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Household Responses to Pricing Garbage by the Bag

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By DON FULLERTON AND THOMAS C. KINNAMAN*

The average tipping fee paid by garbage collectors to landfills has tripled over a six-year period, largely due to rising land prices and new EPA regulations (Robert Steuteville and Nora 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 for 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.

The price per bag might also induce households to compact garbage into fewer bags. This practice, known as the "Seattle Stomp," was noticed first when Seattle started an early unit-pricing program. It is not helpful, since collectors compact the garbage anyway.

This paper employs individual household data to estimate the effect of such a program on the weight of garbage, the number of containers, the weight per can, and the amount of recycling. We also provide two indirect measures of illegal dumping. The data are based on a natural experiment that provides a unique opportunity to study human behavior in response to a change in price. On July 1, 1992, Charlottesville, Virginia, implemented a program to charge \$0.80 per 32-gallon bag or can of residential garbage collected at the curb. 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 by 14 percent, reduced the volume of garbage (number of containers) by 37 percent, and increased the weight of recycling by 16 percent. Our indirect measures suggest that additional illegal dumping may account for 28 percent to 43 percent of the reduction in garbage.

Based on these data, the change in weight of garbage is statistically significant, but small. The implied arc-price elasticity is only -0.076.[1] We also collect aggregate data on residential garbage (available only by weight) for 25 similar cities in Virginia over the same time period. Based on these aggregate data, the reduction in Charlottesville is less than one standard deviation beyond the mean reduction elsewhere. Using either set of data, we conclude that this pricing program has little effect on the weight of garbage. Using the household data, however, we find more substantial effects on volume, density, recycling, and illegal dumping.

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[1] This response is not just to the change in price from zero to \$0.80, but to the whole program. The demand-curve interpretation is useful, however, because any new price must be accompanied by a public-awareness campaign, a level of enforcement, and other program attributes. We use elasticities to compare with previous results, but the same \$0.80 price could have different effects with a different program.

Other studies have estimated the demand for the collection of garbage, often using data for entire communities. Cross sections of cities are employed by J. M. McFarland et al. (1972), Kenneth L. Wertz (1976), Robin Jenkins (1991), and Robert Repetto et al. (1992). Aggregate time-series data from one city are used by Fritz Efaw and William N. Lanen (1979) and Lisa Skumatz and Cabell Breckinridge (1990).[2] Household surveys appear more recently. Seonghoon Hong et al. (1993) use a survey of 2,298 households in the area of Portland, Oregon, where 25 collection firms in 19 municipalities use a variety of block-pricing schedules (such as $12/month for one can per week and $24/month for two cans). Correcting for the endogeneity of price, they find small responses to changes in price or income. Finally, James D. Reschovsky and Sarah E. Stone (1994) survey 1,422 households around Ithaca, New York, facing a variety of unit-pricing and recycling rules. An important result is that curbside recycling pickup increases the probability of recycling more than does unit pricing of garbage.

We build upon these existing studies in several ways. First, by using individual households instead of just a cross section of cities, we avoid the problem that city tonnage data often include amounts from outside the jurisdiction and often mix residential garbage with commercial and industrial garbage.[3] 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 that price is jointly determined with quantities (if cities self-select prices in a way that depends on resident characteristics).[4] Finally, our cross section of households contains more variation in demographic characteristics than does a cross section of communities, since the latter can only provide community-wide means.

Section I will describe the steps taken to gather the data from individual households in Charlottesville, including steps to control for seasonal or other variations. Results in Section II indicate that garbage weight is inelastic to price, but garbage volume does respond to this price per unit volume. We also estimate how these observed responses depend on demographic characteristics, and we provide two indirect measures of the increase in illegal dumping. Finally, in Section III, we consider policy issues. We discuss the pros and cons of collecting revenue from unit pricing, we calculate the effect of introducing a minimum of one bag per week, and we conduct a simple cost-benefit comparison. Welfare benefits from unit pricing range from $0.08 to $0.15 per $0.80 bag of garbage, but administrative costs are likely to exceed $0.19 per bag.

I. The Data

Charlottesville, Virginia, is a university town with a population of 40,341. Residential garbage collection has traditionally been provided by the city and financed by property taxes. To recycle, households had to haul materials to one of two drop-off centers that accepted newspaper, three colors of glass, and aluminum cans. Then, beginning in November of 1991, Charlottesville implemented a voluntary curbside recycling program. The city provided each household with a free plastic

[2] Also, Barbara Stevens (1977) and Peter Kemper and John M. Quigley (1976) use a cross section of cities to examine the effects of a change in the level of service for garbage collection. With a cross section of neighborhoods, Robert A. Richardson and Joseph Havlicek Jr. (1978) and William L. Rathje and Barry Thompson (1981) consider the effect of income on specific components of garbage.

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

[4] Our individual households cannot self-select into unit pricing the same way, but Charlottesville could. Regressions below control for observable characteristics, but Charlottesville might have chosen unit pricing based on residents' characteristics that we cannot observe.

recycling container in which to place any glass, tin, newspaper, aluminum, and certain plastics. The city also expanded the list of materials accepted at the drop-off locations.

In December 1991, the city council decided that a unit-pricing program would begin July 1, 1992. This program requires a sticker, costing $0.80, on each unit of garbage for collection, where a unit can be any container (bag or can) with a volume of approximately 32 gallons. A $0.40 sticker could be purchased for a 16-gallon bag, but garbage without a sticker would not be collected. Collection of recyclable materials would continue to be free and voluntary.

A. *Our Procedures to Collect the Data*

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 a sample of households. We first selected a set of streets spread throughout Charlottesville. This sample of streets represents all major neighborhoods and demographic groups. Then the city directory was used to select a random sample of households located on the selected streets.[5] A total of 400 households received a letter requesting their participation in our study. The letter indicated that their garbage and recycling would be weighed early in the morning over two four-week periods, and that participating households would be expected to complete a questionnaire. They were assured that their answers would be held confidential.[6]

A total of 97 households agreed to participate. Another 68 households responded that they would not participate, and several of these indicated they would be moving during the summer. Of the 97 positive responses, our final sample includes 75 with complete data.[7]

With only a 25-percent positive response rate, our sample could suffer from a self-selection bias. Perhaps only educated, environmentally-aware households would agree to have their garbage weighed. These households may already have been recycling as much as they could before unit pricing, with little opportunity for additional recycling. Conclusions based on such a sample might understate the reduction in garbage of an average household. The data do not allow us to conduct a formal test for selection bias. We cannot compare our sample's garbage per capita to the city's data on "residential" garbage per capita, because the latter includes garbage from small businesses that use bags, and includes population from apartments that use dumpsters. Nor can we usefully compare demographics of our sample to those of the city, because we intentionally excluded dormitories and all multi-family dwellings, which together make up 31 percent of housing in Charlottesville. Thus our sample has higher than average income and education, and it over-samples homeowners, married couples, and full-time workers. Our sample is not representative of the population as a whole, but it could provide useful information about other similar single-family neighborhoods that would be likely sites for similar unit-pricing programs.[8]

[5] We excluded streets located near the University of Virginia, to avoid sampling 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 representative of the population. This two-part selection process is designed to cluster households, in order to reduce the costs and complications involved with weighing household garbage each morning. Even though several households in the sample were located on the same street, they were most often located well apart from each other.

[6] 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 for completing the questionnaire. Each letter included a stamped postcard for their reply.

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

[8] We cannot test for selection bias, but we assess the potential sensitivity of our results to the problem induced by truncation of the sample (G. S. Maddala, 1983 pp. 165–70). We run an ordinary-least-squares (OLS) regression and compare it to a truncated regression that assumes our sample is truncated above our highest observed garbage per capita. The price coefficient changes only in the fourth significant digit.

Each household's garbage and recyclable materials were weighed each week over four weeks in May and early June before implementation of the unit-pricing program, and again over four weeks in September following its implementation. We skipped three weeks before the starting date to avoid anticipation effects, and we skipped two months afterwards to avoid vacations and to provide a short adjustment period. Garbage was not weighed during the week following Memorial Day, to avoid the extra garbage that can be generated over a holiday weekend. Care was taken throughout the term of the study not to weigh yard waste.[9] This involved some inspection of household garbage, which was not a difficult task.

Measurement error can arise from several sources in our data. First, rain can increase the weight of garbage and recycling, so we did not use observations from the two mornings that it rained.[10] Second, the recycling truck does not collect in certain parts of the city until well into the afternoon, so some households might wait to present their recycling. We could only measure amounts in the morning, but on one occasion we returned in the afternoon to households that did not recycle in the morning, and we saw no additional recycling. Third, the volume of garbage containers can vary, as households used different-sized cans, plastic bags, or cardboard boxes. Before implementation, we approximated each household's garbage by the number of 32-gallon containers it would have filled. Following implementation, we measured volume by counting the number of stickers. Thus our measure of volume is the same as the city's. We count the number of containers for which they were charged, rather than the precise volume of garbage per se.

We recorded each week separately, but household garbage and recycling amounts can vary substantially from one week to the next. 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 observations for each household. The first represents an average week's worth of garbage and recycling amounts at a price of zero, and the second provides the same at a price of $0.80.

Following measurement, each household was sent a questionnaire with a self-addressed stamped envelope to report their demographic statistics such as household size, ages, race, income category, marital status, education, and other information that might influence the generation of garbage or recycling. They were also given the opportunity to express their opinions on several subjects relating to the unit-pricing program. Some of their responses are reported in Table 1. Support for the sticker program runs fairly high, with 78 percent of households favoring it over an increase in property taxes,[11] and 73 percent favoring it over mandatory recycling. Yet 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 by that time, and may have become accustomed to it, whereas the sticker program was relatively new to them. See Stuart Oskamp et al. (1991) or Seattle Solid Waste Utility (1991) for more elaborate survey studies.

B. *Control for Seasonal and Other Effects*

The change in garbage from May to September might not all be due to the change in price. How can we control for changes attributable to seasonal or other factors? Ideally, we would like to compare these months in Charlottesville to the same months in another similar town that did not introduce unit pricing, and then take "differences in differences." Unfortunately, we did not have resources to collect similar data for

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

[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).

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

TABLE 1—RESPONSES TO SELECTED QUESTIONS IN OUR SURVEY

Questions	Response	Percentage
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

individual households at the same time in a different city. Instead, we take several approaches. First, we searched the literature for information on seasonal effects. Only Richardson and Havlicek (1974) measure monthly household waste components to determine the size and sources of seasonal variation. The first row of Table 2 indicates that their average weekly weight of garbage fell by 4.8 percent from May to September. That information is only from one city, and only from 1970–1971. Second, we therefore collected aggregate garbage data for Charlottesville (excluding the University of Virginia) in May and September of seven years *other* than 1992. The second row shows that garbage weight fell by an average of 3.8 percent between those months (for 1986–1991 and 1993–1994).[12] That information does not control for events specific to 1992. Third, we therefore collected our own aggregate data for May and September of 1992 by calling solid waste officials of 25 other cities in Virginia. This sample represents virtually every city in Virginia that is similar in size to Charlottesville and not near a beach. It can be used to control for effects of changes in the Virginia economy, changes in the price of newsprint, or changes in any other variables likely to affect garbage in Charlottesville between May and September of 1992. As shown in the third row, garbage fell in those other cities by 3.5 percent.

The three estimates of seasonal effects are close to one another, but their standard errors are high. Aggregate garbage per capita is poorly measured because cities combine the different categories of residents, small businesses, and apartments. The variance is large,

[12] The aggregate garbage weight in Charlottesville fell by 6.0 percent from May to September of 1992, which is not significantly different from the 3.8 percent average change in other years, but these aggregates include small businesses that use garbage bags instead of dumpsters. The 14-percent reduction in our sample includes only single-family households.

TABLE 2—AVERAGE WEEKLY MEASURES PER CAPITA

	May	September	Difference (standard error)	Percent change	Arc-elasticity
Elsewhere (garbage in pounds):					
Richardson and Havlicek, 1970–1971	11.39	10.84	−0.55[a]	−4.8	
Charlottesville, 1986–1991, 1993–1994[b]	11.78	11.33	−0.45 (0.32)	−3.8	
25 Cities in Virginia, 1992[c]	9.68	9.34	−0.34 (0.34)	−3.5	
For our 75 households:					
Weight of garbage (pounds)	10.90	9.37	−1.54** (0.69)	−14.1	−0.076
Volume of garbage (cans)	0.73	0.46	−0.27*** (0.04)	−36.8	−0.226
Density (pounds per can)	15.04	21.49	6.44*** (1.02)	42.8	0.176
Recycling (pounds)	3.69	4.27	0.58* (0.31)	15.6	0.073

[a] Standard error not available.
[b] Includes small businesses that use garbage bags instead of dumpsters.
[c] Some cities' garbage figures include small businesses, and some apartments, whereas population is taken from the census and thus includes the whole city.
* Statistically different from zero at the 10-percent level.
** Statistically different from zero at the 5-percent level.
*** Statistically different from zero at the 1-percent level.

so the observed change in Charlottesville is not statistically different from changes in those other cities.

This estimated aggregate seasonal effect is small, but most importantly, Richardson and Havlicek (1974) find that it is primarily attributable to yard waste, as well as to vacations, holidays, and changes in household composition. Therefore another approach to correct for seasonal effects is given by our data collection procedures. As noted above, we carefully avoided yard waste, we excluded households that moved or went on vacation, we excluded households whose composition changed, and we selected measurement dates to avoid holidays. In addition, we checked whether other events could have affected household waste. We found no changes in state or local recycling laws, no changes in packaging restrictions, and no changes in dumping laws during this period.[13]

[13] On this issue, we benefited from discussions with Nancy Williams, the local government recycling-program analyst of the Virginia Department of Environmental Quality. A remaining source of seasonal variation might be changes in consumption habits between those months.

We feel that these steps constitute the best correction for seasonal and other effects. First, the aggregate statistics are poorly measured. Second, aggregate statistics relate only to weight of garbage, whereas our steps in the collection of household data also correct for seasonal effects on volume and recycling. Third, our data already exclude yard waste and thus should not be corrected again by other cities' seasonal variations that are primarily due to yard waste. Therefore our primary results are based on no further correction. For completeness, we provide estimates based on the 3.5-percent correction for other cities in Virginia, but we show it makes very little difference.

II. Results

This section estimates how the change in garbage depends on price and demographic variables. Our previous working paper (Fullerton and Kinnaman, 1994) estimates how the level of garbage and the probability of recycling depend on demographic variables.

A. *Direct Measures*

The second panel of Table 2 reports the average across our 75 households of per capita garbage weight, garbage volume, garbage density, and recycling weight. The average person in our sample reduced the weight of garbage from 10.90 to 9.37 pounds per week, a 14-percent decrease. This change is statistically different from zero at the 5-percent level.[14] Using this difference, the arc-price elasticity of demand is −0.076 for the collection of garbage, measured in pounds, at mean levels of price and weight. This estimate is a bit closer to zero than in previous studies.[15]

If these figures are adjusted for the 3.5-percent reduction from May to September of 1992 in other cities, then the change is still significant at the 10-percent level. The adjusted arc-elasticity is −0.058, which is similar to (but even smaller than) the unadjusted elasticity.

The average individual reduced the volume of garbage from 0.73 to 0.46 containers per week, a 37-percent decrease, which is statistically different from zero at the 1-percent level. The arc-price elasticity of demand, measured in volume, is −0.226 at mean levels of price and volume. Thus volume fell in greater proportion than weight. Density increased by 43 percent, from 15.04 to 21.49 pounds per container. After all, this "volume-based" pricing program charges not by weight but by the number of bags. Unfortunately, social costs depend on volume after compacting at the landfill, which is better proxied by weight at the curb than by volume at the curb.

Finally, the weight of recycling increased from 3.69 to 4.27 pounds per week, a 16-percent increase. The implied cross-price elasticity is 0.073 at mean levels.[16]

B. *Garbage Reduction and Household Characteristics*

Overall change in weight is small, but this change is averaged over diverse households. We now investigate briefly whether these responses depend on household income or demographic characteristics. These estimates would help some other town that is considering unit pricing. Specifically, the change in each of the four measures is regressed on household income and demographic variables listed in Table 3. For this fixed-effects model,[17] the ordinary-least-squares estimator is efficient. Table 4 reports results from four separate regressions.

Our survey provides much information about each household, but several variables have no effect in any of these four regressions. We wish to conserve degrees of freedom, with only 75 observations, so we omit variables for homeownership, employment, age, and household size. Coefficients on these variables always have large standard errors. Their exclusion has virtually no effect on the coefficient estimates of remaining variables, but reduces their standard errors. Even with the fewer variables, the null hypothesis that all slope coefficients are zero cannot be rejected for three of the four regressions. It is barely rejected at the 5-percent level for the garbage-weight regression.

In the garbage-weight equation, shown in the first column, the (negative) baseline

[14] This test presumes a normal distribution. Using a less-restrictive nonparametric Fisher-sign test, the change in weight of garbage is *not* significant. The reason is that only 38 of the 75 households reduced the weight. However, significant numbers decreased volume, and increased both density and recycling.

[15] 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 (Glenn E. Morris and Denise Byrd, 1990, in two communities), and −0.14 (Skumatz and Breckinridge, 1990).

[16] Using two observations from each city, the U.S. Environmental Protection Agency (1990) estimates this cross-price elasticity for Perkasie, PA (0.49), Illion, NY (0.48), and Seattle, WA (0.06 in 1985–1986 and 0.10 in 1986–1987).

[17] As described in Fullerton and Kinnaman (1994), the garbage level can be expressed as a linear function of price P, exogenous variables X, and interactions PX. Taking first differences, where ΔX is zero, the change in garbage becomes a function of ΔP (a constant 0.8) and $\Delta P \cdot X$. Thus the estimated constant reflects the "baseline" price effect (if all $X = 0$), the coefficients on X reflect interaction terms, and the average price effect can be evaluated at the mean values of X.

TABLE 3—DESCRIPTION OF VARIABLES USED IN REGRESSIONS

Independent variables	Mean (standard deviation)	Description
NEWS	0.47 (0.42)	Number of newspapers delivered daily per person
INFANT	0.03 (0.10)	Fraction of those in the household less than age three
COLLEGE	0.75 (0.44)	1–At least one person with some college in the household 0–No individual with some college
INC	4.63 (2.66)	The household annual income level: 1–Less than $20,000 3–From $20,000 to $40,000 6–From $40,000 to $80,000 9–Greater than $80,000
LINC	0.41 (0.86)	Natural log of per capita income
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 nonwhite household

price effect given by the constant term is dampened for households that subscribe to more daily newspapers, for those with infants, and for married couples. Interestingly, the reduction in garbage is greater for households with more income. Column (2) shows the effect on the number of bags. These coefficients are similar in sign to those in the garbage-weight equation.

Who stomped on their garbage in response to unit pricing? Column (3) of Table 4 shows how demographic characteristics affect the change in garbage density. Stomping is a bit higher for married couples and lower for those with more income. The stomping problem could be addressed by charging households according to the weight of their garbage, but such a system would require scales on collection trucks and more elaborate billing.[18]

C. *Illegal Dumping Behavior*

The biggest concern to policy makers considering unit pricing in their communities is the possibility of increases in illegal forms of garbage disposal. We could not provide direct measures of such behavior, and we could not trust answers to direct survey questions about it either. Instead, we asked each household to indicate whether they 1) did not attempt to reduce garbage, or 2) recycled more, 3) composted more, 4) demanded less packaging at stores, or 5) used "other" means to reduce garbage. Since the first four options would seem to cover all legal alternatives, we think the "other" option is a strong indicator of illegal disposal such as burning, littering, or using commercial dumpsters.[19] Eight of our 75 households (10.7 percent) indicated "other."

We offer two indirect methods of estimating the amount of illegal dumping that took place in Charlottesville during the period of our experiment.[20] For our first measure, we use two

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

[19] The other category might include in-sink garbage disposal, but *changes* in this behavior must be small. It might include changes in the level or composition of consumption. Fullerton and Kinnaman (1994) estimate the probability of using each method, but the sample size is too small for definitive results.

[20] Daniel R. Blume (1991) interviews officials from 14 unit-pricing communities. Four reported significant dumping problems, 4 reported minor problems, and 6 reported no problems. He was unable to explain what causes these differences, even considering the price of garbage collection.

TABLE 4—OLS ESTIMATES OF COEFFICIENTS

	Dependent variable is the change in:			
Independent variables	Weight (1)	Volume (2)	Density (3)	Recycle (4)
Constant	−4.83	−0.52	2.21	1.23
	(−1.76)	(−3.40)	(0.51)	(0.96)
NEWS	4.49	0.17	−0.66	2.36
	(2.04)	(1.37)	(−0.18)	(2.28)
INFANT	13.14	0.75	11.75	5.01
	(1.57)	(1.59)	(0.92)	(1.27)
COLLEGE	1.57	0.13	−0.68	0.02
	(0.75)	(1.11)	(−0.19)	(0.02)
LINC	−3.15	−0.11	−3.31	−0.07
	(−2.71)	(−1.75)	(−1.61)	(−0.12)
MARRY	3.44	0.17	4.54	0.33
	(2.04)	(1.76)	(1.63)	(0.42)
WHITE	−0.48	0.06	4.42	−2.38
	(−0.16)	(0.37)	(0.96)	(−1.69)
R^2:	0.165	0.117	0.143	0.121
$F(6,68)$[a]:	2.243	1.505	1.698	1.558

Note: All variables are defined in Table 3. Descriptive statistics at the bottom of the table show the goodness of fit. *t* statistics are given in parentheses.

[a] The number of observations is 75 for columns (1), (2), and (4). The number is 68 for column (3), because density is undefined for the seven households who put out zero garbage for the entire four-week measurement period following implementation. Therefore the *F* statistic in column (3) is $F(6,61)$.

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. These households were not on vacation, and they were still presenting recyclable materials.

Based on these two criteria, we find that 4 of our 75 households (5.33 percent) disposed of garbage illegally.[21] To estimate the amount, we take their garbage before unit pricing, minus the increase in their recycling, minus an estimate of additional composting.[22] We find that these households dumped an average of 13.38 pounds per person per week. Furthermore, this estimate constitutes 28 percent of the total reduction in garbage at the curb. For comparison, additional recycling constitutes 38 percent of the total reduction in garbage. Thus households may have increased dumping by almost as much as they increased recycling. The remaining 34 percent 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.

For our second measure, we use only the second criterion. Altogether, 7 of the 75 households (9.33 percent) presented zero

[21] These results should be viewed with caution. First, the sample size is small. 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.

[22] 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 is an estimate of per capita change in garbage due to composting.

garbage for the entire four-week period following the price hike (and were not away on vacation). After we account for their additional recycling, and an estimate of additional composting, the missing garbage of these seven households represents 43.0 percent of the total reduction in garbage at the curb.

Social costs can vary over methods of illegal disposal. If a person takes the weekly garbage to a commercial dumpster of an employer, and has permission, the social costs could be quite low. However, if this individual throws garbage along a rural route or burns it in the back yard, then 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.

Recent stories in newspapers tell of increased dumping.[23] 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 percent of households in our sample stated that they had observed more littering since the implementation of the sticker program (see Table 1). Of those observing "a lot" of littering, 75.0 percent lived in densely-populated areas of the city near downtown.

III. Policy Issues

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 post-change average of 1.0822 cans per household per week, at a price of $0.80, the revenue would be $0.86 per single-family household per week.

A. *Pros and Cons*

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

Other arguments can be made against this type of taxation. First, administrative and enforcement costs may be higher than for other sources of revenue. Second, the social cost of noncompliance 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 is 0.55 containers per person for the lowest-income group and 0.46 containers per person for the highest-income group. Fourth, communities that use property taxes to pay for garbage collection enable their residents to take deductions against their federal income tax. Depending on the number who itemize, and their marginal tax rates, this deduction can pass to the federal government a third of the cost of this local public service. A community that switches to unit pricing thus loses a substantial federal subsidy on this portion of revenue.

B. *A One-Bag Minimum*

Some other communities with unit pricing have tried to reduce illegal dumping by using property taxes or monthly fees to collect funds to pay for one bag each week for each household. They then require stickers only for additional bags. The advantage is that households who would otherwise dump their gar-

[23] The Charlottesville *Daily Progress*, Tuesday October 26, 1993, "Illegal Dumping Has County, Landowners Sifting for Answers," tells of increased dumping at more than 30 illegal dumpsites.

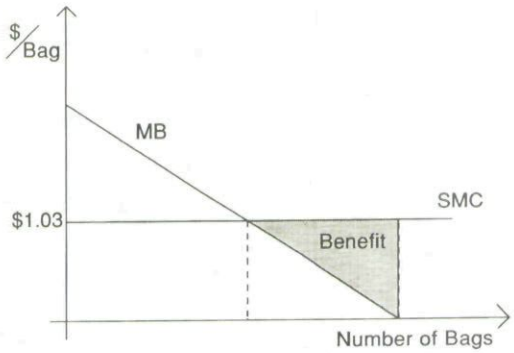

FIGURE 1A. MARGINAL BENEFIT (MB) AND SOCIAL MARGINAL COST (SMC) OF GARBAGE COLLECTION AND DISPOSAL

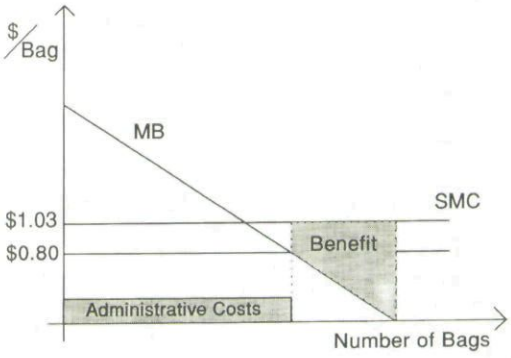

FIGURE 1B. BENEFIT AND COST OF UNIT-PRICING IN CHARLOTTESVILLE

bage might present at least one bag for collection each week. The disadvantage is that nobody has any 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 dump only the excess over one bag, b) that their regular garbage would increase by the amount not dumped, and c) that others presenting up to one bag of garbage per week (33 percent of our sample) are then unaffected by unit pricing. With these assumptions, illegal dumping falls from 0.42 to 0.07 pounds per person per week—an 83-percent reduction. The average person would reduce garbage weight by 1.04 instead of 1.54 pounds per week, reduce volume by 0.21 instead of 0.27 cans per week, and increase recycling by 0.50 instead of 0.58 pounds per week. The one-bag minimum would reduce dumping substantially, but it would also reduce some of the desirable changes in garbage and recycling.

C. *A Simple Cost-Benefit Comparison*

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 creates a welfare benefit shown by the shaded triangle in Figure 1A. This calculation ignores illegal dumping.

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, so their benefit is represented by the shaded trapezoid in Figure 1B. The estimated dollar amounts are shown in the first column of Table 5. With no increase in illegal dumping, this gain is $3.59 per person per year.[24] With illegal dumping, to be conservative, we ignore the cost of cleaning up backwoods dump sites and 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" demand curve in Figure 1B is steeper, so the welfare gain trapezoid is smaller, only $2.67 or $2.17 per person per year.

These benefit estimates are converted into an amount per bag, in the second column of Table 5, to indicate "threshold" costs per bag that would yield zero net gain. With no illegal

[24] We ignore the benefits of additional recycling and composting. Market prices are near zero for most types of recyclable materials, but see William J. Baumol (1977) for potential costs and benefits. Also, SMC in Figure 1B must refer to "constant density" bags of garbage, so we calculate the change from old volume to "constant density" new volume (given by the new weight divided by the old density).

TABLE 5—A SIMPLE COST-BENEFIT COMPARISON

Assumption	Benefits (per person per year)	Threshold administrative, enforcement and compliance costs (per bag)	Estimated administrative costs to government (per bag)[c]
No minimum:			
No dumping	3.59	0.149	0.193
DUMP1[a]	2.67	0.111	0.193
DUMP2[b]	2.17	0.090	0.193
One bag minimum:			
No dumping	2.54	0.105	0.193
DUMP1[a]	2.38	0.099	0.193
DUMP2[b]	1.95	0.081	0.193

Note: All figures are in dollars.

[a] Includes the missing garbage of households who used "other" methods to reduce garbage *and* set out no garbage for collection following the implementation of unit pricing.

[b] Includes the missing garbage of households who may or may not have used "other" methods, but who set out no garbage for collection following implementation.

[c] Excludes enforcement costs to government and compliance costs to households.

dumping, estimated benefits would be completely offset by administrative and enforcement costs that were \$0.149 per bag. With dumping, thresholds are lower.

What are the costs of imposing a price which is per bag of garbage? The municipality must pay to print the stickers, pay commissions to area merchants to sell the stickers, pay employees to distribute the stickers and administer the program, pay to enforce dumping laws, pay to clean up illegal dump sites, and pay to promote the program. In addition, the household must travel to outlets that sell the stickers, spend time and effort to compact more garbage into each container, and spend time and effort to dump their garbage. Private businesses may have to lock dumpsters and pay to remove garbage that has been dumped on their property.

We cannot begin to estimate all such costs, but we do have some information on just the first three. Charlottesville twice purchased stickers from the printer at a cost of at least \$0.13 per sticker. In addition, the city pays a 5-percent commission on sales by merchants, \$0.04 per sticker. Third, the city pays one part-time clerical person (20 hours per week) to administer the program, and another part-time person to deliver the stickers to the 35 vendors and to follow the garbage trucks to report violations.[25] At just \$6/hour, this labor cost would be \$12,000/year, or \$0.023 per sticker actually sold. The sum of just these three costs is \$0.193 per sticker, well above any threshold in Table 5. Consideration of illegal dumping not only makes the benefits smaller in Table 5, but would also make the social costs higher.

IV. Conclusion

This paper has used original data gathered from individual households to estimate responses to the implementation of a price per bag of garbage. We find that households reduced the number of bags, but not necessarily the actual weight of their garbage. Thus households stomped on their garbage to reduce their costs. They also increased the weight of recycling, and they might have increased illegal dumping.

The reduction in weight of garbage at the curb is 14 percent. If we account for the

[25] We are grateful for this help from city officials Chase Anderson and Mike Timberlake. Competition among bids by printers and competition among vendors would suggest that these payments represent social costs, but any pure profits would be a transfer rather than a cost.

amount of illegal dumping, using our lower estimate, then the true reduction in garbage is only 10 percent. Recycling increased by 16 percent. Many in Charlottesville were already participating in the voluntary recycling program before unit pricing began. Thus the incremental benefit of unit pricing is small. In our simple comparison, this social benefit does not cover the administrative cost.

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