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HOUSEHOLD DEMAND FOR GARBAGE AND RECYCLING COLLECTION WITH THE START OF A PRICE PER BAG

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ABSTRACT

This paper estimates household reaction to the implementation of unit-pricing for the collection of residential garbage. We gather original data on weight and volume of weekly garbage and recycling of 75 households in Charlottesville, Virginia, both before and after the start of a program that requires an eighty-cent sticker on each bag of garbage. This data set is the first of its kind. We estimate household demands for the collection of garbage and recyclable material, the effect on density of household garbage, and the amount of illegal dumping by households. We also estimate the probability that a household chooses each method available to reduce its garbage.

In response to the implementation of this unit-pricing program, we find that households (1) reduced the weight of their garbage by 14%, (2) reduced the volume of garbage by 37% and (3) increased the weight of their recyclable materials by 16%. We estimate that additional illegal -- or at least suspicious -- disposal accounts for 0.42 pounds per person per week, or 28% of the reduction in garbage observed at the curb.

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1. Introduction

Rising land prices and new EPA regulations are largely responsible for the tripling over a six-year period of the average tipping fee paid to a landfill for accepting each ton of garbage from collectors (Steuteville and Goldstein, 1993). Several communities and private firms have responded to these economic pressures by implementing volume-based pricing programs that require households to pay for each bag or can of garbage presented for collection. These towns employ unit-pricing not only to collect additional revenue, but to reduce their direct costs and external costs from using landfills and incinerators. Households might recycle more, compost more, and demand less packaging at stores. Unfortunately, they might also burn garbage or dump it along deserted roads. The attractiveness of unit-pricing depends crucially on the extent of each such method of garbage reduction.

In addition, the price-per-bag might induce households to compact their garbage into fewer bags. This practice was noticed when Seattle started one of the first unit-pricing programs, so it is known as the "Seattle Stomp." It is not helpful, since collectors compact the garbage anyway.

This paper employs individual household data to estimate the effect of price and demographic variables on the weight of garbage, the number of containers, the weight per can, and the amount of recycling. We also estimate the probability that a household will choose each method of garbage reduction listed above. The data are based on a natural experiment that provides a unique opportunity to study human behavior in response to a change in price. In Virginia, on July 1, 1992, the City of Charlottesville implemented a program to charge $.80 per 32-gallon bag of residential garbage collected curbside.

Before and after the implementation of this program, we counted and weighed the bags or cans of garbage and recyclable materials of 75 households. In response to this new price, the average person living in these households:

- reduced the weight of garbage from 10.89 pounds per week to 9.37 pounds per week (a 14.0 % decrease),
- reduced the volume of garbage from 0.73 containers per week to 0.46 containers per week (a 37.0 % decrease),
- increased the density of garbage from 14.79 pounds per container to 19.48 pounds per container (a 31.7% increase), and,
- increased the weight of recyclable material presented for collection from 3.69 pounds per week to 4.27 pounds per week (a 15.7% increase).

Also, we estimate that increased illegal disposal accounts for 0.42 pounds per week per person in Charlottesville, or 28% of the total reduction in garbage.

Other studies have estimated household demand for the collection of garbage, often using data for entire communities. Cross-sections of cities are employed by McFarland (1972), Wertz (1976), Jenkins (1991), and Repetto et al (1992). Aggregate time series data collected from one community are used by Efaw and Lanen (1979) and Skumatz and Breckinridge (1990).[1] Household surveys have appeared more recently. Hong, Adams, and Love (1993) use a survey of 2298 households around Portland, Oregon, where 25 collection firms operate in 19 municipalities using a variety of block-pricing schedules (such as $12/month for one can per week and $24/month for two cans). They estimate the demand

[1]Also, Stevens (1977) and Kemper and Quigley (1976) use a cross-section of several cities to examine the effects on total demand from a change in the level of service for garbage collection. With a cross-section of neighborhoods, Richardson and Havlicek (1978) and Rathje and Thompson (1981) consider the effect that the neighborhood's average income has on the demand for the collection of specific categories of garbage material. Another body of literature used telephone interviews with individual households to estimate recycling attitudes and behavior (see Oskamp et al., 1991, for example).

for cans contracted, correcting for the endogeneity of price, and they estimate the frequency that each household will recycle. They find small response to changes in price or income. Finally, Reschovsky and Stone (1994) survey 1422 households around Ithaca, NY, who face a variety of unit-pricing and recycling rules. They estimate the probability of recycling each type of material, as a function of these rules and of demographic characteristics, and they find that curbside pickup alone would increase recycling more than unit-pricing alone.

We build upon these existing studies in several ways. First, by using individual households instead of a cross-section of cities, we avoid a number of problems. Tonnage data from entire communities might mix residential garbage with commercial and industrial garbage,[2] and may include amounts from outside the jurisdiction. Second, by collecting our own data, we avoid potential biases in surveys with self-reported amounts of garbage and recycling. Third, we measure the garbage itself, rather than the weekly number of cans contracted (some of which may be partially empty). Fourth, by taking direct measures of both weight and volume, we can measure the Seattle Stomp, that is, the change in weight per can. Fifth, our data include the weight of recycling rather than just the frequency of recycling. Sixth, in our natural experiment, the change in price is truly exogenous to households. We thus avoid the problem in cross-sections of cities, or of households in different municipalities, that the price per bag may be jointly determined with garbage quantities. Finally, our cross-section of individual households contains more variation in demographic characteristics than does a cross-section of communities, since the latter can only provide community-wide means. More variation in the independent demographic variables can improve the estimation of household demand.

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[2]Jenkins (1991) and Cargo (1978) employ such data by estimating separate equations for commercial waste and mixed waste.

Section 2 will describe the steps taken to gather the data from individual households in Charlottesville. In section 3, we estimate demand for garbage collection and curbside recycling as functions of price, income, and demographic characteristics. Garbage weight is inelastic to price or income, but garbage volume does respond to this price per unit volume. Section 4 estimates whether the observed price-responsiveness itself depends on demographic characteristics. We employ a probit model in section 5 to estimate the probability that a household chooses each method available to reduce its garbage. These choices are identified through responses to a questionnaire. Then section 6 estimates the amount of illegal dumping conducted by households in Charlottesville following the implementation of the program. This estimate is based on observed garbage levels from individual households, and indirectly on responses to the questionnaire. Finally, in section 7, we consider policy issues. We discuss the pros and cons of collecting revenue from per-unit pricing, we calculate the effect of introducing a minimum of one bag per week, and we conduct a simple cost-benefit comparison. Welfare gains from unit-pricing only exceed costs if those costs are less than 10% of unit-pricing revenue.

2. The Data

Charlottesville, Virginia, is a university town located in the foothills of the Blue Ridge mountains. Its population is 40,341. Residential garbage collection has traditionally been provided by the city and has been financed by property taxes. Prior to November of 1991, the only method of recycling was to haul recyclable materials to one of two drop-off centers located within the city. These drop-off centers accepted newspaper, three colors of glass, and aluminum cans. Beginning in November of 1991, Charlottesville implemented a voluntary curbside recycling program for all of its residents. The city provided each household with a free plastic recycling container in which to place any newspaper, tin, glass, aluminum, and certain plastics. These containers were collected each week on the same day as regular garbage. The city also expanded the list of materials it would accept at the drop-off locations by including several other grades of paper, cardboard, and other plastics.

In December 1991, city council decided to implement a unit-pricing program to commence on July 1, 1992. This program would require residents to place a sticker, costing $.80, on each unit of garbage for collection. Each sticker could be attached to any household container (bag or can) with a volume of approximately 32 gallons. The city would not collect garbage without a sticker on it. Households could also purchase a $.40 sticker for a 16 gallon bag. Recyclable materials would continue to be collected free of charge, and participation remained voluntary.

These events provide a natural experiment to study household response to price. Following the decision of the city council in December 1991, we began to assemble our sample of households. We first selected a sample of city streets spread throughout the City of Charlottesville. This sample of streets represents all major neighborhoods and demographic groups.[3] The city directory was then used to select a random sample of households located on the selected set of streets.[4] A total of 400 households received a

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[3]We excluded streets located near the University of Virginia, to avoid sampling university students who frequently leave town or change living locations. We also avoided apartments and town-houses which often use dumpsters. With these exclusions, we then selected streets that appeared to be distributed uniformly across a map of Charlottesville. Density varies, so the sample is not random.

[4]This two-part selection process is designed to cluster households more than would a one-step selection of households from the entirety of Charlottesville. This clustering was necessary to reduce the costs and complications involved with weighing household garbage each morning. Even though many households in the sample were located on the same street, they were often located well apart from each other. Usually only one or two studied households were located on any block.

letter requesting their participation in our study. The letter indicated that their garbage and recyclable materials would be weighed early in the morning over two four-week periods. The letter also indicated that participating households would be expected to complete a questionnaire and were assured that their answers would be held confidential.[5]

A total of 97 households agreed to participate, while another 68 households responded that they would not participate. Several of the "no" responses included a note indicating that the household would be moving during the period of the study. Of the 97 positive responses, our final sample includes 75 with complete data.[6]

Each household's garbage and recyclable materials were weighed each week over four weeks in late May and early June before the implementation of the unit-pricing program, and again over four weeks in September following its implementation. Garbage was not weighed during the week following Memorial day, to avoid the extra garbage that can be generated over the three-day holiday weekend. We skipped July and August in order to avoid vacation weeks, and to provide a short adjustment period. Care was taken throughout the term of the study to avoid weighing yardwaste.[7] This involved some inspection of household garbage, which was not a difficult task.

We also counted the number of cans of garbage presented by each household each

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[5]The letter informed households that the Charlottesville City Council had been made aware of this study, and had agreed to all terms. Households were also informed that they would receive $5.00 for their time spent completing the questionnaire. Each letter included a stamped postcard which the household could return indicating whether it would be willing to participate in the study.

[6]Several households were removed from the sample because the original occupants had moved during the period of the study or because the building contained more than one family unit. Some other households refused to complete the questionnaire.

[7]Residents are not supposed to mix yardwaste with regular garbage. Instead, Charlottesville conducts special collection of yardwaste several times each year. Some households still included yardwaste with regular garbage, however, and we took care to exclude it.

week. Measuring volume presents certain difficulties, as households used different-sized plastic bags or boxes as containers. Counting a small plastic kitchen bag or box as one can would not be appropriate. Therefore, we approximated a household's garbage by the number of 32-gallon containers it would have filled. Following the implementation of the pricing program, we measured volume by counting the number of stickers. Problems still arise with this procedure, as households were allowed to attach stickers to any container of about 32 gallons in size. Several households used even larger containers. By counting stickers, we determined only the volume for which they were charged rather than the precise volume of garbage per se.

We recorded each week separately. However, household garbage and recycling amounts can vary substantially from one week to the next. In fact, to save on disposal costs, several households presented garbage only every other week. Therefore, we average the four weeks for each household before implementation, and we calculated a separate average for each household over the four weeks following implementation. We are left with two averaged observations for each household. The first observation represents an average week's worth of garbage and recycling amounts at a price of zero, and the second observation provides the same at a price of $.80.

With only a 25% positive response rate to our initial mailing, our sample could suffer from the presence of a self-selection bias. For example, it could be suggested that only educated, environmentally-aware households would agree to have their garbage weighed each week. These households may have already been recycling as much as they could before the implementation of the unit-pricing program, leaving little opportunity for additional recycling. Conclusions based on such a sample might under-estimate the increase in recycling of an average household in Charlottesville.

The data do not allow us to conduct a formal test for selection bias. We can make some general observations, however, by comparing the means of garbage and recycling weights of households in the sample with those for all households in Charlottesville. Mean demographic characteristics can be compared as well.

The first column of Table 1 summarizes data gathered from our sample of 75 households, and the second column summarizes data from the entire City of Charlottesville. Garbage and recycling information for the city was provided by the Rivanna Solid Waste Authority (RSWA). For comparability with earlier studies, both columns provide amounts per capita. The average individual in our sample presented 10.89 pounds of garbage per week before unit-pricing began. For all of Charlottesville, RSWA data includes both residential and commercial waste. Total garbage divided by the total number of individuals amounts to 37.30 pounds of garbage per person over an average week before unit-pricing. Following implementation of the program, the average individual in our sample decreased the weight of garbage by 1.52 pounds per week, whereas the average person in Charlottesville reduced the weight of garbage by 2.59 pounds per week.[8] This change for the city could include changes in commercial waste. Commercial establishments that do not use dumpsters are subject to the volume-based pricing program.

The data on recycling indicate that the average person in our sample recycled 3.69 pounds per week before the implementation of the pricing program, 0.95 pounds more than the average person in Charlottesville. The average household in our sample recycled more than the average household in Charlottesville following the implementation of the pricing

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[8]This last figure is adjusted for seasonal variation. Over a 5-year period prior to unit-pricing, 0.88 more pounds of garbage per person per week were collected in June than in September. The student population and household yardwaste could account for much of the city's seasonal variation. Since our sample excludes both of these sources, we assume that no seasonal adjustment is appropriate for our sample.

program as well. Surprisingly, it appears that the average person in Charlottesville reduced the weight of recyclable material from 2.74 pounds per week to 2.46 pounds per week following the implementation of unit-pricing. An inspection of the RSWA data reveals that this reduction is due to a decrease in the recycling of old newspaper. RSWA officials can offer no explanation for this decrease in newspaper recycling.[9] Perhaps households, over time, found the cost of storing newspapers to be higher than first expected.

Demographic information for the city is taken from the U.S. Census. However, the U.S. Census data include both students in university dormitories and persons in multi-family dwellings, which together comprise 31.1% of all housing in Charlottesville. Therefore, our exclusion of neighborhoods with students and apartments likely explains a significant portion of the differences between our sample and the entire city for demographic variables. Our households live in single-family dwellings, so they have higher values for income, homeownership, age, employment, and education.

Measurement error can arise from several sources in our data. First, rain can increase the weight of garbage and recyclable material. It rained heavily on two mornings during the period of the study, so we did not use those observations.[10] Second, households may have learned that the recycling truck does not collect in certain parts of the city until well into the afternoon. If so, they might wait until the afternoon to present their recyclable

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[9]This result is maintained even with correction for seasonal variation. Households in the City recycled an average of 181.55 tons from November 1991 to June 1992, before the implementation of unit-pricing, and recycled an average of 173.89 tons over these same months after implementation. This overall reduction is still attributable to a reduction in the recycling of old newspaper.

[10]We did note whether each household presented any garbage for collection. If so, we designated the following week's garbage as one week's worth. If not, the following week's garbage was assumed to represent two week's worth (or the number of weeks since the last presentation). The same algorithm was followed for recyclable material.

materials for collection. Unfortunately, we could only measure amounts put out by 7:00 AM. On one occasion we returned to households that did not recycle in the morning, and no additional recycling was observed. Finally, as mentioned above, the volume of garbage containers used by households could differ. Instead of measuring the volume of each container, we measured volume the same way the city does -- by counting containers.

Following the measurement period, each household was sent a questionnaire with a self-addressed stamped envelope. Completed questionnaires reported each household's demographic statistics such as household size, ages, race, income, marital status, education, and other information that could be expected to influence the generation of garbage or recyclable materials. Households were also given the opportunity to express their opinions on several subjects relating to recycling and the unit-pricing program. Some of their responses are reported in Table 2.

Support for the sticker program runs fairly high, with 77.7% of households favoring it over an increase in property taxes, and 72.8% favoring it over a mandatory recycling law.[11] However, households found it more inconvenient to purchase and place stickers on their garbage than to recycle. Households had been recycling for more than one year at the time of completing the questionnaire, and may have become accustomed to it, whereas the sticker program was relatively new to them. See Oskamp et al. (1991) or Seattle Solid Waste Utility (1991) for more elaborate survey studies.

3. A Model of Household Demand For Garbage Removal

We assume that individuals maximize a utility function, defined over consumption and

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[11]Among only owner-occupied households, 79% prefer unit-pricing to an increase in property taxes.

several methods of garbage removal, subject to a budget constraint. This maximization process provides a demand for each method of garbage disposal that is a function of the prices, of income, and of taste parameters which themselves depend on demographic characteristics.[12] We observe the quantity of garbage collection and recycling demanded by each household, and these demands are estimated in this section. The use of other forms of garbage removal can only be proxied by household responses to a questionnaire, and these are estimated in a later section.

In previous studies using cross-sections of cities, garbage per capita is a function of price and the city's mean level of income per capita, percent married, percent homeowners, percent in each age group, and other demographic variables. To be comparable, we divide all quantities by the number of persons in each household. These variables are defined in Table 3.

Four separate equations were independently estimated: for per-capita weight of garbage, volume of garbage, density of garbage, and weight of recycling.[13] In all these estimations, we use panel data gathered from N=75 households over T=2 regimes. These two regimes are the periods of time before and after the implementation of the unit-pricing program. Let Y_{it} denote the per-capita weight of garbage (or volume of garbage, or density of garbage, or weight of recyclable materials, depending on the equation) presented for collection over an average week by household i during regime t. Initially, we assume that

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[12]First order conditions from this type of maximization are shown in Fullerton and Kinnaman (1993), where we proceed to solve for optimal tax and subsidy rates on garbage and recycling, in the presence of externalities. This simple formulation ignores differences in the level of service (curbside vs backdoor collection), and time spent on these chores (Wertz, 1976).

[13]Density is just weight divided by volume, or pounds per can. The four equations could be estimated together, using seemingly unrelated regressions, but results are unaffected because all four equations use the same right-hand variables.

Y_{it} can be represented as a linear function of the price of garbage collection during regime t (P_t), exogenous income and demographic variables that are constant across regimes for household i (the 1xK vector X_i), and a household-specific, time-invariant unobserved factor (μ_i).[14] We assume that μ_i is distributed independent of X_i, the demographic variables. The demand for the collection of household garbage can then be represented by

(1) $$Y_{it} = \alpha + P_t\beta + X_i\gamma + \mu_i + \epsilon_{it}$$

where the unknown parameters are α, β, and the (Kx1) vector γ.

Because of the appearance of μ_i, the error term for a particular household will be correlated across regimes. Therefore we use the Generalized Least Squares (GLS) estimator to provide efficient estimates of the unknown parameters.

3.1 Garbage Weight

First, we estimate the effect of the price of garbage and demographic characteristics on the per-capita weight of garbage presented for collection each week. All of our variables are defined in Table 3, and GLS estimates of the unknown parameters appear in Table 4. In the first column, for weight per person, the coefficient on price is negative and significantly different from zero at the 95 percent confidence level. Using this coefficient, the price elasticity of demand for the collection of garbage, measured in pounds, at mean levels of price and weight is equal to -0.075. This estimate is a bit closer to zero than in previous

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[14] We need μ_i because the Breusch and Pagan Lagrange multiplier test rejected the null hypothesis that $\sigma^2_\mu = 0$ for all equations, at the .99 confidence level. We do not want to estimate μ_i as fixed-effects, however, because then we could not measure coefficients for demographic variables. Since X_i do not change, first differences would leave ΔY as a function only of ΔP. Fortunately, we can treat μ_i as random. In a Hausman test, we cannot reject the null hypothesis that μ_i is independent of X_i.

studies.[15]

Owner-occupied households presented 4.41 more pounds per person than renters did, controlling for other differences. Homeowners usually conduct more home repairs and maintenance than renters do, activities which generate more waste. Households with individuals who work full-time presented 5.32 fewer pounds of garbage each week, perhaps because they were away from home more of the time. Households with retired persons presented less garbage weight on average, than did others.

We include household size in order to capture economies of scale, that is, the reduction in pounds-per-person from having a larger household. We use the natural log of household size, however, to allow the change in the pounds-per-person to vary across household sizes. In this case, an increase in household size from 2 to 3 is found to reduce weight of garbage by 2.44 pounds per person, while an increase in household size from 5 to 6 is found to reduce garbage weight by only 0.97 pounds per person.

The coefficient on the natural log of income is slightly positive, but the standard error is large. The income elasticity generated from this coefficient is 0.049, at mean levels of income and garbage weight. Coincidentally, this estimate exactly matches that of Hong, Adams, and Love (1993) using individual data. It is smaller than has been found using other kinds of data.[16]

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[15]We measure an arc-elasticity, since price is only zero or eighty-cents. No other study employs a cross-section of households around the start of unit-pricing. Using aggregate data, others have estimated the price elasticity to be -0.12 (Jenkins, 1991), -0.15 (Wertz, 1976), -0.26 and -0.22 (Morris and Byrd, 1990, in two communities), and -0.14 (Skumatz and Breckinridge, 1990).

[16]Although ours is the only estimate based on weight of garbage in a cross-section of households, other kinds of data have been used to estimate this income elasticity. Richardson and Havlicek (1978) estimate 0.242, Wertz (1976) estimates 0.279 and 0.242 in two different samples, Petrovic and Jaffee (1978) estimate 0.2, and Jenkins (1991) estimates 0.41.

The coefficient on race is perhaps the most surprising. White households presented 5.93 fewer pounds per person for collection each week than non-white households.[17] As indicated in Table 1, however, only four of our 75 households were non-white. In addition, all of these non-white households live within the same neighborhood. As a consequence, this variable could represent just a neighborhood effect.

3.2 Garbage Volume

Second, we estimate how the per-capita volume of garbage is affected by the same set of independent variables. The GLS estimates of the coefficients of this equation appear in the second column of Table 4.

The sign of each coefficient in the volume equation is identical to that in the weight equation for every variable except income. In both equations, however, the coefficient on income is small and insignificant. We might have expected the volume demanded to increase with income, but the volume of garbage is not well measured by the number of cans. High-income households often used larger, sturdier containers with wheels. They are also more apt to use garbage compactors. Low-income households typically have containers with no wheels, so they may carry two light cans to the curb instead of one heavy can. In the long run, with unit-pricing, we could expect everyone to purchase larger containers with wheels in order to decrease disposal costs.

The price elasticity of demand, measured in volume, at mean levels of price and volume is -0.227. By comparing this price elasticity to the one for weight given in the previous section, we see that individuals responded to the volume-based pricing program by reducing the volume of garbage in greater proportions than they reduced the weight of

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[17] Richardson and Havlicek (1978) consider the effects of race on garbage generation and find no significant relationship. Richardson and Havlicek (1974) find a positive relationship between percent-black and garbage-weight.

garbage. This result is not surprising since, after all, the price is charged for the number of bags of garbage rather than the weight. Unfortunately, however, landfill costs depend on weight (or really on compacted volume, which is best proxied by weight).

3.3 Garbage Density

The third column of Table 4 shows how the price per can of garbage and various demographic characteristics affect the density of garbage as defined by weight per can. The coefficient on price is positive, large, and significantly different from zero at the 95% confidence level. Controlling for price and other variables, households with infants presented garbage that weighed 11.55 more pounds per can than did others. (As those who are parents know, wet disposable diapers are rolled into a tight, dense ball, held with tape, before disposal.) As the education level of the household increases, the density of its garbage decreases. Lastly, larger families present denser garbage.

3.4 Weight of Recyclable Materials

The fourth equation considers the demand for the collection of recyclable materials, measured by weight, with estimates appearing in the fourth column of Table 4. Households respond to a price for garbage by increasing their recycling. The implied cross-price elasticity is 0.074 at mean levels.[18]

Homeowners and households subscribing to additional daily newspapers put greater amounts of recyclable material into collection containers. The coefficient on NEWS is significantly different from zero in the recycling equation, whereas it was not significant in any garbage equation. Less collection of recyclable materials was demanded by large households and those with retired persons.

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[18]Using only two observations from each community, U.S. EPA (1990) estimates this cross-price elasticity for Perkasie, PA (0.49), Ilion, NY (0.48), and Seattle (0.06 in 1985-6 and 0.10 in 1986-87).

4. Varying Parameters in the Demand For Garbage and Recycling

In this section, we consider interaction terms which allow the coefficient on price to vary over demographic characteristics. This model will allow us to estimate how these demographic characteristics affect the change in weight or volume of garbage that results from the start of a price per bag. These estimates would be helpful to a local government that is considering the implementation of such a program in its community. Specifically, we modify equation (1) to add interaction terms with P_t times every X_i, giving us:

$$(2) \qquad Y_{it} = \alpha + P_t\beta + X_i\gamma + P_tX_i\delta + \mu_i + \epsilon_{it}$$

In this case we can take first differences, since the interaction terms remain:

$$(3) \qquad \Delta Y_i = \Delta P\beta + \Delta PX_i\delta + \Delta\epsilon_i$$

where $\Delta\epsilon_i$ is an error with mean zero, distributed independently of X_i. For this fixed-effects model, the OLS estimator is efficient. In other words, since ΔP is always 0.8, we just regress ΔY on a constant, income, and demographic variables.

Again four separate equations were estimated, for garbage in pounds, garbage in volume, the density of garbage, and recyclable materials in pounds. The OLS estimates are reported in Table 5.

The first column of Table 5 reports the estimated coefficients for the garbage weight equation. This negative price effect (the constant term) is dampened for households that subscribe to more daily newspapers, for those with infants, and for households with married couples. Perhaps households with infants, whose garbage contains a large proportion of disposable diapers, are not willing to switch from disposable to cloth diapers. Interestingly, the reduction in garbage in response to the unit-fee is greater for higher income households than for lower income households.

The second column of Table 5 presents estimated coefficients of the demand for collection of garbage volume. These coefficients are similar in sign to the coefficients estimated in the garbage weight equation.

Who stomped on their garbage in response to the implementation of the volume-based pricing program? In column 3 of Table 5, we estimate how demographic characteristics affect the change in garbage density. None of the coefficients are significantly different from zero, but the signs for RETIRE and INCOME are negative. Retirees probably find stomping difficult, especially when it would require hauling the dense garbage to the curb. Individuals with high incomes apparently find the economic incentive less attractive, given the opportunity cost of their time. Households with married couples, those with infants, and large households appear to react by increasing the density of their garbage.

One possible solution to the stomping problem would be to implement a weight-based instead of a volume-based pricing system. Households would be billed according to the weight of their garbage. This system would require scales on collection trucks and a more elaborate billing system.[19]

The fourth column of Table 5 presents the estimated coefficients for the recycling equation. Households with infants and those subscribing to more newspapers responded to the implementation of the unit-pricing program by recycling more. White households

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[19]The city of Seattle has been considering the implementation of a weight-based system in their city later in this decade. A pilot project (Seattle Solid Waste Utility, 1991) revealed that operation and administrative costs of such a program would not be prohibitive. A problem, however, is that scales were not sensitive enough to meet federal standards for weights and measures.

responded by recycling less than non-white households.

5. Unobserved Methods of Garbage Removal

As households are made to face a positive marginal cost for garbage collection, they have several options available to reduce the amount of garbage they present for collection. Each household was asked to reveal which methods it had used. Each household could indicate that it (1) did not attempt to reduce its garbage, or that it had (2) recycled more, (3) composted more, (4) demanded less packaging at stores, or (5) used "other" means to reduce its garbage. We wanted to know which households disposed of garbage in some illegal fashion, but we did not ask such a question directly since households would be reluctant to admit it. Since the first four options would seem to cover all possible legal alternatives, however, we think the "other" option can only mean illegal disposal such as burning, littering, or using commercial dumpsters.[20]

We have gathered data on the weight of each household's garbage and recyclable material, so we can determine to some extent the accuracy of these responses. Table 6 shows the change in the weight of garbage, the change in the volume of garbage, and the change in the weight of recyclable material, for households choosing each method of garbage reduction in the questionnaire.

For households indicating they "did not reduce" their garbage, the actual weight of garbage fell by only 0.05 pounds per person per week. This amount is substantially lower than the 1.53 pound average reduction per person observed overall. This subset also reduced their volume of garbage by 0.25 containers per person per week, so they may have done

[20]The questionnaire did not include an option for putting more food through an in-sink garbage disposal, but the <u>change</u> in this behavior must be small.

some stomping.

For households indicating they "recycled more," actual recycling increased by 0.70 pounds per person per week. This amount is somewhat greater than the increase of 0.58 pounds observed from all households, but it exceeds more substantially the increase of 0.35 pounds per person per week observed from the households that did not indicate they "recycled more." In addition, households may indicate more than one of the four methods of reducing its garbage. For households indicating they "composted more" the weight of garbage fell by 2.25 pounds per person per week. Little of this amount reappeared as additional recycling, so that garbage does seem to have been removed from the waste stream.

For households that indicated they "demanded less packaging at stores," the weight of garbage and of recycling both increased, by 1.26 pounds and by 0.66 pounds per person per week, respectively. That they were unable to reduce garbage is not entirely surprising. We doubt the ability of households to reduce substantially their garbage through this method over the short time period of our study. We offer no explanation for why garbage and recycling increased, except measurement error.

Finally, for households indicating they used "other" means, actual garbage fell by 5.10 pounds per person per week. This figure is more than twice the amount associated with any other answer to the question about which methods were used to reduce household garbage. The weight of recyclable material decreased for these households as well. In fact, several of these households presented no garbage at all following the implementation of unit-pricing.[21] We return to the issue of illegal dumping in the next section.

We now turn to an econometric model of household choice for each of four methods

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[21]Several households presented recyclable material and no garbage for the entire four-week observation period following implementation. We deleted households that were on vacation, as revealed in the questionnaire.

available to reduce garbage in response to the implementation of unit-pricing. For this model, we have only one observation per household. Let Y_i^* be the value to household i of choosing a method to reduce garbage. Furthermore, assume that

(4) $$Y_i^* = X_i\gamma + \mu_i$$

where X_i represent demographic variables. We do not observe Y_i^*, but we do observe

(5) $$Y_i = 1 \text{ if } Y_i^* > 0$$
$$= 0 \text{ otherwise}$$

In other words, we observe the choice made by each household. We assume μ_i is distributed Normal (o, σ^2), so we employ the basic probit model. Maximum likelihood estimates of γ are reported in Table 7.

The first column of Table 7 reports the estimated coefficients of variables expected to influence the probability of a household choosing to "recycle more" following the implementation of unit-pricing. Although the small sample precludes high t-statistics, recycling seems more likely for households subscribing to more newspapers, owner-occupied households, and better educated households. Households subscribing to more newspapers may have selected this choice because newsprint is relatively easy for a household to recycle. Households with infants and with high income levels were less likely to choose recycling as a method of reducing garbage. The opportunity cost of recycling may be high for households with higher incomes.

The second column of Table 7 reports the estimated coefficients of variables expected to influence the probability of a household choosing to compost. Owner-occupied households and better educated households are more likely to compost. Owner-occupied households could have more yard space and could perform more yardwork themselves, circumstances that are conducive to composting.

The fourth column of Table 7 provides estimates for the "other" equation. Other methods are less likely to be chosen by households with an in-sink garbage disposal and by those with children. Several "other" methods of garbage reduction could have been chosen by the household, including illegal methods discussed in the next section.

6. Illegal Dumping Behavior

The possibility of increases in illegal forms of garbage disposal have worried policymakers who have considered unit-pricing in their communities. We offer a method of estimating the amount of illegal dumping that took place in Charlottesville during the period of our experiment.[22] We use two criteria. We suspect illegal dumping only if (a) the household indicated that "other" means were used to reduce garbage, and (b) the amount of garbage presented for collection fell to zero for the entire four-week measurement period following implementation of unit-pricing. If the number of bags presented for collection decreased from 3 in May to 2 in September, then we are willing to believe that the household found a legal form of "other" disposal such as the use of an in-sink garbage disposal. However, if the number of bags fell from 3 to 0, then we suspect more strongly that illegal dumping has occurred. If a person goes to the trouble of transporting trash to a commercial

[22]Blume (1991) attempts to explain illegal dumping by conducting interviews with officials from 14 communities with unit-pricing programs. Of these, 4 reported significant problems, 4 reported minor problems, and 6 reported no significant problems. Blume was unable to explain what causes these differences across communities, even having considered the price of garbage collection.

dumpster, he or she will probably take the entire week's store of trash rather than one bag.

Based on the above criteria, we find that 5.33% of households disposed of garbage in some illegal fashion.[23] To estimate the amount, we take their garbage before unit-pricing, minus the increase in their recycling, minus an estimate of additional composting.[24] We find that these households dumped an average of 13.38 pounds per person per week. Given the sample size, the implication is that unit-pricing induced an additional 0.42 pounds per person per week of illegal dumping in Charlottesville. Furthermore, this estimate constitutes 28% of the total reduction in garbage at the curb. For comparison, additional recycling constitutes 38% of the total reduction in garbage. Thus households may have increased dumping by almost as much as they increased recycling! The remaining 34% of the total reduction in garbage could be explained by additional composting, less packaging demanded at stores, additional recycling at drop-off locations, or even additional illegal dumping.

The social costs can vary over methods of illegal dumping. For example, if a person takes the weekly garbage to a commercial dumpster where he is employed, and has permission from his employer, the social costs could be quite low. However, if this individual throws his garbage along a rural route or burns it in his back yard, the social cost could be quite large. Unfortunately, we have no means to identify what kind of "other" methods were used by households in our study.

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[23]These results should be viewed with caution. First, the sample size is small. Only 4 households in our sample met our dual criteria for dumping. Second, our sample includes a disproportionate number of high income, well educated, single family households. Third, households who dump could have selected themselves out of our sample either by refusing to participate in the study or by refusing to return the questionnaire.

[24]Some households indicated more composting as well as "other" methods. We regress the change in garbage on the same demographic variables and a dummy variable for composting. The coefficient on this dummy gives us an estimate of the per capita change in garbage attributable to composting.

Recent stories in newspapers tell of increased dumping.[25] The recycling coordinator of the University of Virginia is aware of "many, many" private reports of individuals dumping in UVA dumpsters. The Albemarle school system has also observed quantities of unidentified garbage in their dumpsters. One person who was warned to stop dumping his garbage in a commercial dumpster was subsequently convicted for continuing the practice. Major department stores around Charlottesville have placed locks on their dumpsters to prevent residents from dumping their garbage. Over 40% of households in our sample stated that they had observed more littering since the implementation of the sticker program (see Table 2). Of those observing "a lot" of littering, 75.0% lived in densely-populated areas of the city near downtown.

To get a handle on <u>who</u> might do such dumping, we estimate another probit model. We wonder which demographic characteristics influence the probability of a household choosing to dump their garbage in this fashion. These results are reported in the first column of Table 8.

The equation estimating the probability of dumping may not be well specified, as no coefficient is different from zero at the 95% confidence level. Perhaps dumping behavior is difficult to predict without unobserved characteristics such as the degree of risk aversion, community awareness, or accessibility to commercial dumpsters. Also, perhaps households were not dumping illegally, even when their garbage fell to zero. On the other hand, the model easily passes the test for joint significance of all these variables together.

A few other households presented no garbage following the price hike, were not on vacation, and did not indicate that "other" methods were employed to reduce garbage. These

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[25]The Charlottesville <u>Daily Progress</u>, Tuesday October 26, 1993, "Illegal Dumping has County, Landowners Sifting for Answers", tells of increased dumping at more than 30 illegal dumpsites scattered around the county.

households may have reduced their garbage to zero through recycling, composting, and by demanding less packaging, or they could have used illegal methods without acknowledging it. The second column of Table 8 reports the coefficients on variables expected to influence the probability of a household reducing its garbage to zero, whether or not it indicated that "other" methods were used. Individually the variables are not significant, again, but jointly the variables are significant.[26]

7. Discussion of Policy Issues

7.1 Revenue To The Municipal Government

A community may be interested in the amount of revenue it could earn with a unit-pricing program. These revenues could be used to finance recycling collection programs and to pay tipping fees. Based on our results, at mean values for Charlottesville, the additional revenue would be $0.86 per single-family household per week.

Several economic arguments favor unit-charges for garbage as a source of revenue. First, such charges can help reduce the city's garbage and thus its expenditures on disposal. Second, garbage collection and disposal is not a "public good". Each bag incurs additional cost (rival), and collection can be limited to those with paid stickers (excludable). Third, the "benefit principle" suggests that such charges are "fair", since each household pays only according to its use of this service. Fourth, we find that the demand for garbage is inelastic. Established optimal tax theories suggest that the total dead-weight loss to an economy can be reduced by taxing goods with inelastic demand.

Other arguments can be made against this type of taxation. First, administrative and

[26]If we assume these additional households dumped or burned garbage illegally, then we find that 9.33% of households in our sample dumped an average of 11.26 pounds of garbage per person per week, representing 43.0% of the total reduction in garbage at the curb.

enforcement costs may be higher than for other sources of revenue. Second, the social cost of non-compliance can be large. Illegal dumping could require costly cleanups of backwoods dump sites. Third, our results suggest the tax on garbage is regressive. With unit-pricing, the volume of garbage varies from 0.55 containers per person for the lowest income group to 0.46 containers per person for the highest income group. Thus high-income households would pay a lower fraction of their income in garbage fees. Fourth, communities that use property taxes to pay for garbage collection enable their residents to deduct those local taxes against their federal income tax. Depending on the number who itemize, and their marginal tax rates, this deduction can pass to the federal government up to 30% of the cost of this local public service. If the community switches to unit-pricing, it loses a substantial federal subsidy on this portion of revenue.

7.2 A One-Bag Minimum

Some other communities with unit-pricing have tried to reduce illegal dumping by requiring households to purchase a minimum of one bag each week. Households pay for this first bag either through an annual flat fee or through property taxes, and they must purchase stickers only for additional bags they place at the curb. The advantage of a one-bag minimum is that households who would otherwise dump their garbage might be expected to present at least one bag for collection each week. The disadvantage is that no households have any economic incentive to reduce garbage below one bag per week.

We can calculate the effects of such a policy in Charlottesville, if we assume (a) that households dumping all of their garbage would now only dump garbage in excess of one bag, (b) that their regular garbage would increase by the amount not dumped, and (c) that other households presenting up to one bag of garbage per week are unaffected by unit-pricing. With these assumptions, and a one-bag minimum, the amount of illegal dumping would decrease from 0.42 to 0.07 pounds per person per week -- an 83% reduction. These households might even stop dumping entirely since the savings from doing so decreases by the price of one bag. Unit-pricing becomes less effective at reducing garbage, however, because the amount not dumped becomes extra garbage and because behavior is unaffected for the 32.6% of households in our sample that produced one or fewer bags of garbage over an average week before the implementation of the price-per-bag. With unit-pricing and a one-bag minimum, the average person in our sample would:

- reduce the weight of garbage by 1.04 pounds per week (compared to 1.52 pounds per week in the absence of a one-bag minimum)
- reduce the volume of garbage by 0.21 containers per week (compared to 0.27 containers per week in the absence of a one-bag minimum)
- increase the weight of recyclable material presented for collection by 0.50 pounds per week (compared to 0.58 pounds per week in the absence of a one-bag minimum)
- increase the density of garbage by 4.44 pounds per container (compared to 4.69 pounds per container in the absence of a one-bag minimum).

The one-bag minimum would decrease dumping substantially, but it would also reduce some of the desirable changes in garbage and recycling.

7.3 A Simple Cost-Benefit Analysis

What are the social benefits of a unit-pricing program? Repetto et al (1992) use a diagram like our Figure 1A, where the demand for garbage collection is the marginal benefit (MB). They also find that the social marginal cost (SMC) for a town like Charlottesville is $1.03 per bag. Thus a price of zero generates too much garbage, and a price of $1.03/bag results in a welfare gain shown by the shaded triangle in Figure 1A.

We follow Repetto et al (1992) by assuming that the social marginal cost of garbage collection and disposal is \$1.03 per bag. Charlottesville charges only \$0.80 per bag of garbage. Therefore the benefit to Charlottesville from charging \$0.80 is represented by the shaded trapezoid in Figure 1B. This gain is \$3.14 per person per year.[27]

Unit-pricing also imposes several types of costs, mostly administrative and enforcement costs. The municipality must (1) pay to print and distribute the stickers to area merchants, (2) pay to enforce laws against illegal dumpers, (3) pay to clean up illegal dump sites, and (4) pay to promote the program. Additional costs to the household arise from (5) traveling to outlets that sell the garbage stickers, (6) spending time and effort to compact more garbage into each container, and (7) spending time and effort to dump their garbage. Further costs to private business include (8) locking dumpsters and (9) paying to remove garbage that has been dumped on their property. These costs are difficult to quantify, so we consider three cases. We assume that the sum of these administrative and enforcement costs amounts to 5%, 10%, or 15% of the price of a garbage sticker. Then the cost of a per-bag pricing program can be represented by the shaded rectangle in Figure 1B.

Table 9 summarizes these estimated benefits and costs of a unit-pricing program. In the first row of the table, where we ignore illegal dumping, the estimated benefits of unit-pricing exceed costs that are 5% or 10% of the sticker price, but not costs that are 15% of the sticker price.

The next two rows allow for our two measures of illegal dumping. To be conservative, we ignore the cost of cleaning up backwoods dump sites. Instead, suppose illegal dumpers just use commercial dumpsters. In this case the "true" reduction in garbage at the landfill would be less than the reduction in garbage observed at the curb. The "true"

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[27]We ignore the benefits of additional recycling and composting. The price of recyclables is near zero or less than zero for most types of material. See Baumol (1977) for a good discussion of the possible costs and benefits to recycling.

demand curve in Figure 1B is steeper, so the welfare gain trapezoid is smaller and the cost rectangle is larger. Benefits in the second and third row of the table exceed costs that are 5% of the sticker price, but not costs that are 10% or 15% of the sticker price.

As mentioned above, household behavior is affected if per-bag pricing is accompanied by a one-bag minimum. Dumping is less, but so is the reduction in garbage. The last three rows of Table 9 provide estimated benefits and costs with this modified policy. In this case, dumping is less relevant. In all three rows, welfare gains are more than offset by administrative costs that are only 10% of sticker revenue.

8. Conclusion

This paper has used original data gathered from individual households to estimate household response to the implementation of a volume-based pricing program for the collection of garbage. We find that households responded by reducing the weight and volume of their garbage and by increasing the weight of their recyclable materials. We also find that households increased the density of their garbage as they engaged in stomping to reduce their garbage bill. The favorite method to reduce garbage by households in our sample was through additional recycling. Households also engaged in composting, less packaging, and perhaps illegal dumping.

Many communities across the nation have implemented unit-pricing programs to finance garbage collection, especially since 1987. Supporters of these programs emphasize the reduction in garbage and the increase in recycling that can be expected to follow implementation. Critics of these programs worry about excessive amounts of illegal dumping as well as the administrative difficulties that may arise.

In general, we find the reduction in garbage weight and increase in recycling to be rather small. In fact, after accounting for illegal dumping, we estimate that total garbage decreased by only 1.10 pounds per person per week. Many in Charlottesville were already participating in the voluntary recycling program before unit-pricing began.

TABLE 1

A Comparison of Our Sample to All of Charlottesville

	SAMPLE (Excludes students and apartments)	ENTIRE CITY[a]
Number of individuals	208	40,341
Number of households	75	16,009
Individuals per household	2.77	2.52
Average weight of garbage per week per individual before	10.89 pounds	37.30 pounds[b]
Average weight of garbage per week per individual after	9.37 pounds	33.83 pounds[b]
Average change in weight of garbage	-1.52 pounds	-2.59 pounds[c]
Average volume of garbage per week per individual before	0.73 containers	NA
Average volume of garbage per week per individual after	0.46 containers	0.34 containers
Average change in volume of garbage	-0.27 containers	NA
Average weight of recyclables per week per individual before	3.69 pounds	2.74 pounds
Average weight of recyclables per week per individual after	4.27 pounds	2.46 pounds
Average change in weight of recyclables	0.58 pounds	-0.28 pounds
% of households that set out any recycling before	73.3	65.0
% of households that set out any recycling after	69.6	65.4
Mean household income	$46,267	$33,729
% of households owner-occupied	85.3	42.4
% of households married	65.3	51.4
% of households white	94.7	76.1
% of individuals under 3 years	3.9	3.8
% of individuals 18 to 26 years	9.6	23.4
% of individuals 26 to 64 years	54.3	46.4
% of individuals over 65	13.5	12.2
% of individuals work full-time	44.2	28.4
% of individuals over 25 with high school degree	92.2	75.5
% of individuals over 25 with bachelors degree	62.4	34.1

[a] Garbage and recycling data for the entire city were provided by the Rivanna Solid Waste Authority. NA means not available.

[b] Total city garbage includes commercial waste. Any increase of household trash put in commercial dumpsters would be included in this figure.

[c] This figure is adjusted for seasonal variation. Over the pervious 5 year period, 0.88 more pounds of garbage per person per week were disposed of in June than in September. The student population and household yardwaste account for much of the seasonal variation. Since our sample excludes both of these sources, we assume that no seasonal adjustment is required to our sample data.

TABLE 2

Household Responses to Selected Questions in Our Survey

Assuming that the city must face higher costs for the collection and disposal of your garbage, would you rather have your property taxes increase or participate in a sticker program such as the one Charlottesville currently has implemented to pay for the higher costs?

Sticker 77.7%   Property Tax 22.3%

Other cities across the United States have passed laws requiring households to recycle certain material each week or they must pay a fine. Would you rather have such a law instead of the sticker program?

Yes 27.8%   No 72.8%

How inconvenient is it for you to purchase and place stickers on your garbage?

Not Very 46.7%   Somewhat 36.4%   Very 11.7%   Extremely 5.2%

How inconvenient is it for you to place your newspaper, plastic, aluminum and tin in the green recycling container?

Not Very 75.3%   Somewhat 14.3%   Very 5.2%   Extremely 5.2%

Do you think the city of Charlottesville should collect a larger variety of recyclable material from households each week?

Yes 86.9%   No 13.1%

Have you observed a greater incidence of litter in Charlottesville since the sticker program began in July?

Yes, A Lot 15.6%   Yes, A Little 24.7%   No 59.7%

Have you experienced any problems with people stealing garbage stickers?

Yes 3.9%   No 96.1%

TABLE 3

Description of Variables Used in Demand Equations

DEPENDENT VARIABLES	MEAN (S.D.)	DESCRIPTION
WEIGHT	10.14 (6.48)	Average weekly pounds of garbage per person in the household
VOLUME	0.60 (0.32)	The average weekly number of cans of garbage per person
RECYCLE	3.97 (3.38)	The average weekly pounds of recyclable material per person
INDEPENDENT VARIABLES	**MEAN (S.D.)**	**DESCRIPTION**
PRICE	0.40 (0.40)	The price paid by households for one can or bag of garbage
NEWS	0.47 (0.42)	The number of daily delivered newspapers per person
OWN	0.85 (0.36)	1 - The occupants own the house 0 - The occupants are renting the house
WORK	0.47 (0.36)	The fraction of those in the household who work full-time
INFANT	0.03 (0.10)	The fraction of those in the household less than the age of 3
CHILD	0.16 (0.23)	The fraction of those in the household less than the age of 18
RETIRE	0.20 (0.35)	The fraction of those in the household over the age of 65
COLLEGE	0.75 (0.44)	1 - At least one person with some college lives in the household 0 - No individual with some college
INC	4.63 (2.66)	The household annual income level is. 1 - Less than $20,000 6 - Between $40,000 and $80,000 3 - Between $20,000 and $40,000 9 - Greater than $80,000
LINC	0.59 (0.48)	Natural log of INC divided by the number of persons in the household
MARRY	0.65 (0.51)	1 - An adult married couple lives in the household 0 - No married couple
WHITE	0.95 (0.28)	1 - A white household 0 - A non-white household
HHSIZE	0.90 (0.51)	The number of individuals in the household (LHHSIZE = log of HHSIZE)
DISP	0.37 (0.49)	1 - The household has an in-sink garbage disposal 0 - The household does not have an in-sink garbage disposal
PET	0.36 (0.45)	The number of pets (cats or dogs) per person in the household

TABLE 4

GLS Estimates of Coefficients in Demand Equations

	Dependent Variable							
	WEIGHT		VOLUME		DENSITY		RECYCLE	
Independent Variables	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat
CONSTANT	22.04	6.10	1.36	9.03	12.06	2.79	2.13	1.23
PRICE	-1.91	-2.22	-0.34	-7.17	5.87	3.85	0.73	1.84
NEWS	2.65	1.29	0.12	1.39	1.98	0.81	4.88	5.00
OWN	4.41	1.99	0.20	2.16	4.15	1.57	1.46	1.38
WORK	-5.32	-2.22	-0.15	-1.46	-4.40	-1.54	-0.57	-0.50
INFANT	-2.54	-0.39	-0.32	-1.19	11.55	1.50	-1.68	-0.55
RETIRE	-4.71	-1.79	-0.14	-1.32	-5.08	-1.62	-1.99	-1.58
COLLEGE	-3.03	-1.91	-0.02	-0.32	-5.12	-2.71	-0.03	-0.04
LINC	0.86	0.19	-0.29	-1.50	7.67	1.40	0.39	0.18
MARRY	-0.93	-0.65	-0.10	-1.70	0.59	0.34	-0.53	-0.77
WHITE	-5.93	-2.62	-0.27	-2.86	-1.23	-0.46	0.00	0.008
LHHSIZE	-4.87	-2.53	-0.38	-4.72	4.11	1.79	-1.11	-1.21
$s^2\mu$	17.42		0.019		9.49		4.13	
$s^2\epsilon$	17.77		0.053		55.62		3.73	

Number of observations = 150. All variables are defined in Table 3. Descriptive statistics at the bottom of the table show the goodness of fit. $s^2\mu$ is the estimated variance of the individual-specific effects, and $s^2\epsilon$ is the estimated variance of the remaining error term.

TABLE 5

OLS Estimates of Coefficients in Varying-Parameter Demand Equations

	Dependent Variable is the Change in:							
	WEIGHT		VOLUME		DENSITY		RECYCLE	
Independent Variables	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat
CONSTANT	-1.35	-0.27	-0.58	-2.02	4.76	0.52	1.02	0.43
NEWS	4.58	1.60	0.21	1.31	4.69	0.90	2.97	2.21
OWN	-2.91	-0.94	-0.01	-0.05	-2.45	-0.43	-0.85	-0.58
WORK	-0.28	-0.08	-0.00	-0.02	-2.68	-0.44	1.88	1.19
INFANT	14.62	1.62	0.68	1.32	15.40	0.94	6.72	1.58
RETIRE	-0.33	-0.09	-0.10	-0.45	-5.88	-0.87	0.91	0.52
COLLEGE	1.59	0.72	0.07	0.58	-2.17	-0.54	0.43	0.41
LINC	-5.34	-1.91	-0.13	-0.79	-3.15	-0.62	-1.17	-0.89
MARRY	3.45	1.71	0.12	1.01	4.95	1.35	0.64	0.67
WHITE	-0.23	-0.07	0.04	0.23	0.75	0.13	-2.17	-1.45
LHHSIZE	-0.54	-0.20	0.07	0.45	2.86	0.58	-0.22	-0.17
R^2	0.195		0.116		0.148		0.149	
F(10,64)	1.555		0.836		1.113		1.125	

Number of observations=75. All variables are defined in Table 3. Descriptive statistics at the bottom of the table show the goodness of fit.

TABLE 6

Change in Per-Capita Garbage and Recycling for Households That Indicated Each Method of Reduction[a]

		HOUSEHOLDS INDICATING:				
	All Households (100%)	Did Not Reduce (25.3%)	Recycled More (65.3%)	Composted More (30.6%)	Demanded Less Package (17.3%)	Other (10.7%)
Change in Garbage Weight (Pounds)	-1.53	-0.05	-1.76	-2.25	1.26	-5.10
Change in Garbage Volume (Cans)	-0.27	-0.25	-0.25	-0.26	-0.12	-0.35
Change in Recycling Weight (Pounds)	0.58	0.41	0.70	0.07	0.66	-0.80
Change in Total Weight (Pounds)	-0.95	0.36	-1.06	-2.18	1.92	-5.90

[a]This table shows weights and volumes per person. Households were allowed to indicate more than one method of reduction, in response to the question: "Since the sticker program was implemented on July 1, 1992, which of the following means have you used to reduce the amount of garbage you have collected each week."

TABLE 7

Estimation Results for Probit Choice Model

	RECYCLE MORE		COMPOST		LESSPACK		OTHER	
Variable Name	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
CONSTANT	-1.00	-1.04	-1.54	-1.54	-2.49	-1.86	-3.94	-1.84
NEWS	0.42	1.32	0.00	0.01	0.41	1.12	0.38	0.74
DISP	-0.37	-0.81	-0.97	-2.10	-0.03	-0.06	-2.66	-1.84
PET	0.24	1.31	-0.14	-0.77	0.12	0.64	0.84	1.80
OWN	1.12	1.82	0.78	1.28	-0.16	-0.24	-0.18	-0.13
WORK	-0.39	-1.57	-0.38	-1.39	-0.00	-0.01	-0.00	-0.01
INFANT	-0.94	-1.77	-0.52	-1.23	-0.46	-0.90		
CHILD	0.37	1.25	0.29	0.98	0.30	1.00	-1.01	-1.43
WHITE	0.89	1.24	0.48	0.68	0.66	0.67	-1.35	-1.04
RETIRE	-0.02	-0.07	0.11	0.30	0.17	0.41	1.24	1.91
MARRY	0.05	0.12	-0.23	-0.55	-0.50	-1.04	-0.80	-1.00
COLLEGE	0.70	1.43	0.60	1.25	0.42	0.73	-1.48	-1.18
INC	-0.17	-1.62	-0.08	-0.76	-0.01	-0.15	0.68	1.86
HHSIZE	-0.09	-0.44	0.23	1.02	0.11	0.45	0.42	1.09
$-2[L(0)-L(\beta)]$	96.80		92.46		69.17		50.92	
$-2[L(c)-L(\beta)]$	74.14		72.71		60.33		31.26	

Number of observations=75. All variables are defined in terms of households, not in terms of individuals as in Table 3. Descriptive statistics at the bottom of the table show the goodness of fit.

TABLE 8

Further Estimation Results for Probit Choice Model

	DUMP1[a]		DUMP2[b]	
Variable	Coefficient	t-stat	Coefficient	t-stat
CONSTANT	-7.27	-1.18	-3.79	-1.30
NEWS	0.96	1.12	0.67	1.00
PET	1.01	1.83	0.68	1.93
DISP	-2.23	-1.57	-1.46	-1.53
OWN			-1.03	-0.94
SIZE	0.04	0.09	-0.59	-1.28
CHILD	-0.16	-0.26	0.61	1.16
RETIRE	1.03	1.36	0.67	0.62
MARRY	-1.62	-1.41	-1.59	-1.93
WORK	-0.18	-0.36	0.29	0.62
WHITE	1.59	0.32	1.79	0.69
COLLEGE			0.20	0.67
INC	0.54	1.63	0.24	1.31
$-2[L(0)-L(\beta)]$	31.23		46.53	
$-2[L(c)-L(\beta)]$	19.69		32.22	

Number of observations=75. All variables are defined in terms of households, not in terms of individuals as defined in Table 3. Descriptive statistics at the bottom of the table show the goodness of fit.

[a]The household indicated it used "other" methods to reduce garbage, and the household set no garbage out for collection following the implementation of volume-based pricing.

[b]The household may or may not indicate that "other" methods were used, but the household set no garbage out for collection following implementation.

TABLE 9

A Simple Comparison of Benefits and Costs per Person per Year

		Administrative and Enforcement Costs[a]		
Assumption	Benefits	5%	10%	15%
No Dumping	$3.14	$1.32	$2.64	$3.96
DUMP1[b]	$2.19	$1.38	$2.76	$4.14
DUMP2[c]	$1.74	$1.41	$2.82	$4.23
1 Bag Minimum				
No Dumping	$2.49	$1.36	$2.72	$4.08
DUMP1[b]	$2.33	$1.37	$2.74	$4.11
DUMP2[c]	$1.90	$1.40	$2.80	$4.20

[a]As a percentage of the price of the garbage sticker.

[b]We include the missing garbage of households that indicated it used "other" methods to reduce garbage and set no garbage out for collection following the implementation of unit-pricing.

[c]We include the missing garbage of households that may or may not have indicated that "other" methods were used, but set no garbage out for collection following implementation.

Figure 1A
Marginal Benefit (MB) and Social Marginal Cost (SMC) of Garbage Collection and Disposal

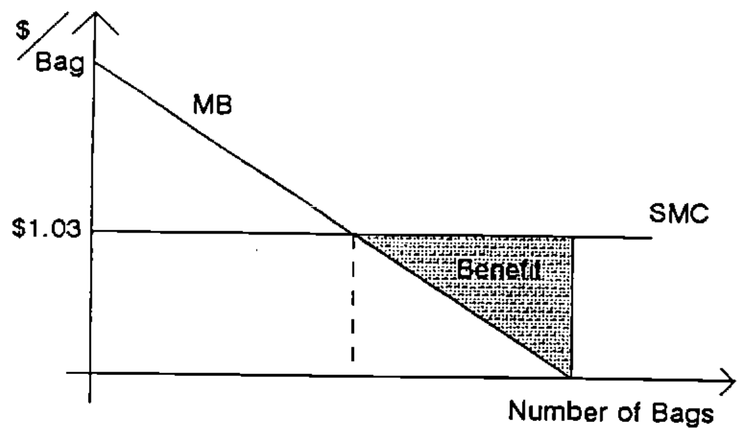
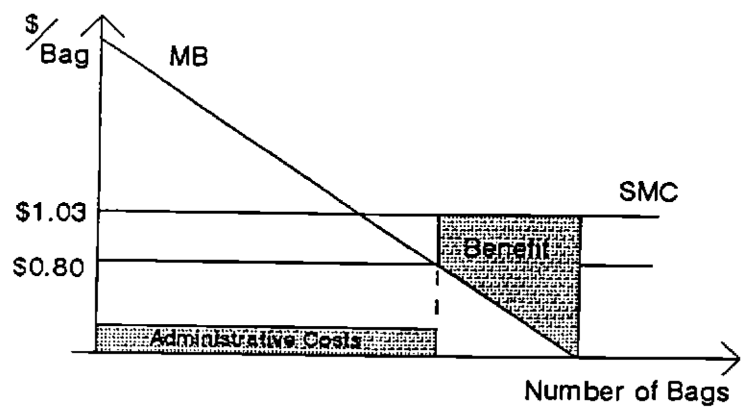


Figure 1B
Benefit and Cost of Unit-Pricing in Charlottesville



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