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Recycling: An Economic Analysis

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Trash disposal and its ensuing environmental impact is becoming one of the central concerns of the nation. Dwindling landfill space, the resulting dramatic increase in landfill costs and the accompanying environmental concerns are being discussed at all levels of government. There are three basic options available for resolving the crisis: (1) building new landfill sites that are environmentally safe, (2) building incineration plants, and (3) reducing the waste stream by changing consumer behavior through price incentives and/or recycling.

Several studies have pointed out the political problems of siting new landfills due to the "not in my backyard syndrome" (Cook, 1988; Zandi, 1989). Likewise, various articles have pointed out the limitations of incineration plants because they produce potentially toxic ash which must be disposed of in a landfill (Ecenberger, 1989; Lagone, 1989). It is not surprising, therefore, that most of the research focuses on the third option. However, it has concentrated on the price and cost of trash disposal rather than the role of the household recycling effort.

During the seventies there were numerous studies which analyzed the household price elasticity for waste disposal. Wertz (1976) developed a broad theoretical model of household behavior regarding the production of waste. In an empirical test of his model he found a negative price elasticity. Two econometric studies, one based on a cross-section analysis of 13 municipalities (McFarland, 1972) and the other, a time-series analysis of three cities, (Eflaw and Lanen, 1979) estimated that the price elasticity was negative and inelastic. More recent research, using a case study approach, has also calculated a negative price elasticity (RTI, 1990) which implies an inverse relationship between the price the household pays for waste disposal and the amount of waste it puts out for collection. Gueron (1972) argued that unit pricing of household waste collection would result in negative alternative household disposal, with increased pollution and social costs outweighing any waste collection savings. Other researchers have suggested that government ordinances on burning and littering would reduce this impact (Goddard, 1975).

More recent case studies have suggested that the introduction of unit pricing to household waste collection not only results in total waste reduction, but may also increase the household recycling effort (Skumatz, 1989; RTI, 1990; Jenkins, 1990). However, the RTI report points out that case studies of unit pricing policies do not establish if the reduction in waste collection is the result of unit pricing or recycling programs. They regard the two as complementary, but acknowledge that their conclusions reflect limited information.

The studies that have concentrated on the recycling issue focus primarily on the cost aspect (Spaulding, 1987; Stauffer, 1989; Rankin and Nosker, 1989; Morris and Platt, 1987; and Vasuki, 1988). Morris and Platt examined the cost effectiveness of trash to steam plants, central recycling facilities, and recycling at the household level. They concluded, using a case study approach, that recycling at the household level was the most cost-effective. Rankin and Nosker measured the relationship between recycling capture rates and the breakeven disposal cost finding that programs with capture rates of approximately 80% tend to produce positive net revenues through a combination of avoided cost of solid waste disposal and revenues from the sale of recyclables.

To our knowledge, there have been only two research efforts that attempt to examine the factors that influence the household incentive to recycle. Mersky (1988) analyzed the reactions and opinions of participating residents to mandatory newspaper recycling in six municipalities in Delaware County,

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Pennsylvania. Using survey response data and simple correlation analysis, his results showed no correlation between socioeconomic factors and the amount recycled. McGrath (1989) examined recycling rates in 53 municipalities in Monmouth County, New Jersey. Looking at the total recycling of newspaper, glass, and aluminum, he grouped the municipalities using three different classifications: whether or not they (1) were required to separate the items, (2) had an administrator from the Department of Public Works, and (3) used public vs private trash haulers. Calculating the simple arithmetic average of each group's recycling rate, he concluded that municipalities that did not require households to separate, by source, had a Department of Public Works administrator, or utilized public trash haulers had significantly higher recycling rates.

A review of the relevant literature reflects the absence of a theoretical framework for explaining the factors underlying the household recycling effort. (The Wertz 1976 study did not include recycling as an option). Nor has there been any systematic statistical analysis of the relationships that the theory might imply, using a broad data base. Most of the studies to date on recycling have used a case study approach. Case studies are basically individual snapshots of a much larger picture. The fallacy of composition warns us that without the whole picture, extending the analysis of individual efforts to conclusions about group results can be misleading. This paper is a first step towards filling some of the large gaps in the recycling research.

Economic welfare analysis tells us that the amount of recycling undertaken by consumers will be less than optimal for two reasons. First, recycling creates a positive externality in that everyone benefits from my recycling efforts (saving landfill space and reducing landfill costs). In the absence of a one to one correspondence between those who make the effort and those who reap the benefit, many will not make the effort voluntarily. Second, recycling is an intergenerational public good. Our recycling efforts today will help to eliminate a potential problem in the future. Given the myopic time preference of most individuals, people will undervalue the current benefits of recycling.

The above two factors cause the private marginal benefit from recycling to be less than the social marginal benefit. From society's perspective, not enough recycling will be done by individuals because they cannot capture, or are not compensated for, all of the benefits of their efforts. Therefore, any large scale recycling program must be government initiated, either through mandatory regulations or economic incentives. Considering the magnitude of the problem, it is only a matter of time before legislation is introduced to implement recycling on a national level. To develop a successful program, it is crucial to understand what factors induce the largest household recycling response.

For the most part, municipalities have been on their own to set up their recycling programs and to encourage the residents to actively participate in such programs. Currently, there are about 8,000 recycling programs in the United States, with the percentage of solid waste recovered showing tremendous variation by municipality. However, the individual municipality responses have generated a wealth of data which can be used to examine the relative effectiveness of the different programs and to study what best induces a resident to be an active participant.

We develop a structural equation within the framework of economic theory, and statistically analyze the data generated in the various municipalities, to explain the tonnage of material recycled at the household level. We formulate separate functions for each recycled material, using socioeconomic explanatory variables that are implied by the theoretical model. This paper presents the results of a study of newspaper and glass recycling, utilizing data from 39 municipalities in Delaware County, Pennsylvania, and 19 municipalities from Glouster County, New Jersey.

THE MODEL

We develop the structural specification of our recycling function from the vantage point of the principle of household utility maximization, where the household seeks to maximize the total utility received from the consumption of goods and services subject to the household's income constraint:

$$\text{maximize TU} = f(X_1, X_2, \ldots X_n, X_{tr}, X_{tn})$$

where:

TU is total utility
$X_1, X_2, \ldots X_n$ are economic goods and services
X_{tr} is the amount of recycled trash removed
X_{tn} is the amount of nonrecycled trash removed
$X_t = X_{tr} + X_{tn}$ = total trash removed

subject to the budget constraint:

$$Y = \sum_{i=1}^{n} (P_i/P)X_i + (P_t/P)X_t$$

and:

$$P = \sum_{i=1}^{n} \theta_i P_i + \theta_t P_t \qquad \theta_i, i = 1 \ldots n, \text{ and } \theta_t \text{ are weights that must add up to one.}$$

where:

Y = the level of real income
P_t = the price of trash removal
P_i = the price of the ith good or service
P = the absolute price level (1982 = 100)

There is interdependence among the goods and services. Trash removal is an economic service which gives utility to the consumer, and like all goods and services has a positive price attached to it.

In the process of maximizing utility, trash is generated as a by-product of consumption. Under the standard assumption that consumption is a positive function of income, one can infer that higher income households will generate more trash. Households that generate more trash will potentially have more material to recycle. Therefore, we would expect a higher tonnage recycled from higher income households, ceteris paribus.

Some individuals may derive utility from activities they perceive will improve or protect the environment either currently or in the future. We characterize these individuals as having a high ecological conscience, and assume that recycling provides satisfaction to these individuals and increases their utility. Hence, households with a higher conscience about ecology (possibly higher level of education households) should recycle more per household. Therefore, X_{tr} is a function of what may be termed "ecological consciousness" which is designed as EC.

$$X_{tr} = e(EC)$$

There are costs incurred by the household, if recycling is instituted at the household level, in terms of the effort required. This effort consists of the time needed to sort the materials and the storage space that must be set aside. These factors are considered opportunity costs because there are other opportunities for the individual's time and other things that could be stored in these spaces. Any factors that reduce the time or space necessary for recycling should increase the amount recycled by the households.

Given this concept of opportunity cost, if the municipalities pickup at the curb instead of having the residents drop off at designated centers, that should increase the recycling effort. Likewise, if the municipalities pick up four times a month instead of once a month, an increase is expected in the amount recycled because the households need not set aside such a large space for storing the materials. Alternatively, if the recycled trash is picked up as often and on the same day as the regular trash, then the amount of trash recycled should increase because it is easier for the household to remember. The household can also take advantage of time economies by not having to put out different types of trash on different days. In addition, it does not require extra storage space for recycled trash as compared to nonrecycled trash.

We would also expect the length of time a recycling program has been in existence to impact positively on the amount recycled, because households will have had a longer time to incorporate recycling into their lifestyles, thereby decreasing the amount of effort required. Along the same lines, the number of items recycled should reinforce the habit of recycling thereby positively impacting the amount recycled.

Finally, if the amount recycled lowers or prevents increases in the price of trash removal, then households will have an incentive to recycle. This incentive should be powerful in view of the fact that the total quantity of trash generated is likely to be relatively inelastic with respect to the price of trash removal. As such, the only option households have to prevent increases in their total expenditures on trash removal services is to keep the price from increasing. Furthermore, this incentive will be greater, the higher the price of trash removal because a larger percentage of the household budget will go towards paying for trash. In addition to this incentive to recycle, any enforcement penalties imposed by the municipalities when a household includes recyclable material with nonrecycled trash, would discourage residents from not recycling via the price relationship at the household level.

The uniqueness of trash removal as an economic service, as specified in the theoretical assumptions outlined above, implies the following demand function for recycled trash:

$$X_{tr} = g(X_1, X_2, \ldots X_n, O_{tr}, P_t/P, EC)$$

where O_{tr} is the opportunity cost of recycling.

The demand function for each X_i, derived from traditional utility analysis is:

$$X_i^d = h_i(Y, P_1/P, P_2/P, \ldots P_n/P, P_t/P)$$

Summing over all commodities to obtain an aggregate demand function of the "composite commodity" yields:[2]

$$X^d = h(Y)$$

therefore:

$$X_{tr} = g(Y, O_{tr}, P_t/P, EC)$$

We postulate that ecological consciousness is a positive function of education, and the opportunity cost of recycling is a positive function of the effort needed to recycle:

$$EC = j(\text{Education})$$

$$O_{tr} = k(\text{effort spent on recycling})$$

We can reduce this set of equations to a single equation explaining the determinants of recycled trash:

$$X_{tr} = d(Y, \text{Education, effort spent on recycling}, P_t/P)$$

However, in reality, the price of trash removal to the individual household may not be directly linked to the amount of nonrecycled or recycled trash that the household generates. Many municipalities provide trash removal out of real estate taxes collected. Although recycling may change the cost of trash disposal to the individual municipalities,[3] which could eventually lower real estate taxes imposed on the household, because there is no direct linkage it would not be perceived as a reduction in the price of trash removal. Additionally, even in those communities where individual households contract with private trash removal services, flat monthly fees are generally charged rather than per bag fees. Consequently, under these circumstances, there is no price relationship, and the household has no incentive to change the composition of recycled vs nonrecycled trash generated.

We empirically evaluate the demand function X_{tr} by performing multivariate statistical analysis. We explain tonnage per household by education levels, income levels, frequency of pickup and alternatively the ratio of the frequency of nonrecycled trash to that of recycled trash pickup (ratio variable), whether or not the material is picked up at curbside, the number of years (duration) the program has been in existence, and the total number of items recycled. The price of nonrecycled trash removal was not included in the empirical analysis since there was no direct linkage between the quantity of trash removed and the price of trash removal in the municipalities studied here. However, we did use a proxy variable to capture the effect of enforcement of recycling laws with potential penalties on the amount recycled.

We expect income and education to have a positive impact on the amount recycled. We expect frequency of pickup, ease of pickup (curbside), duration of the program, number of items recycled, and the enforcement proxy to also have a positive impact. Alternatively, using the ratio variable contrasting frequencies of nonrecycled to recycled trash pickup will affect the amount recycled negatively. Because of the characteristics of different recyclable commodities, we expect to find different marginal impacts of the relevant explanatory variables.

DATA

The socioeconomic data were obtained from the 1980 census. Family median income (FMEDY) was selected for use as the income measure. The percent of the population over 25 with four or more years of college (CGPER) was used as a measure of the level of education. The 58 municipalities in the study were each contacted and information concerning their individual recycling programs was obtained. From this information we used:

FREQN and FREQG which measure the frequency of newspaper and glass pickup respectively, with values ranging from 0 to 4 (4 indicates pickup 4 times a month).
PICKUP: dummy variable with:
PICKUP = 1 if curbside pickup available
PICKUP = 0 if drop-off centers only
TOTITM: the total number of items that the municipality recycles.
NRATIO and GRATIO are the ratios of the frequency of nonrecycled to recycled trash pickup in our study.

DURN and DURG are variables which measure the number of years the recycling programs for newspaper and glass have been in effect.
ENFOR is a dummy variable with:
ENFOR = 1 if the municipality enforces the recycling laws with fines, refusal to pickup trash containing recyclables, or gives warnings to violators.
ENFOR = 0 otherwise
N = the total pounds of newspaper recycled per household per year.
G = the total pounds of glass recycled per household per year.

County reports on solid waste were the source for the last two variables.

EMPIRICAL RESULTS

Separate equations were estimated, using ordinary least squares regression analysis, to explain recycled material per household of newspaper and of glass. Considering that we are dealing with cross section data, there is a respectable degree of explanation provided by the independent variables for the newspaper equation, and a remarkable degree of explanation for the glass equation. The most reasonable equations, from a large number that were run, are reported in Tables 1 and 2 for newspaper and glass respectively. The preferred equation, from a theoretical and statistical point of view, is given first.

In both newspaper and glass, the enforcement variable was not significant and equations using it as

TABLE 1

Regression Results for Newspaper Pounds of Recycled Newspaper Per Household Per Year

	FMEDY	CGPER	DURN	NRATIO	TOTITM	R^2	d.F.
(1)	5.35****	2.24*	17.08***			.47	49
	(4.0)	(1.7)	(2.6)				
(2)	5.99***	2.26	18.43***	−2.52	−3.66	.45	45
	(2.6)	(1.5)	(2.6)	(0.4)	(0.42)		
(3)	6.36****		22.17****	−1.30		.44	47
	(3.7)		(3.4)	(0.2)			
(4)	8.29****	3.56***		−5.23		.39	48
	(5.5)	(2.6)		(0.8)			
(5)	5.36****	2.46*	17.75***	−1.45		.46	46
	(3.0)	(1.8)	(2.6)	(0.2)			
(6)	7.41****	3.33***				.39	46
	(6.7)	(2.6)					

t statistics in parenthesis.
*significant at the 10% level.
**significant at the 5% level.
***significant at the 2% level.
****significant at the 1% level.

an explanatory variable are not being reported. We feel that although penalties for not recycling exist, they are seldom levied and are therefore not binding.

Total number of items recycled does not play a role in the amount of newspaper recycled (equation 2, Table 1), but is significant in the case of glass (Table 2). Unlike glass, newspaper separation is not

TABLE 2

Regression Results for Glass Pounds of Recycled Glass Per Household Per Year

	FMEDY	CGPER	DURG	FREQG	TOTITM	R^2	d.F.
(1)			2.96**	23.2****	6.39****	.70	34
			(2.2)	(6.3)	(3.8)		
(2)		0.50***		24.57****	6.93****	.71	40
		(3.2)		(7.3)	(4.6)		
(3)		0.32	2.10	23.73****	5.84****	.71	33
		(1.0)	(1.3)	(6.4)	(3.3)		
(4)		0.68**	3.81**	27.41****		.62	34
		(1.9)	(2.2)	(6.8)			
(5)	0.63**		3.71**	26.57****		.62	34
	(2.00)		(2.1)	(6.6)			
(6)	0.78*	0.48		28.97****		.54	42
	(1.99)	(1.1)		(7.3)			
(7)		0.32	2.10	23.73****	5.84****	.71	33
		(1.0)	(1.3)	(6.4)	(3.3)		
(8)	−1.12**	0.95**	2.38	22.63****	9.62****	.73	32
	(2.1)	(2.2)	(1.5)	(6.3)	(3.9)		
(9)	−0.85*	0.99****		23.86****	10.02****	.72	39
	(1.8)	(2.8)		(7.1)	(4.5)		

t statistics in parenthesis.
*significant at the 10% level.
**significant at the 5% level.
***significant at the 2% level.
****significant at the 1% level.

made easier when one is separating other household items. Newspaper is trash that is not generated in the kitchen, and as such can easily be kept separate.

The estimated coefficient of the relative frequency of regular trash vs. recycled trash pickup had the right sign in the explanation of newspaper, but was never significant. The standard error of the coefficient was reduced in the absence of the duration variable (equation 4, Table 1), lending some support to the need for convenience, particularly when the program is first instituted.

In the case of glass, we used the frequency of glass pickup since there was not enough variation in the relative ratio variable. Frequency of pickup was significant in every variant of the equation for glass, confirming the hypothesis that storing glass over a longer period is an added burden which discourages residents to recycle.

The role of education, measured by the percentage of college graduates, is significant in almost all of the newspaper equations and in many of the glass equations. Comparing equations 1 and 6 (Table 1), and equations 2 and 3 (Table 2), the percentage of college graduates becomes more significant when the duration variable is excluded. This seems to indicate that communities with a higher level of education are more willing to participate irrespective of how long the program has been in existence. In the case of glass, the percentage of college graduates becomes more significant when total number of items is not included (equation 4, Table 2).

The family median income is significant in the newspaper equations, but gives conflicting results with glass. The two cases in which income has the expected sign and is significant are: (1) when education and total items are excluded as explanatory variables (equation 5, Table 2) and, (2) when duration and total items are excluded (equation 6, Table 2). It appears that education and/or duration of program interact with family median income leading to unsupportable estimates for income.[4]

CONCLUSIONS AND POLICY IMPLICATIONS

In our best equation, two of the three variables significant in determining the amount of recycled newspaper are socioeconomic (education and income) and as such municipalities can not do much to directly affect them. Municipalities can take comfort in the fact that the longer the program is in existence, the larger the amount of trash recycled per household (effect of duration).[5]

In the case of glass, there are two competing equations (equations 1 & 2, Table 2). The first uses duration of program, frequency of pickup and total number of items as the explanatory variables. The equation explains over 70% of the variation. The second equation uses education instead of duration of program and comes up with the same degree of explanation. Within our sample, the municipalities whose populations have a higher level of education are also those that started their recycling programs sooner. As such the two variables, education and duration, are substitutes for each other from a statistical point of view. This explains the almost identical R^2 values for these equations.

The frequency of pickup is a very important variable in the case of glass. By picking up glass once a week instead of once in two weeks, the amount of recycled glass increases by about 23 pounds per household per year (95% confidence interval has a range of 16 to 31 pounds per year). The feasibility of doing so, of course, has to be judged by the municipality in the context of higher costs of collection implied by the higher frequency. The fact that the number of items recycled affects the success of glass, due to what we believe is habit forming behavior in the sorting of materials, suggests that municipalities should be implementing several programs simultaneously.

The institutional structure in which household payment for trash removal is not dependent on the quantity of trash removed does not allow our function to capture the effect of the price of trash removal. This price relationship would be discernible when municipalities utilize direct economic incentives to encourage people to recycle. Economic incentives would be present if households received a direct subsidy when they recycled, or their taxes fell when they recycled, or they had to pay for removal of nonrecycled trash via a per bag fee, or pay penalties in mandatory recycling communities. We plan in a future study to estimate the effect on recycling of the price of trash removal by incorporating data from municipalities where such direct economic incentives are provided. This analysis will go a long way in helping the municipalities to measure the costs and benefits of recycling.

NOTES

1. Obviously, if new landfills could be created that were proven environmentally safe, and could be located in a cost effective manner, then this position would need to be re-examined.
2. Technically the relative prices would not net out when we aggregate over the commodities because the price of trash removal is included in the calculation of the absolute price level

$$P = \sum_{i=1}^{n} \theta_i P_i + \theta_t P_t$$

However, we assume that the weight θ_t is relatively insignificant.

Also, by aggregating over all commodities we are making the simplifying assumption that the composition of consumption does not affect the amount of recycled trash per household.
3. Some municipalities receive a subsidy for each ton of recycled material collected. All municipalities realize a cost saving through lower landfill costs, and gain revenues from the sale of recycled material.
4. We learned from County officials that they do observe larger quantities of glass available for recycling in lower income neighborhoods. We attribute this to the hypothesis that lower income households have a consumption pattern that generates more glass as a percentage of total trash, a case in which our simplifying assumption pointed out in endnote 2 is invalidated.
5. It is important not to extrapolate the marginal impact implied by the empirical estimate of the duration parameter to values of duration will eventually level off as the program matures. We will address in future work the issue of duration and the inevitable leveling of the learning effect not recognized in this study.

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