Through extensive probing and word-of-mouth communications, we have expanded this list to include 148 communities. We have 101 with complete data for some of the estimation below. Most of these communities are located in California, Oregon, Illinois, Pennsylvania, New Jersey, and Michigan. A majority are small, with populations between 1,000 and 20,000.

Some communities contract residential garbage collection to a single private hauler, and in these cases we conducted the telephone interview with an agent of the private hauler. A few communities have several private haulers competing for household

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[1] Jenkins (1991, 1993) and Repetto et al (1992) use a monthly panel of 14 communities, 9 with a user fee. Podolsky and Spiegel (1995) use a cross section of 180 communities, 12 with a user fee. Miranda et al (1994) show data from 21 communities before and after implementation of a user fee but do not use econometrics to control for changes in other variables. Other kinds of data have been used as well. Aggregate times series from one community are employed by Efaw and Lanen (1979) and Skumatz and Breckinridge (1990). Household surveys with self-reported garbage and recycling behavior appear in Hong, Adams, and Love (1993) and Reschovsky and Stone (1994). In contrast, Fullerton and Kinnaman (1996) take direct measures of garbage and recycling weight and volume for 75 households before and after the implementation of a user fee program.

business, and these were excluded from our sample.[2] Once we reached the right official, we asked for tonnage of residential garbage and recyclable material collected in 1991.[3] Several contacted communities either do not keep data on residential garbage or were reluctant to release it to us, and these communities were also excluded from our sample. Private collectors were especially reluctant to provide these data. We asked how each community measured its residential tonnage. If this process did not seem reliable or accurate, we did not include the community in our sample.[4] Most communities are starting to gather and store more accurate residential data, in order to prove they are meeting state-imposed recycling quotas.[5]

The solid waste official from each included community also provided us with information on the user fee or pricing schedule, whether a curbside recycling program had been implemented, and whether household participation in that recycling program is voluntary or mandatory. We gathered information on two types of user fee pricing systems. The first is a "subscription system", in which residents pay a monthly fee for a specified number of cans each week. The monthly price for the first can each week is often larger than the price charged for additional cans. The second type of pricing system is a "bag or sticker program", in which households buy either special program bags or stickers to place on each of their own garbage containers. Garbage is collected only if it is in the special bag or has the special sticker attached. We show results below for both kinds of programs, but we feel the results are more reliable for just the bag or sticker

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[2] Our objective is to model the community's endogenous choice of price to be charged, not to model the endogenous price in a market with competitive suppliers.

[3] We started this effort in 1992. Many of these communities did not start keeping records until recently, so 1991 is the first year with a large cross section. We have been calling back the same officials to ask for more recent data, but this effort must continue a few more years before we have a panel of decent length. Only the 1991 cross section is complete. In addition, this original 1991 data can be combined with our second source of data described below that includes only 1991 garbage and recycling tonnages for 1,000 more communities with various recycling programs.

[4] After collecting this information from many communities, we discovered that some of them had provided us an estimate of their aggregate garbage (our dependent variable) that was obtained by multiplying their local population times the EPA estimate of the U.S. average garbage per person! We did not include these communities in our sample.

[5] We are not able to control for a possible sample selection bias that might arise if towns that keep good records also care more about solid waste in some way.

programs where households pay for each additional bag of garbage presented at the curb. The problem with the subscription system is that often the cans are very large, and the household must pre-commit to paying for one or two cans every week. Most households leave some portion of a can empty most weeks, so the "true" marginal cost of extra disposal is still zero.[6] We, therefore, exclude these communities in our analysis. For comparison, our model is also run with "subscription systems" in order to estimate which price schedule is more effective in reducing residential garbage tonnages.

In order to estimate our model, we also need information from communities without a user fee. Therefore our second source of data is a large sample of communities provided by the International City Managers Association (ICMA). This organization sent a questionnaire to over 4,000 communities across the U.S., asking about many aspects of their solid waste programs, including curbside recycling programs plus garbage and recycling quantities. More than 1,000 communities responded, and 811 of these have sufficient information to use in our model. We describe below how we combine the 811 communities without a user fee and the 148 communities with a user fee, for a full data set with 959 communities.

For our third source of data, we use the 1990 U.S. Census report to obtain demographic characteristics for all 959 communities in our full sample. As discussed below, we need information for each community about family size, age, education, income, home ownership, population, and area (to calculate density).

Finally, for our fourth source of data, we use the annual survey of the National Solid Waste Association (NSWA), as reported in *Biocycle Magazine* (Steuteville and Goldstein, 1993), to obtain the local tipping fee facing each community and all state regulations expected to affect the local government's choice of solid waste policies.

B. Estimation of Both Garbage and Recycling

Several papers mentioned above estimate the demand for garbage collection, but not recycling. Using a survey of 2298 households, Hong, Adams, and Love (1993) are able to estimate the frequency that households recycle, but not the amount. Using a different survey of 1422 households, Reschovsky and Stone (1994) estimate the

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[6] See Nestor and Podolsky (1996) for a careful description of household behavior when facing a "subscription" program.

probability that a household will recycle, for each type of material. Tawil (1995) estimates the probability that a community will adopt curbside recycling. Only Browne (1994) estimates the amount of household recycling as a function of a user fee for garbage collection, and other variables, using 34 communities (16 with a user fee). None of these studies estimate both garbage and recycling.

For each of our 148 communities with a user fee, we were able to collect annual tonnages both for residential garbage collection and for curbside recycling collection. Thus we can estimate both of these demands as functions of the same set of right-hand variables, both corrected for endogeneity of local policy.

C. A Third Option, for Illicit Burning or Dumping

In previous models, garbage and recycling are the only two disposal options and therefore must be substitutes. A price per bag of garbage has only favorable effects, since it reduces garbage and increases recycling. Several of these papers mention illicit dumping, but they believe it can be minimized by appropriate local policy. They take the optimal price for garbage to be its marginal social cost of disposal, and they proceed to use the estimated price elasticity to measure the welfare gain triangle from charging this price per bag instead of zero.[7] Yet the inclusion of illicit burning or dumping can reverse this result. Fullerton and Kinnaman (1995) allow for all three options, make no restrictions on the nature of the substitution among them, and assume only that the negative externality from dumping is greater than the negative externality from garbage. They find that the optimal price per unit of garbage is below the marginal social cost of disposal, and may well be zero, to help avert illegal dumping.

Thus, to evaluate user fee programs, we need to know not just whether the garbage demand curve slopes down, but why. Source reduction and substitution into recycling are socially favorable responses, and illegal dumping is not. We believe illegal dumping is potentially important. Of the 1422 households in the Reschovsky and Stone (1994) survey, 20% admitted to burning their own garbage in response to a user fee, and 51% said they thought that illegal dumping had increased. Browne (1994) also considers

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[7] See, for examples, Jenkins (1991, 1993), Repetto el al (1992), Podolsky and Spiegel (1995), and Strathman, Rufolo, and Mildner (1995).

illegal dumping. Fullerton and Kinnaman (1996) estimate the reduction of garbage from a user fee and find indirect evidence that illegal dumping may account for one-third of it.[8]

For these reasons, we consider all three disposal options in our model below. We cannot estimate dumping behavior, but we have some proxies to use for the household's cost of dumping. The cost of this third option can affect observed amounts of garbage and recycling. Moreover, with three options, an increase in the price of garbage need not increase the amount of recycling by the same amount as the reduction in garbage.

D. Corrections for Endogeneity

No existing studies of garbage demand include a correction for the endogeneity of local government decisions about the price per bag collected.[9] Our model accounts for some particular features of these decisions by local governments. In our data, described below, we observe a variety of prices charged in different communities. No community charges a price below 30 cents per 32-gallon bag, however, probably because the low revenue would not be enough to cover the administrative cost of the program. Community officials in our model first calculate the optimal user fee to charge, which may depend upon community characteristics. They then calculate the total social benefits of instituting that price, and the total social costs including both fixed and variable administrative costs. The community then institutes this program, and we observe this optimal price, only if the total benefits exceed the costs.

The community thus faces a dichotomous choice about whether to implement a pricing program, and a dichotomous choice about whether to implement a free curbside recycling program. In general, with two such choices, the community would have four

[8] They also find that households reduce the number of bags by 34%, but the total weight of garbage by only 14%. Thus households stuffed 37% more in each bag.

[9] Most studies assume the price is exogenous. An exception is Hong, Adams, and Love (1993) who use a survey of 2298 households in 19 communities with 25 collection firms that use a variety of block-pricing schedules (such as $12/month for one can per week and $24/month for two cans). They do not deal with the setting of these price schedules, which are assumed fixed, but they correct for endogeneity that arises from the fact that the household's quantity choices determine its location on the price schedule. Browne (1994) considers endogeneity of the community's chosen price, and rejects it. Tawil (1995) corrects for the self-selection of communities into curbside recycling programs, to estimate the probability of adopting such programs. None of these papers corrects for this kind of self-selection in the estimation of garbage or recycling quantities.

possible combinations. Of the 959 communities in our full data set, however, not a single community has a pricing program without a free curbside recycling program. We believe this outcome is not a coincidence. The purpose of the price for garbage is to reduce the demand for garbage collection, but households must have somewhere else to put it. The community can provide an attractive alternative for at least some of this trash, in the form of free curbside recycling, or else people will find an unattractive alternative like illegal dumping. The basic logic of municipal solid waste makes it foolhardy to attempt a price per bag of garbage without free curbside recycling, and communities know it.[10]

We can use this logic, and the consequent form of our data, as a powerful tool in our estimation procedure. We do not have two independent choices by communities, but a logical limitation on their choices. We assume they cannot choose to charge a price per bag of garbage unless they also choose to provide free curbside recycling collection. Even if the two programs are enacted simultaneously, the curbside recycling program is *logically* prior. We therefore model a sequence of decisions by communities. First they make the dichotomous choice about whether to collect recycling. Of the 959 communities in our full data set, 399 have curbside recycling. The communities that choose curbside recycling might also think about what price to charge per bag of garbage. They calculate the optimal price using marginal conditions, and then determine whether total social benefits exceed total social costs. Of the 399 with curbside recycling in our combined data, 55 have enacted a "bag or tag" fee per unit garbage. Finally, after each community has chosen whether to collect recycling, and whether to charge a price, households determine garbage and recycling quantities.

III. MODELING DEMAND FOR GARBAGE AND RECYCLING

Our full model involves a sequence of decisions by different agents. In order to explain the model, we start with the household's waste disposal choices, and then work our way back to the local government's policy choices.

A. Household Behavior

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[10] Several communities, especially in California and Oregon, had "subscription" programs to finance garbage collection long before implementing a recycling program. We exclude "subscription" programs from our sample since they provide weaker incentives on the margin to reduce garbage than do pure "bag or tag" programs.

Assume that a community with a single local government is comprised of N households. Each household buys a single composite consumption good c, and each generates waste in three forms. All waste must appear as regular garbage collection (with amount g), recycling (with amount r), or illicit burning and dumping (with amount b). We use lower case letters to denote amounts for each household, and later we use upper case letters to denote amounts for each community. Household preferences among these three disposal methods may depend on a vector of demographic characteristics, α. Thus each household maximizes utility:[11]

(1) $$u = u[c, g, r, b, \alpha]$$

subject to the budget constraint

(2) $$m = c + p_g g + p_r r + p_b b$$

where m is income, the consumption good c is numeraire, and p_j denotes the price of disposal option j for j = g, r, b. This maximization process yields demand functions for each method of waste removal

(3a) $$g = g(p_g, p_r, p_b, m, \alpha)$$

(3b) $$r = r(p_g, p_r, p_b, m, \alpha)$$

(3c) $$b = b(p_g, p_r, p_b, m, \alpha).$$

The price of garbage collection facing the household (p_g) may include time and effort to store garbage and to put it out to the curb, plus the value of any user fee charged by the i^{th} community (P_i).[12] We have no data on the time and effort components, but we assume they are functions of household income and demographic characteristics (m, α). Other variables might also affect the household cost of disposing of garbage. First, several

[11] See Fullerton and Kinnaman (1995) for more description of this household choice.

[12] In some towns, residents pay one price (P1) for their first bag of garbage each week and another price (P2) for the second bag. Households may *have* to use at least one bag each week, so we include only P2 as P, the price at the margin for garbage.

states prohibit yardwaste from entering landfills.[13] We define the indicator variable I^{YW} = 1 if the community bans yardwaste from the garbage, and 0 otherwise. We expect such a ban to increase the cost of disposing of yardwaste with regular garbage collection. Second, many communities mandate that all households participate in curbside recycling (I^{MAN} = 1, and 0 otherwise).[14] This law increases the cost of disposing of garbage at the curb by the expected fine for not recycling. These considerations explain the first of our three price equations:

$$p_g = p_g(P_i, m, \alpha, I^{YW}, I^{MAN}) \tag{4a}$$

$$p_r = p_r(I^R, m, \alpha, I^{DR}, I^{MAN}) \tag{4b}$$

$$p_b = p_b(m, \alpha, D, D^2) \tag{4c}$$

In equation (4b), the household's price of recycling (p_r) includes the cost of separating, storing, transporting, and possibly paying a firm to accept the recycled material (this last component could be negative). Time costs can be functions of household income and demographic characteristics (m, α). The presence of a curbside recycling program diminishes these costs significantly, since transportation, and payments to firms are handled by the community. Let I^R = 1 if community i has free curbside recycling collection, and 0 otherwise. Several states may have a deposit-refund program for certain types of drink containers. We define I^{DR} = 1 for communities in such states, and 0 otherwise. A refund for bottles returned to the store serves to increase the cost of putting those bottles into curbside collection. Thus we expect I^{DR} to increase the cost of curbside recycling. It would also increase the cost of garbage and litter, at least in communities that do not have free curbside recycling.[15]

The household's price for burning or dumping (p_b) is not a market price, but it includes implicitly the time required to find a suitable dump site, the costs of traveling to

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[13] Communities in these states often provide special collections for leaves, shrubs, and grass clippings and take them to special composting piles.

[14] In most cases, this decision is imposed by the state and therefore exogenous to the community. We treat both I^{YW} and I^{MAN} as exogenous, in order to focus on local choices about whether to implement a curbside recycling program and a pricing program.

[15] This policy variable (I^{DR}) is also determined by the state government and exogenous to both the household and the local government.

the dumpsite, and the possible fine for breaking a local litter ordinance.[16] We tried to collect information on litter laws and fines in each community, but enforcement varies widely. Adequate data on penalties are not available. Instead, we hypothesize that easier opportunities for illegal dumping are provided by very high population densities (urban areas) and very low population densities (rural areas). Urban areas provide plenty of commercial dumpsters for residents to dump their garbage, while rural areas have remote spots for dumping. Communities with middle densities (suburbs and residential communities) provide fewer opportunities to dump. Suburban areas could also provide greater social pressure not to dump. We therefore enter density (D) in a nonlinear fashion, using both population density and its square in the regressions. Hence (4c) above.

Upon substitution of (4a-c) into 3(a-c), we get demands as functions of observed variables defined above. These are summed across all households in the community to obtain aggregate demands for garbage (G), recycling (R), and burning or dumping (B):

(5a) $$G = G(I^R, P_i, m, \alpha, D, D^2, I^{YW}, I^{DR}, I^{MAN})$$

(5b) $$R = R(I^R, P_i, m, \alpha, D, D^2, I^{YW}, I^{DR}, I^{MAN})$$

(5c) $$B = B(I^R, P_i, m, \alpha, D, D^2, I^{YW}, I^{DR}, I^{MAN}).$$

A linear econometric specification of these equations is:

(6) $$Y_i = \beta_0 + I_i^R\beta_1 + (P_i \times I_i^R)\,\beta_2 + X_i\beta_3 + \mu_i$$

where Y_i denotes either the per-capita weight of garbage (G) or recycling (R) for community i, I_i^R is the indicator variable for the presence of a curbside recycling program, P_i denotes the (observed) price of garbage collection, X_i is a vector of exogenous variables in (5), and μ_i is an error term. The vector X_i includes variables such as income, demographic characteristics, population density, its square, and state laws ($m, \alpha, D, D^2, I^{YW}, I^{DR}$ and I^{MAN}).

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[16] Some of these costs may be fixed costs or marginal costs. Implicitly, therefore, we allow for the possibility in Kinnaman and Fullerton (1995) that a higher price for garbage could induce the household to incur the fixed cost of dumping, and thus to reduce both its garbage and its recycling.

This specification accounts for the sequential nature of the policy process since the coefficient on price is estimated using only those communities that have implemented curbside recycling programs ($I^R \neq 0$). Notice the price variable P_i does not appear for communities without curbside recycling ($I_i^R=0$).[17]

Previous studies have estimated (6) directly by ordinary least squares (OLS) or generalized least squares (GLS). Estimates of β_1 and β_2 are used to interpret the effects of free curbside recycling and of the user fee. For comparability, we also show OLS estimates of (6) below. These OLS estimates will be biased, however, if I_i^R and P_i are endogenous. Communities choose whether to collect recycling, and whether to charge a price for garbage, and these choices are likely to be based on the expected consequences for aggregate garbage and recycling. The next subsection describes instruments for these endogenous variables.

B. Local Government Behavior

Each local government has several policy instruments available to control the quantities of garbage, recycling, and illegal dumping. The two primary policies of concern are free curbside recycling and a user fee for garbage. As described above, these two decisions are not independent because no community would ever charge a user fee without having free curbside recycling collection. Therefore we model these policy decisions as if they were sequential. First, a local government can decide whether or not to implement a curbside recycling program. Second, those that have decided to implement curbside recycling can choose whether or not to implement a user fee.

The Choice To Implement a Curbside Recycling Program

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[17] This specification is an extension of the mixture model (Maddala, 1983, Section 9.7):

$$(Y \mid I^R = 1) \sim N(\beta_{10} + P\beta_{12} + X\beta_{13}, \sigma_{11})$$
$$(Y \mid I^R = 0) \sim N(\beta_{20} + X\beta_{23}, \sigma_{22})$$
$$I^R \sim N(Z\gamma, 1)$$

The Z vector includes exogenous variables described later. These equations relate to equation (6) by $\beta_{10} = \beta_0 + \beta_1$, $\beta_{20} = \beta_0$, and $\beta_{12} = \beta_2$. In addition, we restrict the estimation such that $\beta_{13} = \beta_{23}$, and $\sigma_{11} = \sigma_{22}$. An earlier version of this paper used a "switching regressions" model, but that model defines Y as the potential outcome, unconditional on I^R. Since unit-pricing requires curbside recycling, we want Y conditional on I^R, as provided by the mixture model (Poirier and Rudd, 1981). We are grateful to Joe Terza for making this point.

Each local government is assumed to compare the costs and benefits of implementing a curbside recycling program. The first benefit to the community is the reduction in garbage collected (ΔG) times the tipping fee that must be paid to the landfill (P_T). The reduction in garbage collected depends on the vector X_i of variables in the household's demand for garbage collection in equation (6) above. A second benefit to the community is the price that it receives (P_R) for the collected recycling R. This total R is the same as the change ΔR from introducing the free curbside recycling program, since our data for household recycling includes only amounts collected at the curb (which is zero without curbside recycling). This amount also depends on household income and characteristics in X_i of equation (6).[18]

The cost to the community of curbside recycling includes the total cost of labor and capital to collect the recycled materials from the household (TC_R). Also, the community's choice about this policy might be affected by any of several state laws. First, some states require every community to recycle a certain fraction of their total waste stream. For example, the state of California requires all communities to recycle 50% of their waste by the year 2000. We define this quota (Q) as the required fraction $R/(R+G)$. We expect that communities in these states are more likely to implement free curbside recycling, in order to meet the state recycling quota. The impact of this quota could depend on the length of time before it must be met. We therefore include the length to deadline (QTIME) and their interaction (Q*QTIME) in our estimation. Second, some states forbid yardwaste from entering landfills. If properly enforced, households in these states cannot include yardwaste with their other trash for collection. Communities in these states may consider this law when deciding whether to implement a curbside recycling program. Third, some states have implemented deposit-refund systems for bottles and aluminum cans. Households in these states can take these materials directly to stores for a refund. A community in one of these states would therefore realize fewer benefits from implementing curbside recycling, since fewer materials will be collected and sold. Finally, some states like New Jersey have passed laws requiring all communities to implement curbside recycling ($I^{SL} = 1$, and 0 otherwise). This law does not guarantee that communities actually implement the required program, but it may increase the probability.

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[18] In the reduced form below, the probability of a curbside recycling program depends directly on household characteristics X_i, so the policymaker's decision can equivalently depend directly on local voter preferences rather than a formal cost-benefit test.

The final choice still remains with the community, and only 57% of communities in these states had implemented curbside recycling in the year of our data. These various considerations give us the following equation for I_i^{R*}, defined as the true net benefits to the community from providing free curbside recycling collection:

$$(7) \qquad I^{R*} = I^{R*}(P_T, P_R, \Delta G(X), \Delta R(X), TC_R, Q, QTIME, Q{\times}QTIME, I^{YW}, I^{DR}, I^{SL})$$

This equation suggests certain variables that enter the community's choice that do not enter the household's choice. For econometric implementation, we specify:

$$(8) \qquad I_i^{R*} = Z_i\gamma + \varepsilon_i$$

where $\varepsilon_i \sim N(0, 1)$, and γ is a vector of parameters to be estimated. The vector Z_i includes all of the variables that help determine household choices (the X_i), and it includes other exogenous variables on the right hand side of equation (7). We have no data on the labor or capital costs of collection (TC_R), but proxy it with the population density of the community. Recycling trucks in communities with high densities do not have to drive as far between houses. We have direct observations of the region's tipping fee (P_T), the state's quota (Q), and QTIME. All of these regional and state variables are treated as exogenous to the local government decision maker. We do not have direct observations of the price received for recycling (P_R), but we have a couple of good proxies. First, we have an indicator variable $I^{SH} = 1$ if the state helps stimulate demand by providing economic incentives to firms that purchase recycled materials (and 0 otherwise). Second, we have another indicator variable $I^{SB} = 1$ if the state buys recycled materials for its own operation (and 0 otherwise). We expect both of these variables to increase the probability that the community will implement free curbside recycling collection.

We do not observe these true net benefits to the community from a curbside recycling program. Instead, we only observe whether a community has implemented such a program:

$$(9a) \qquad I^R = 1 \qquad \text{iff } I^{R*} > 0$$

$$(9b) \qquad I^R = 0 \qquad \text{otherwise.}$$

We use the Probit model to estimate the γ, and then we use these coefficients to generate a predicted probability that each town will choose to implement curbside recycling. This predicted variable is used to replace the actual (endogenous) variable I^R in equation (6) to estimate household demands.

We next model the decision to implement a user fee, for governments with recycling programs, in order to replace P_i in (6) with its predicted value as well.

The Choice to Implement a User Fee

If and when a local government has decided to implement a curbside recycling program, it can then choose a user fee. This choice itself is modeled in a two part process. First the community chooses the optimal value for its user fee, if it were to charge a fee. Second, the community determines whether the implementation of that fee is worthwhile at all. The program is only worthwhile if the total social benefits exceed total social costs, including the fixed administrative costs.

Presuming first that the community will implement a fee, the optimal fee would be determined by a tradeoff between benefits and costs at the margin. The location of the marginal cost and marginal benefit curves for additional garbage, and hence the value of P*, will vary across communities. Each community must carefully examine all relevant variables. In particular, a slightly higher fee might generate more revenue, reduce the amount of garbage that has to be sent to the landfill, and increase the amount of curbside recycling that can be sold by the community.

Thus we expect the chosen price per bag of garbage to depend upon the area's tipping fee (P_T), the price received for recycled materials (P_R, or its proxies I^{SH} and I^{SB}), and the household's determination of G and R (which depend upon income and household characteristics in X_i). A higher user fee might help meet a recycling quota (Q and QTIME), and its revenue might help alleviate the problem of dealing with a state limitation on local property taxes. We define the indicator variable $I^{PT} = 1$ if the community is located in a state with a property tax limitation (and 0 otherwise). On the other hand, a slightly higher fee might generate more illegal burning and dumping. This response may be greater in areas with very low population density (where garbage can be dumped in the woods) and with very high density (where garbage can be dumped in commercial dumpsters). A community's choice may also be influenced by a state law that requires all communities to implement curbside recycling ($I^{SL}=1$, and 0 otherwise). Marginal costs depend to some extent on whether garbage collection is conducted by the municipality or by a private regulated firm. Private firms may be more efficient. We define the indicator variable $I^{MUN}=1$ for communities with municipal collection and 0 for those that franchise or contract the collection service to a single private firm (communities with more than one collector are excluded). These considerations together suggest that the optimal price to charge is:

$$(10) \quad P_i^* = P_i^*(P_T, P_R, \Delta G(X), \Delta R(X), \Delta B(X), Q, QTIME, Q\times QTIME, I^{PT}, I^{SL}, I^{MUN})$$

where ΔG, ΔR, and ΔB are the changes attributable to the user fee. These changes are functions of X, defined in equations (5) to include m, α, D, D^2, I^{YW}, I^{DR}, and I^{MAN}. Assume the econometric specification of (10) is:

$$(11) \qquad P_i^* = X^P{}_i\delta + u_i$$

where $X^P{}_i$ is the vector of exogenous variables in (10), including demographic characteristics for community i, where $u_i \sim N(0, \sigma^2{}_u)$, and where δ is a vector of parameters to be estimated.

Once the local government solves for this optimal price, it must still determine whether the program overall is worthwhile. It essentially measures the area under the marginal benefit curve to determine total benefits, and the area under the marginal cost curve to determine total variable costs. In addition, however, the community incurs a fixed cost to implement and administer the program. The local government must pay to print and distribute the stickers or bags, to promote the program, and to enforce litter laws. These fixed administrative costs are functions of the same exogenous variables that appear in the marginal condition (equation 10) such as X, I^{PT}, and I^{MUN}. We assume that the government will only implement the user fee P^* if the net social gain is positive.[19]

[19] This model is similar to that of a private firm contemplating a new product. The firm uses marginal conditions to determine the profit-maximizing price, and then it checks total costs and revenues at that price. Only if those maximum profits are positive does the firm proceed. In our case, the community may consider social costs, such as illegal dumping. Only if the social gain is positive does the community proceed.

We do not observe the optimal price, the total social benefits (TSB), or the total social costs (TSC). We observe only the user fee that is charged by each community:

$$(12) \qquad \begin{array}{ll} P_i = P_i^* & \text{if TSB} \geq \text{TSC} \\ P_i = 0 & \text{otherwise.} \end{array}$$

Because the dichotomous choice ($P_i = 0$ or positive) depends on the same variables as the continuous choice on P_i^*, we use the Tobit model to estimate the reduced form.[20]

Next, to obtain a consistent estimate of the effect of price in equation (6), we use the predicted price $\hat{P}_i$ calculated from (12) as an instrument for P_i when we estimate garbage (or recycling) as a function of price and other exogenous variables.[21]

IV. Results

We start with a summary description of the variables used in the estimation. These variables are defined in Table 1, starting with those determined endogenously within the full model. The main goal is to estimate the demands for garbage (G) and recycling collection (R), but the model includes endogenous determination of whether the

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[20] As an alternative, we estimated a censored regression model where the dichotomous decision is based on whether the optimal price P^* is above or below some "stochastic unobserved threshold" (Maddala, 1983, pp. 174-78). This model has two problems, however. First, net social benefits (TSB-TSC) are not monotonic in price, since a higher price might increase dumping. Thus the decision should be based not on whether the price is high enough, but whether net social benefits are high enough. Second, that model uses a probit on the decision to implement a positive fee, the inverse Mills ratio to correct the estimation of P^* for those with a positive price, and the predicted optimal price $\hat{P}^*$ for *all* communities in the sample (with or without user fees) to replace the endogenous price in the garbage demand equation (6). That P^* may be quite high for a community that faces a high administrative cost and chooses not to implement that price. Yet households in (6) generate garbage in response to the actual price of zero, not the hypothetical high price P^*. The predicted $\hat{P}^*$ is very weakly correlated with actual price, and its use in (6) would not help determine household behavior. Instead, we need an instrument for both positive prices and zero prices, given that communities choose endogenously whether to implement a fee. Such an instrument is provided by the Tobit estimation of (12) which provides a prediction of the actual price, whether zero or positive. The correlation coefficient between the actual price and our predicted price is 0.74.

[21] Because the predicted prices are estimated with error, we adjusted appropriately the standard errors of the estimated coefficients in equation (6).

community has curbside recycling (I^R), and the value of the user fee. For some communities, especially the 50 using "subscription" programs (where $I^{SUB} = 1$), the user fee for the first can of garbage (P1) differs from the second (P2).[22] We eliminate these 50 communities from most of our regressions, which reduces our sample size to 909.

Summary statistics for all 909 communities are shown in Table 2. Garbage averages 911.68 pounds per person per year. Recycling averages only 47.84 pounds per person per year, but the third row shows that only 44% of the communities have curbside collection. Our data for household recycling includes only amounts collected at the curb. The price variable is relevant only for the 399 communities with curbside recycling. In those towns, price ranges from zero to $2.18 and averages $.14 per 32-gallon bag.

The second panel of Table 1 shows the exogenous variables X_i that help determine the demands for garbage and recycling. Table 2 shows that our communities display considerable variation in income and demographic characteristics. We use per capita income for each community from the U.S. Census to represent aggregate income, which varies from $4,461 per person to $51,170 per person. The retired population varies from 2% to 56%, family size varies from 1.8 to 4.1, fraction with college degrees varies from 3% to 83%, and the fraction that own homes varies from 18% to 98%. The overall average fraction for homeowners in our sample is 64%, closely matching the overall average for the United States. Population density varies from 32 per square mile to 21,040 per square mile. Finally, 39% of our communities ban yardwaste from their garbage, 17% of our communities are located in states with deposit-refund systems, and 48% require households to participate in curbside recycling.

Other panels of Table 1 indicate additional variables that influence local policy. The average tipping fee faced by our communities is $26 per ton and varies from $2.41 to just over $107. In our sample, 55% of communities are in states that help incentives in recycling markets, while 72% are in states that require agencies to buy recycled materials. The average recycling quota is 12% of the waste stream, with deadlines ranging up to 9

[22] We do not estimate the community's choice between a "bag or tag" or "subscription" program. Also, subscription plans employ a rather large can, so they do not have a well-defined price. An increment of garbage may cost P1 for the first can, or it may cost zero if that can is half-empty. It might cost P2, for the second can, or the increment might cost more than P2 if it makes the household buy a second can that is larger than needed. In contrast, the "bag or tag" plans employ smaller units. If each household must have at least one bag of garbage each week, then P2 is the relevant price variable for our regressions.

years away. Finally, 33% of our communities are in states with property tax limitations, and 45% have municipal collection.

A. Estimation of Local Government Behavior

Our model specifies sequential local government decisions. If the community first chooses to collect recycling, it can then choose a price to charge for garbage.

The Probability of Implementing a Curbside Recycling Program

The community's choice about curbside recycling in equation (9) depends on the expected outcomes for recycling and garbage collections, and thus on the vector of demographic characteristics (X_i). It also depends on the tipping fee, quota, and price of recyclables (proxied by I^{SH} and I^{SB}) and other state imposed variables. This probit specification can be estimated using all 959 communities in the entire combined sample.

Results from this stage are presented in Table 3, where several demographic variables are significant at the 1% level. The probability of curbside recycling is higher in communities with smaller families, with more educated citizens, and with more homeowners. Perhaps college-educated homeowners have greater preference for a clean environment and thus encourage their local government to implement curbside recycling.[23] The third column of Table 3 presents the marginal effect of a change in an independent variable on the probability that a government implements curbside recycling. The probability of recycling is estimated to increase by 0.86% for a 1 point increase in the percentage of citizens with bachelor degrees, to increase 0.43% for a 1 point increase in the homeownership rate, and to decrease by 28% for an additional person per household.

We suggested above that population density helps determine the cost of implementing a curbside recycling program. With higher density, for example, the collection truck does not have to drive as far between houses. But communities with very high density (apartment buildings) may *not* be likely to implement residential curbside collection, so we also use density squared. In accordance with our predictions, results in Table 3 indicate that a community with 1,000 more people per square mile is 4.2% more likely to implement curbside recycling. The negative (but insignificant) coefficient on density-squared indicates that cities with very high densities might be less likely.

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[23] Tawil (1995) devotes an entire paper to the estimation of this probability of recycling.

Several states have implemented deposit-refund programs for the collection of bottles at stores. As predicted, we find that communities in these states are 23% less likely to implement curbside recycling collection. We find, also as expected, that the probability of curbside recycling collections is higher for communities in states that provide help to firms that purchase these materials (I^{SH}), and only insignificantly higher in states that purchase recycled materials for their own operation (I^{SB}).[24]

The model also suggests that the probability of implementing a curbside recycling program increases with the tipping fee (P_T), since these fees put pressure on the budget of the local government. Faced with additional costs for disposing of garbage in landfills, these communities can use curbside recycling to decrease collections of garbage. Indeed, much of the previous literature attributes the recent popularity of curbside recycling programs to higher tipping fees. Our data support these claims. After controlling for other relevant variables, we find that the likelihood of implementing a curbside recycling program increases by 8.8% with every $10 increase in the tipping fee.

Several states have implemented quotas that require communities to recycle more. For example, every community in the state of California must recycle 50% of its waste by the year 2000. The effect of such a quota may depend on the time until it must be achieved (QTIME). For completeness, we include Q, QTIME, and their interaction in the regression, but find none of these to be significant.[25]

Finally, we note that a major purpose of estimating this probit model is to generate a prediction to substitute for the endogenous dummy variable I^R in the estimation of equation (6) above. Before estimating those demand equations, however, we need to calculate an instrument for the price per unit garbage.

The Choice of User Fee

For the 399 communities with curbside recycling, the decision about the user fee is itself modeled in two stages. The community first calculates the optimal price to charge, and then implements the program if the total benefits exceed the total cost including fixed

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[24] See Steuteville and Goldstein (1993) for a description of all these state policies.

[25] The mean of QTIME is 1.76, so the overall marginal effect of the quota is -0.4371 + 0.228(1.76) = -0.0359. Given the high standard errors, this effect is essentially zero.

administrative costs. We employ the Tobit model to estimate the reduced form of equation (12), as presented in Table 4.

The coefficient on income is negative and significant, as a $1,000 increase in per-capita income reduces the optimal user fee by $.17. One explanation for this negative coefficient is that communities using property taxes to pay for garbage collection enable their residents to deduct those local taxes against federal income tax. In contrast, user fees are not deductible. Communities with high per-capita incomes have more residents who itemize, and who face high income tax rates, so they find a user fee to be costly in terms of lost deductions. Also, high income households may not reduce garbage in response to a user fee, which reduces the benefits of implementing the program.

Education is the only demographic variable that has a significant effect on the value of the user fee. We estimate that the optimal user fee increases by $.30 for a 10% increase in the ratio of college graduates. Perhaps the communities find that educated individuals are less likely to engage in illegal dumping. The value of the user fee increases, but insignificantly, with the percentage retired and with family size.

We hypothesized above that household choices for the three disposal methods would depend on the three relative prices. Knowing this, the community projects that household dumping in response to the implementation of a user fee is a function of the relative ease of dumping, which is assumed to depend nonlinearly on the population density.[26] Results do not substantiate this hypothesis since the coefficients on density and density squared are insignificant. Either communities are not worried about illegal dumping when considering the implementation of a user fee, or we have a weak proxy for the household "price" of illegal disposal.

The optimal user fee increases significantly for communities in a state that bans yardwaste from landfills. Also, many have conjectured that the optimal user fee increases with the tipping fee. Faced with additional costs of landfilling their garbage, these communities can turn to a user fee for revenue and to reduce costs by decreasing the amount of garbage that needs to be landfilled. Our results support this conjecture; a $10 increase in the tipping fee (per ton at the landfill) is estimated to increase the optimal user fee by $0.23 (per bag at the curb). Next, our theory suggested that the optimal user fee

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[26] Fines for littering and the level of enforcement could also play a role in determining the costs of household dumping, but we were not able to obtain data on these variables.

would increase if the community receives a higher price for its collected recyclable material. We proxy this price by two state policies. The coefficient on the "state buy" variable is positive, as expected, but insignificant. The coefficient on the "state helps" variable is the wrong sign and insignificant. Lastly, in Table 4, the significant effect of a quota, and its interactive term, are difficult to explain.[27]

Results in Tables 3 and 4 provide the necessary instruments for estimation of household demands, but they also provide an interesting analysis of local policymaking. These results show how local government decisions respond to state mandates, demographic variables such as education, and economic variables such as income.

B. The Effect of Policy on Household Garbage

In the last stage of this process, equation (6) regresses aggregate garbage or recycling quantities on the exogenous variables in X_i and on the predicted values of the curbside recycling variable from (9) and user fee variable from (12). The G regressions use only 756 towns without subscription programs and with complete data on garbage.

Ordinary Least Squares

The first column of Table 5a presents estimates from a model of the type used in the previous literature. These OLS estimates do not account for the possible endogeneity of the user fee or recycling variable. For towns with recycling (I^R=1), the coefficient on the user fee variable is negative and significant at the 1% level. The implementation of a one-dollar user fee is estimated to reduce garbage by 247 pounds per person per year. Even though this coefficient is statistically highly significant, the implied elasticity of demand for garbage collection at mean levels of price and garbage quantity is only -0.0203. This estimate is closer to zero than all previous studies.[28] Previous studies with

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[27] Indeed, using the coefficient on QUOTA, its interactive term, and the mean of QTIME, we calculate that a higher recycling quota *decreases* the optimal user fee. For example, a recycling quota of 10% to be met in 5 years reduces the optimal user fee by $1.19.

[28] Others have estimated this price elasticity to be -0.12 (Jenkins, 1991), -0.15 (Wertz,1976), -0.26 and -0.22 (Morris and Byrd, 1990, in two communities), -0.14 (Skumatz and Breckinridge, 1990), -0.42 (Podolsky and Spiegel, 1995), and -0.075 (Fullerton and Kinnaman, 1996).

smaller samples might have used high-profile communities with large price responses. The larger sample in this study might just extend the analysis to those with lower elasticities.

The coefficient on curbside recycling is also negative, but it is not significant at the 10% level. Among towns with no user fee (P=0), a curbside recycling program is predicted to decrease garbage quantity by 33.5 pounds per person per year.

Other OLS estimates in Table 5 are similar to those in previous studies. The coefficient on income is positive and significantly different from zero at the 1% level. The income elasticity calculated from this coefficient is 0.305.[29] Households with high income not only have more waste material to remove, but they also face a high opportunity cost of time spent recycling or dumping. Therefore, these households throw out more garbage. Also, the quantity of garbage decreases significantly with education. Better educated citizens may have greater preference for a clean environment, switching some of their disposal from regular garbage to recycling (as seen in the next section).

We also estimate the impact of state policies. Communities in states that ban yardwaste from landfills (I^{YW}=1) produce 46 fewer pounds of garbage per person per year. This yardwaste is usually placed in special compost piles. Households that reside in states with a mandatory deposit-refund system for bottles and aluminum cans (I^{DR}=1) present roughly 57 fewer pounds per person per year to the curb for disposal in landfills. These households are presumably returning these materials to outlets instead of discarding them in the garbage. While communities that have curbside recycling (I^{R}=1) generate 33 fewer pounds per person, as mentioned above, those that mandate household recycling generate another 44 fewer pounds per person per year.

Endogenous Choice Model

The second column of Table 5a presents the estimates from the endogenous choice model. These estimates control for the endogeneity of the user fee and curbside recycling program variables. For towns with curbside recycling (I^{R}=1), the coefficient on the user fee is negative and significant. This coefficient is more than that of the OLS model (column 1). Communities with curbside recycling programs that implement a user fee can

[29] Others have estimated this income elasticity to be 0.242 (Richardson and Havlicek, 1978), 0.279 and 0.242 (Wertz, 1976), 0.2 (Petrovik and Jaffee, 1978) and 0.41 (Jenkins, 1991), 0.049 (Hong, Adams, and Love, 1993), 0.22 (Reschovsky and Stone, 1994), 0.57 (Podolsky and Spiegel, 1995), and 0.05 (Fullerton and Kinnaman, 1996).

expect a reduction of 373.5 pounds per person per year. If this estimate is indeed greater than the OLS estimate, then the lower levels of garbage experienced by communities with user fees in the data set understate the true reduction in garbage attributable to a user fee. Unobserved variables that make a community more likely to implement a user fee also increase the amount of garbage disposed by that community. The OLS model could not separate the effects of these other variables from the user fee variable.[30]

In communities with no user fee, curbside recycling increases garbage by an insignificant 34 pounds per person per year. The fact that neither model (OLS or endogenous choice) is able to establish a significantly negative relationship between curbside recycling and garbage quantity is an interesting result in itself.

Estimates of the effect of exogenous variables in the corrected model are similar to those from the OLS model in Table 5a. The effect of income on garbage is positive, while the effect of education is negative.[31]

For comparison, Table 5b provides estimates of the effect of a user fee on garbage amounts using communities that have implemented "subscription" programs ($I^{SUB}=1$). Recall that "subscription" programs require households to pre-commit to a number of cans each week, and the household is charged for those cans whether empty or full. Economic theory (see Nestor and Podolski, 1996) predicts that "subscription" programs are less effective at reducing garbage, since only "bag and tag" programs provide marginal incentives. We also run separate regressions using just P1 and just P2.

The first two rows of Table 5b provide estimates of the effect of price on garbage using all communities, those with "bag and tag" and "subscription" programs. The effect of price (P2) falls from -247 (Table 5a) to only -80 (Table 5b). Thus we find that a "bag and tag" program reduces garbage by much more than a "subscription" program.

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30 A joint Hausman test for correlation between the error and the price variable and recycling dummy does not reject the null hypothesis that no correlation is present in the garbage equation, F[2,741]=0.438, but does reject the null in the recycling equation, F[2,643]=8.272. Monte-Carlo simulations have shown that the Hausman test has poor power (the probability of accepting a false null is high).

31 Some variables in Z and X^P are excluded from X (every variable in Table 3 or 4 that is not in Table 5). To check for overidentification, we test whether these variables should be added to X in Table 5, and cannot reject the null that their coefficients are zero.

C. The Effect of Policy on Household Recycling

The OLS model in column 1 of Table 6a treats as exogenous the community's choices about whether to collect curbside recycling and whether to charge a price per bag of garbage. Column 2 corrects for possible endogeneity in these decisions. For these results, we use 658 observations without subscription plans and with complete data on recycling quantities.

Ordinary Least Squares

The implementation of a curbside recycling program in the OLS model increases the total quantity of curbside recycling by an average of 114 pounds per person per year for communities without a user fee. The coefficient on the interactive term indicates that the effect of a curbside recycling program on the quantity of recycling increases with the value of the user fee. The implementation of a user fee also has a direct effect on recycling, increasing the quantity of recycling by 33 pounds per person per year for those communities already with recycling programs. According to these estimates, the cross-price elasticity of demand for recyclable material collection is 0.045 at mean levels.[32]

We expect various offsetting effects of income on aggregate recycling. First, if an increase in income leads to more consumption, it could generate more waste material for disposal in all three forms, including more aggregate recycling. Second, a higher wage could increase the opportunity cost of time spent recycling, so it could decrease aggregate recycling. Third, the higher wage could increase the opportunity cost of time spent illegally dumping waste, so the net effect on recycling could depend on which type of disposal is more time-intensive. The estimated coefficient on income in Table 6a is negative (but insignificant), suggesting that the second effect could be slightly stronger than the others.

Demographic characteristics also play a role in determining aggregate recycling quantities. Significantly more recycling per person is generated in communities where households are older, larger, more educated, and own more of their own homes. Retired individuals may have more time to separate and store recyclable waste. Educated individuals may be more aware of recycling opportunities and may also have greater taste

[32] The U.S. EPA (1990) estimates this cross-price elasticity to be 0.49, 0.48, and 0.06 for various different communities. Browne (1994) finds it to be 0.102 for glass and cans, and -0.02 for paper recycling. Fullerton and Kinnaman (1996) find 0.074 for all recycling.

for a clean environment. Owner-occupants may generate more waste and therefore recycle more, especially if they have more room to store and separate recyclable material.

Endogenous Choice Model

Equation (6) above represents the demand either for garbage collection or for recycling collection. The second column of Table 6a shows the impact of local policies and of exogenous variables on recycling quantities, correcting for endogenous policy.

The impact of curbside recycling on aggregate recycling is calculated by using both the coefficient on the curbside recycling variable and the interactive term. Controlling for all other variables, and for endogeneity, the implementation of a curbside recycling program is estimated to increase aggregate recycling by 192.91 pounds per person per year in communities without a user fee. This estimate is slightly larger than the 114 pounds found in the OLS model. Thus the impact of curbside recycling as estimated in the OLS model may be biased downward.

The estimate of the effect of a user fee on aggregate recycling is positive but insignificant, implying that an increase in the price of garbage may not increase aggregate recycling in communities with curbside recycling programs. Therefore, the significant amount of additional recycling estimated by the OLS model may not be attributable directly to the user fee, but to other unobserved characteristics that jointly affect the optimal user fee and the quantity of recycling in opposite directions.

Again more recycling is generated by the retired, the college-educated, and homeowners, but the significance of all these variables is reduced in the endogenous choice model compared to the OLS model. These demographic variables may primarily affect the probability of curbside recycling, as estimated in Table 3 above.

Table 6b shows coefficients for the effect of a user fee on recycling using various definitions of the user fee. Again, the "bag and tag" method is more effective than the "subscription" program at increasing the amount of recycling.

V. Conclusion

This paper makes several contributions to the empirical literature on the impact of a user fee and a curbside recycling program on aggregate solid wastes. First, we collect original data for more than a hundred communities around the United States that have implemented a price per bag of garbage. We combine this original data with other data for a thousand communities without a price per bag of garbage, hundreds of which have curbside recycling programs, and with other data for demographic characteristics, state policies, and other exogenous variables.

Second, we estimate the effect of these prices and curbside collection programs not just on garbage collections, but also on recycling collections. Thus we estimate the cross-price effect for garbage price on recycling quantity. Third, our model allows for a third disposal method, illegal burning or dumping. We do not have data to estimate the amount of this behavior, but allowing for this third form of disposal creates interesting substitution possibilities that affect the determinants of garbage and recycling. It also affects the observed amounts of those two forms of disposal.

Fourth, and most important, we provide the first correction for endogeneity in these local government decisions about whether to provide free curbside recycling collection and whether to charge a price per bag of garbage. Where previous studies treat these variables as exogenous, we model how local decision makers may implement these programs only if projected garbage and recycling outcomes provide benefits in excess of costs to the community. We develop and estimate a simple sequential model of these decisions. With the correction for endogeneity, and with the predicted policies substituted into the garbage demand equation, the negative effect of price is enlarged. However, the significant effect of this price on aggregate recycling disappears. In other words, the OLS estimate of the positive effect of the garbage price on the recycling quantity would not apply to other communities considering a pricing program.

TABLE 1: Definitions of Variables

Endogenous Variables:	
G	Pounds per person per year of collected residential garbage
R	Pounds per person per year of collected recyclable material
I^R	1 if city-wide, free curbside recycling collection (0 otherwise)
I^{SUB}	1 if user fee program is of the subscription type (0 otherwise)
P1	Price of first bag of garbage collected, divided by local price index
P2	Price of second bag collected, divided by local price index
Exogenous Variables in Household Demand (X_i in equation 6):	
m=INCOME	Per capita income in 1,000's of dollars, divided by local price index
RETIRE	The percentage of all persons that are 65 years and older
FAM SIZE	Average number of persons per household
EDUC	Percent of those 25 years or older with bachelor's degree or higher
OWNER	The percentage of households that own their own home
D=DENSITY	The number of 1,000's of persons per square mile
I^{YW}	1 if a state law prohibits yardwaste from landfills (0 otherwise)
I^{DR}	1 if the state has a deposit/refund system for bottles (0 otherwise)
I^{MAN}	1 if the city mandates that households recycle (0 otherwise)
Exogenous Variables in Probability of Curbside Recycling (Z_i in eq. 8) include X_i plus:	
P_T	The tipping fee paid by the city, divided by the local price index
I^{SH}	1 if state helps incentives to buy recycled materials (0 otherwise)
I^{SB}	1 if state agencies must buy recycled materials (0 otherwise)
Q=QUOTA	State mandated minimum for the recycling rate, R/(R+G)
QTIME	Number of years until quota takes effect
I^{SL}	1 if state law "requires" the city to collect recycling (0 otherwise)
Exogenous Variables in the Optimal Price (X^P_i in eq. 11) include the Z_i plus:	
I^{PT}	1 if state law limits the town's property taxes (0 otherwise)
I^{MUN}	1 if collection is handled by municipal employees (0 otherwise)

TABLE 2: Summary Statistics

	Mean	Standard Deviation	Min	Max	Number
G (in pounds per person per year)	911.68	392.17	88.75	2115.	756[1]
R (in pounds per person per year)	47.84	103.41	0	1155.	658[1]
I^R (curbside recycling is in place)	0.44	0.50	0	1	909
I^{SUB} (subscription, not sticker or bag)	0.46	0.50	0	1	101[2]
P1 (price of first bag of garbage)	0.1506	0.4183	0.00	2.76	399[3]
P2 (price of second bag of garbage)	0.1378	0.3829	0.00	2.18	399[3]
INCOME (per capita, in $000)	12.69	5.31	4.46	51.2	909
RETIRE (% ≥ 65 years of age)	14.12	6.07	2.10	56.0	909
FAM SIZE (number per household)	2.57	0.29	1.80	4.13	909
EDUC (% with bachelor's)	23.60	13.51	2.76	82.8	909
OWNER (% homeowners)	64.12	13.30	17.6	98.3	909
DENSITY (1,000's per sqare mile)	2.59	2.10	0.03	21.0	909
I^{YW} (ban on yardwaste in garbage)	0.39	0.49	0	1	909
I^{DR} (state has deposit-refund)	0.17	0.37	0	1	909
I^{MAN} (mandatory recycling)	0.48	0.50	0	1	909
P_T (local tipping fee)	26.07	20.70	2.41	107.7	909
I^{SH} (state help to recycling)	0.55	0.50	0	1	909
I^{SB} (state buys recycled materials)	0.72	0.45	0	1	909
Q (quota for min % recycled)	0.12	0.17	0	0.5	909
QTIME (years before quota)	1.74	3.07	-1	9	909
I^{SL} (state law on city recycling)	0.11	0.31	0	1	909
I^{PT} (property tax limitation)	0.328	0.486	0	1	399[3]
I^{MUN} (municipal collection)	0.451	0.502	0	1	399[3]

[1] Number of towns with quantity data available.
[2] Only towns with curbside recycling and user fees.
[3] Only towns with curbside recycling.

TABLE 3: Probit Estimation of the Probability of Curbside Recycling
Dependent Variable: I^R (=1 iff curbside recycling)

VARIABLE	COEFFICIENT	(STANDARD ERROR)	MARGINAL EFFECTS
CONSTANT	-1.0023	(0.8381)	
INCOME	-0.0230	(0.0178)	-0.0077
RETIRE	-0.0049	(0.0132)	-0.0016
FAM SIZE	-0.8310***	(0.3182)	-0.2803
EDUCATION	0.0256***	(0.0069)	0.0086
OWNER	0.0128*	(0.0067)	0.0043
DENSITY	0.1245*	(0.0646)	0.0420
DENSITY SQUARED	-0.0065	(0.0048)	-0.0022
I^{YW} (yardwaste ban)	0.3290	(0.3330)	0.1110
I^{DR} (deposit refund)	-0.6837**	(0.2717)	-0.2306
P_T (tipping fee)	0.0262***	(0.0046)	0.0088
I^{SH} (state helps)	0.4519	(0.3194)	0.1524
I^{SB} (state buys)	0.2062	(0.2039)	0.0696
Q (quota)	-0.4371	(0.9709)	-0.1474
QTIME	0.0083	(0.0714)	0.0028
Q×QTIME	0.2288	(0.1961)	0.0772
I^{SL} (state law)	-0.1256	(0.2197)	-0.0424
Sample Size		959	
ZM Statistic		0.583	
Likelihood Ratio Index		0.365	
-2[L(0)-L(b)]		483.456***	

Note: *, **, and *** indicate significance at the .10, .05, and .01 level, respectively. The ZM Statistic and Likelihood Ratio Index measure goodness of fit. The last row jointly tests whether all coefficients are equal to zero.

TABLE 4: Tobit Estimation of the Optimal User Fee

Dependent Variable: P (price per bag of garbage)

VARIABLE	COEFFICIENT	(STANDARD ERROR)
CONSTANT	-7.7292	(30.44)
INCOME	-0.1727***	(0.0434)
RETIRE	0.0226	(0.0266)
FAM SIZE	0.8369	(0.7837)
EDUCATION	0.0304***	(0.0117)
OWNER	0.0036	(0.0103)
DENSITY	-0.0828	(0.1463)
DENSITY SQUARED	-0.0031	(0.0166)
I^{YW} (yardwaste ban)	1.6939***	(0.4986)
I^{DR} (deposit refund)	0.1054	(0.4117)
P_T (tipping fee)	0.0234***	(0.0077)
I^{SH} (state helps)	-0.1504	(0.5225)
I^{SB} (state buys)	3.6519	(30.36)
Q (quota)	-5.5848***	(1.623)
QTIME	0.3334***	(0.1015)
Q×QTIME	0.1268	(0.4084)
I^{SL} (state law on recycling)	-0.7403	(0.5757)
I^{PT} (property tax limit)	-0.5854	(0.5732)
I^{MUN} (municipal collection)	0.3945*	(0.2173)
Inverse Mills Ratio	0.9270***	(0.1063)
Sample Size	399	

Note: *, **, and *** indicate significance at the .10, .05, and .01 level, respectively.

TABLE 5a: Determinants of the Annual Weight of Garbage
Dependent Variable: G (pounds of garbage per person per year)

VARIABLE	OLS		ENDOGENOUS CHOICE	
	Coefficient	Standard Error	Coefficient	Standard Error
CONSTANT	762.40***	197.5	745.46***	198.9
I^R (curbside recycling)	-33.529	32.57	34.428	131.6
$P2 \times I^R$	-247.60***	55.09	-373.51***	111.5
INCOME	22.229***	4.907	20.874***	5.070
RETIRE	-0.1078	3.333	-0.2568	3.357
FAM SIZE	3.1166	72.87	13.438	75.54
EDUCATION	-7.5509***	1.764	-7.6700***	1.898
OWNER	1.6485	1.558	1.7140	1.588
DENSITY	5.4175	14.14	3.8101	15.15
DENSITY SQUARED	0.0543	1.049	0.0460	1.062
I^{YW} (yardwaste ban)	-46.491	33.89	-39.532	40.20
I^{DR} (deposit refund)	-56.855	38.50	-55.148	38.73
I^{MAN} (mandatory recycling)	-43.633	31.54	-66.612	43.35
Sample Size	756		756	
R^2	0.099		0.090	

Note: *, **, and *** indicate significance at the .10, .05, and .01 level, respectively.

TABLE 5b: Estimated Price Responses Using Other Price Definitions

	OLS		ENDOGENOUS CHOICE	
Specification	Coefficient (S.E.)	Elasticity	Coefficient (S.E.)	Elasticity
Include $I^{SUB} = 1$: P1	-43.316 (27.85)	-0.0034	-77.407 (58.80)	-0.0061
Include $I^{SUB} = 1$: P2	-80.569** (34.92)	-0.0049	-116.92** (47.84)	-0.0072
Use only $I^{SUB} = 1$: P1	5.6313 (31.75)	0.00023	-30.122 (54.91)	-0.0012
Use only $I^{SUB} = 1$: P2	9.3351 (43.37)	0.00024	0.8597 (70.53)	0.000022

This panel omits the estimated coefficients on all variables other than the price variable.

TABLE 6a: Determinants of the Annual Weight of Recycling
Dependent Variable: R (pounds of recycling per person per year)

VARIABLE	OLS		ENDOGENOUS CHOICE	
	Coefficient	Standard Error	Coefficient	Standard Error
CONSTANT	-147.13**	45.09	-123.73**	49.04
I^R (curbside recycling)	113.69***	7.894	192.91***	27.22
$P2 \times I^R$	33.381**	12.64	16.891	25.78
INCOME	-0.6258	1.146	-1.0214	1.259
RETIRE	1.5216**	0.7542	1.1238	0.8239
FAM SIZE	26.481*	16.46	26.440	17.75
EDUCATION	0.8197**	0.4120	0.3096	0.4692
OWNER	0.8065**	0.3536	0.7087*	0.3827
DENSITY	-2.1634	3.263	-6.0632*	3.710
DENSITY SQUARED	0.1546	0.2341	0.2687	0.2543
I^{YW} (yardwaste ban)	14.087*	7.956	-5.1316	10.17
I^{DR} (deposit refund)	-11.821	9.202	-11.582	9.919
I^{MAN} (mandadory recycling)	2.6484	7.253	-10.308	9.371
Sample Size	658		658	
R^2	0.402		0.306	

Note: *, **, and *** indicate significance at the .10, .05, and .01 level, respectively.

TABLE 6b: Estimated Price Responses Using Other Price Definitions

Specification	OLS		ENDOGENOUS CHOICE	
	Coefficient (S.E.)	Elasticity	Coefficient (S.E.)	Elasticity
Use $I^{SUB} = 1$: P1	20.243**	0.0133	12.234	0.00802
	(9.332)		(23.44)	
Use $I^{SUB} = 1$: P2	26.791**	0.0152	-2.3042	-0.00130
	(10.31)		(24.44)	
Use only $I^{SUB} = 1$: P1	2.5586	0.00044	7.2583	0.00124
	(14.20)		(46.85)	
Use only $I^{SUB} = 1$: P2	9.5832	0.00098	-114.83	-0.0118
	(17.08)		(85.88)	

This panel omits the estimated coefficients on all variables other than the price variable.

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