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Recycling and Waste Diversion Effectiveness: Evidence from Canada

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Abstract. In this paper, we investigate the relationship between recycling policy options and recycling behavior to study the most effective methods of diverting post-consumer waste from landfills. We employ data from a unique, micro-data set collected from households in communities across Ontario, Canada. We estimate the relationships between several commonly recycled materials (newsprint, glass, plastics, aluminum cans, tin cans, cardboard, and toxic chemicals) and individual household characteristics, recycling program attributes, and garbage collection financing methods. We find that user fees on garbage collection have significant impacts on recycling levels for all materials except toxic chemicals, and mandatory recycling programs on particular items have significant effects on recycling for almost all materials. Limits on the amount of garbage that can be placed at the curb, and providing free units under user fee systems, however, generally have a negligible or detrimental impact on recycling.

Key words: environmental policy, household waste, ordered probit, recycling, user fees

JEL classification: D10, H23, Q28

1. Introduction

Recent developments in theoretical environmental economics have suggested many options for correcting the externalities in household waste production and for the promotion of the recycling of post-consumer waste products. Many of these suggestions have made their way into public policy, as governments have introduced garbage financing reform and expanded recycling options in response to increasing landfill costs, reduced landfill options, increasing garbage collection costs, and general public environmental concerns. User fees for waste disposal, relatively rare a decade ago,[1] have been introduced in thousands of municipalities across North America, and most communities would currently have access to some form of curbside recycling, with some introducing multiple-stream recycling programs for yard waste, household organic waste, composting, in addition to typical “dry” material recycling programs. Other cities have also experimented with low limits on the amount of waste that can be placed at the curb at each collection (typically bag limits). While all of these options have the intention of diverting waste from landfills or incinerators, user fees (often referred to as "pay as you throw" systems) and bag limits have the additional goal of reducing the amount of waste produced, either to lower garbage collection costs or to correct for the over-production of waste due to the zero marginal price of disposal under general tax revenue financing.

The proliferation of waste management policies provides a prime opportunity to examine which policies are most effective at increasing the amount of recycling performed at the household level. By collecting and examining data from several communities with different recycling options, it is possible to test whether theoretical predictions have been found to be effective in practice, in addition to collecting information useful to local governments for future policy-setting as cost-effectiveness could potentially be improved if it is known which programs result in greater recycling of high-valued materials (Jenkins et al. 2000). Understanding the link between policies and particular material recycling would also allow municipalities to increase the diversion of those materials known to be problematic.

Studies on related issues have often employed aggregate quantity data, despite the fact that recycling effort is determined at the household level. These community level analyses include Wertz (1976), Saltzman et al. (1993), Callan and Thomas (1997), Podolsky and Spiegel (1998), and Kinnaman and Fullerton (2000). Several recent studies have avoided the limitations of aggregated data through the use of household-level data, including Hong et al. (1993), Reschovsky and Stone (1994), Fullerton and Kinnaman (1996), Nestor and Podolsky (1998), Sterner and Bartelings (1999), Van Houtven and Morris (1999), Jenkins et al. (2003), and Linderhof et al. (2001). However, many of these studies are either not concerned with the impact of policies on recycling, or do not have the data to make comparisons across policies.

Of the studies primarily concerned with the production of garbage (and not recycling), Fullerton and Kinnaman (1996) collected data prior to and after the implementation of a unit pricing system in households in Virginia. They concluded that the response to such as system was that households significantly reduce the volume but not the weight of garbage put out for collection. Sterner and Bartelings (1999) estimated linear relationships between the reported quantities of recycling by weight, and attitudes, information and household characteristics, across three municipalities in Sweden. Although the chosen communities had slightly different programs and financing methods, there was not sufficient variation in policies and accordingly it was impossible to discern comparative individual policy effects. Finally, Linderhof et al. (2001) employed panel data from a single community with weight-based pricing in the Netherlands, estimating linear equations for both compostable waste and non-recyclable waste. The concern was the impact on waste production over time, and not on recycling habits. Both long- and short-run price effects were found to be significant.

On the recycling issue, Hong et al. (1993) estimated the likelihood of recycling (vs. not recycling) controlling for, among other items, user fees. Recycling participation concerned the frequency of recycling (never, less than once per month, etc.) and not the quantities or proportions of recycling. Their results indicated that a user fee increases the probability that a household recycles frequently, suggesting a positive relationship between the amount of recycling performed and marginal pricing. Quantity-based analysis was introduced by Reschovsky and Stone (1994), who studied the probability of recycling various materials as a function of recycling attributes and volume-based pricing. The price of garbage alone was estimated to have no significant impact on the probability that a household recycles; however, when combined with a curbside recycling program, recycling rates increase by 27–58%, depending on type of material. Nestor and Podolsky (1998) found that subscription programs are about as effective as bag/tag programs at reducing garbage, but neither program encourages source reduction in the presence of a curbside recycling program (since such programs subsidize overall disposal practices). In a comparison of unit pricing systems, Van Houtven and Morris (1999) employed a unit pricing dummy variable (as opposed to a unit price), finding that bag/tag programs reduce garbage by 36%, compared to just a 14% reduction under subscription programs, but that both programs have negligible effects on the aggregate quantity of recycled materials. Lastly, Jenkins et al. estimated the probability of households recycling particular proportions of five different materials (newspaper, glass, plastics, aluminum, and yard waste) in a specification similar to that of Reschovsky and Stone.[2] An overwhelming majority of the observations came from communities without user fee programs (116 with marginal pricing, only 12 of which with tag/bag/sticker programs, relative to 933 without unit pricing). While access to recycling programs generally had a significant impact on recycling, the unit price was found to have no impact on the recycling of any of the five materials.

Here, we employ a relatively large, unique, household-level data set in an attempt to clarify the relationship between the recycling intensity for several different materials and the features of garbage collection, recycling collection, and garbage collection financing. The detail of the data set allows us to examine issues that have not been examined in previous studies, including bag limits, the provision of "free" units under unit pricing, and recycling frequency.[3] In section 2, we describe the data that we employed. In sections 3 and 4, we detail the estimation procedure employed and the results of that estimation. Finally, we provide concluding comments in section 5.

2. Data

The data set employed in this study was gathered by the Hitachi Survey Research Centre at the University of Toronto at Mississauga in August, 2002. Approximately 1800 structured interviews were conducted from single-family households in 12 municipalities across Ontario, which were pre-selected on the basis of recycling program characteristics and waste management financing method. The communities chosen for the study were Cornwall, Georgina, Guelph, Northumberland County, Orillia, Ottawa, Peterborough, St. Catharines, St. Thomas, Stratford, Timmins, and Toronto. A representative sample would have returned more than half of the observations from Toronto and Ottawa, and almost two-thirds from the six largest cities in the province. The stratification permitted a more balanced mix of recycling and financing programs than would have been achieved otherwise. Each city in the sample has curbside recycling, as all major centres and 94% of the population have access to this type of program.

Each interview entailed answering questions on recycling participation by material (newspaper, aluminum, glass bottles, etc.), recycling program details (user fees, bag limits, collection frequency, etc.), and household characteristics (income, education, etc.). The final data set included 1409 observations after eliminating several observations due to missing values on key variables or a lack of information on the part of the respondent.[4] Of the final set of observations, approximately 40% came from the five communities in the survey with user fee programs (that is, households face a positive marginal price of waste disposal). Each of these programs was a bag/tag program, for which households must purchase tags or stickers to be placed on each garbage container (typically a standard bag). Bag/tag is closer to true marginal pricing than other types of user fee systems, as households can easily vary the quantity of waste put out for collection simply by buying more or fewer tags.

Table I shows the mean values and standard deviations of the independent variables used in the ordered probit analysis detailed in section 3, for both the entire sample of 1409 observations as well as for unit pricing communities only. Some variables apply (or have non-zero values) only to programs with user fees, particularly the marginal price of waste disposal and the number of units that can be placed out for collection before incurring the marginal price. Thus, for the entire sample, the mean marginal price is under $0.50, but among user fee program communities, the mean marginal price is $1.24. The marginal price applies to six of the seven materials to be studied, with the one exception being toxic chemicals. These toxic wastes included pesticides,

Table I. Mean values of independent variables, all observations ($N = 1409$) and only for communities with unit pricing ($N = 562$)

Variable	Mean (SD)	Mean (SD)
	All observations	Unit pricing
Marginal price of garbage disposal	0.49 (0.62)	1.24 (0.22)
Weekly recyclable collection indicator	0.48 (0.50)	0.58 (0.49)
Free units under unit pricing indicator	0.16 (0.36)	0.39 (0.49)
Unit disposal limit indicator	0.16 (0.37)	0.19 (0.49)
Mandatory recycling indicator	0.32 (0.47)	0.39 (0.49)
Home ownership indicator	0.92 (0.28)	0.95 (0.22)
Highest education high school diploma indicator	0.18 (0.39)	0.22 (0.42)
Highest education some college or university indicator	0.07 (0.26)	0.07(0.25)
Highest education college diploma indicator	0.25 (0.43)	0.27 (0.45)
Highest education undergrad. university degree indicator	0.24 (0.43)	0.22 (0.42)
Highest education postgrad. university degree indicator	0.16 (0.36)	0.12 (0.32)
Household income $20,000–$39,999 indicator	0.13 (0.34)	0.14 (0.34)
Household income $40,000–$59,999 indicator	0.19 (0.39)	0.22 (0.42)
Household income $60,000–$79,999 indicator	0.16 (0.37)	0.18 (0.39)
Household income $80,000–$100,000 indicator	0.11 (0.31)	0.10 (0.29)
Household income over $100,000 indicator	0.16 (0.37)	0.14 (0.35)
Household size	3.09 (1.87)	3.21 (2.37)
Indicator for head of household 35–49	0.34 (0.47)	0.31 (0.46)
Indicator for head of household 50–65	0.32 (0.47)	0.35 (0.47)
Indicator for head of household over 65	0.22 (0.41)	0.23 (0.42)

paints, oils and solvents. With a greater potential for contaminating soil, generating toxic fumes, damaging sewer systems and polluting water supplies, these chemicals were banned from normal garbage collection in all of the communities included in the survey.

Each of the households in the survey had curbside recycling programs for newspaper, glass bottles, plastic bottles, aluminum cans, tin cans, and cardboard, and had drop off recycling depot programs for toxic chemicals.[5] Recycling was mandatory for 32% of households, and slightly more for those communities with unit pricing. Alternatively, mandatory recycling is more often combined with unit pricing than without. Other recycling policy variables were the frequency of recyclable collection (weekly vs. bi-weekly),[6] and the presence or absence of low limits on the number of bags/cans that a household could put out for collection at any one time. Of the 12 communities, almost all had some form of ‘‘bag limit’’ but most were quite high (8–12 32-gallon containers in most cases) and could reasonably be considered non-binding for single-family households. Three communities in our survey imposed low limits (between 0.77 and 3 bags),[7] and for these communities we have included an indicator for a binding unit limit.

The data set includes information on five household demographics, namely home ownership (as opposed to renting), income, education, size and the age of the "head" of the household. Summary statistics for all of these variables are included in Table I. Ninety-two percent of respondents indicated that the current occupants of the house were also the owners. This high percentage may be attributed to the selection of single-family, non-condominium properties. Information was gathered on the highest education attained among members of the household, from some high school to post-graduate university degrees. Income was separated into six categories (under $20,000, $20,000–$39,999, etc.).[8] The means in Table I indicate the percentages of households falling into each category. The same can be said for the age indicators, where the household's head falls into one of four categories, from "under 35" to "over 65." For the indicator variables income, education, and age, one missing category (at the low end in each case) is excluded from the table.

The dependent variable for each material is categorical. Survey respondents were asked about what would best describe the proportion of actual recycling relative to the amount that could have been recycled, from five categories: 0%, approximately 25%, approximately 50%, approximately 75%, or approximately 100%. We employed all five categories in our analysis. Roughly, similar trends were reported for all items except toxic chemicals. For each material, the categories with the highest proportions were consistently "approximately 100%" and "approximately 0%," indicating that most households report recycling most of their recyclables or not recycling at all. Newspaper had the highest recycling rates, and toxic chemicals the lowest.[9]

3. Model Specification

Many theoretical papers have attempted to clarify the relationship between recycling effort, garbage production, and waste management policies (output taxes, user fees, collection frequency). These include, among others, Wertz (1976), Dinan (1993), Jenkins (1993), Atri and Schellberg (1995) and Fullerton and Kinnaman (1995) on user fees, and Ferrara (2000) and Ferrara (2003) on collection frequency. Fullerton and Kinnaman suggest financing waste collection from general revenues (such as property taxes) leads households to view collection as free, and consequently, households over-produce waste. A positive marginal disposal price (or change in collection frequencies) causes households to both re-allocate their time toward recycling and alter their consumption habits to produce less non-recycled waste. As mentioned above, this implication has been disputed empirically by studies such as Reschovsky and Stone (1994), Nestor and Podolsky (1998), Van Houtven and Morris (1999), and Jenkins et al. (2000), and substantiated by others such as Hong et al. (1993) and a few aggregate-level data studies. One unintended possibility is that households instead shift to illegal disposal. In theory, illegal disposal does not imply user fees will be sub-optimal, however, although the appropriate user fee may be negative rather than positive.[10] Fullerton and Kinnaman note that free garbage collection is appropriate if the subsidy on legal disposal is close to the direct resource cost.

If the theory is accurate, recycling effort should depend positively on factors such as the unit price, recycling subsidies (such as more frequent recyclable collection), and whether recycling is mandatory. Bag limits could be expected to increase recycling as households over the limit reduce their waste disposal by switching to recycling (but could decrease recycling as household under the limit curb more garbage in order to maintain their non-binding limit). Free units available under unit pricing effectively reduce the marginal price to zero for part of the household's garbage disposal, and accordingly should reduce the positive impact of unit pricing on recycling.

To test these theories, we utilize an ordered probit analysis for each of the seven recyclable materials under consideration. The ordered probit is well developed elsewhere, and so we shall only provide an outline of the procedure employed. Unobserved recycling effort y_{ij}^* (the proportion of material j recycled) for household i is estimated as

$$y_{ij}^* = \boldsymbol{\beta}_j'\mathbf{x}_i + \varepsilon_j,$$

where $\boldsymbol{\beta}_j'$ is the vector of coefficients estimated by MLE, $\mathbf{x}_i$ is the vector of independent variables such as the unit price, collection frequency and household characteristics, and ε_j is a normally distributed error term. The last assumption ensures that the probabilities of household i falling into the five categories are given by

$$\Pr(y_{ij} = 0) = \Phi(-\boldsymbol{\beta}_j'\mathbf{x}_i),$$
$$\Pr(y_{ij} = 1) = \Phi(\mu_1 - \boldsymbol{\beta}_j'\mathbf{x}_i) - \Phi(-\boldsymbol{\beta}_j'\mathbf{x}_i),$$
$$\Pr(y_{ij} = 2) = \Phi(\mu_2 - \boldsymbol{\beta}_j'\mathbf{x}_i) - \Phi(\mu_1 - \boldsymbol{\beta}_j'\mathbf{x}_i),$$
$$\Pr(y_{ij} = 3) = \Phi(\mu_3 - \boldsymbol{\beta}_j'\mathbf{x}_i) - \Phi(\mu_2 - \boldsymbol{\beta}_j'\mathbf{x}_i),$$
$$\Pr(y_{ij} = 4) = 1 - \Phi(\mu_3 - \boldsymbol{\beta}_j'\mathbf{x}_i),$$

where Φ is the standard normal cdf. The following section provides the estimation results and the corresponding marginal effects of the relevant policy variables.

Table II. Ordered probit estimation results by material type

Variable	Newspaper	Glass	Plastic	Aluminum	Tin/Steel cans	Cardboard	Toxic chemicals
Intercept	0.23 (0.22)	−0.12 (0.20)	0.08 (0.20)	0.10 (0.21)	0.16 (0.21)	0.06 (0.20)	−0.94 (0.22)
Unit price	0.18 (0.08)**	0.22 (0.08)***	0.32 (0.07)***	0.32 (0.08)***	0.28 (0.08)***	0.18 (0.08)**	0.09 (0.07)
Weekly recycling	−0.00 (0.09)	0.14 (0.08)*	0.07 (0.08)	0.15 (0.09)*	0.01 (0.09)	−0.00 (0.08)	0.30 (0.08)***
Free units	−0.25 (0.15)*	−0.23 (0.14)*	−0.37 (0.13)***	−0.24 (0.15)*	−0.28 (0.14)**	−0.25 (0.14)*	−0.24 (0.14)*
Unit limit	−0.08 (0.17)	−0.06 (0.14)	−0.36 (0.15)**	−0.13 (0.16)	−0.22 (0.16)	−0.21 (0.16)	−1.02 (0.16)***
Mandatory recycling	0.26 (0.12)**	0.01 (0.11)	0.40 (0.11)***	0.26 (0.12)**	0.25 (0.12)**	0.29 (0.11)***	0.76 (0.12)***
Home ownership	0.50 (0.13)***	0.32 (0.13)***	0.25 (0.12)**	0.29 (0.13)**	0.37 (0.13)***	0.51 (0.12)***	0.33 (0.14)**
Education:							
High school grade	0.13 (0.15)	0.19 (0.14)	0.14 (0.14)	0.20 (0.15)	0.06 (0.14)	0.11 (0.14)	0.20 (0.15)
Some coll/univ	0.26 (0.20)	0.43 (0.18)**	0.34 (0.18)**	0.15 (0.18)	0.08 (0.18)	0.17 (0.18)	0.03 (0.19)
College grad	0.10 (0.15)	0.25 (0.14)*	0.00 (0.13)	−0.01 (0.14)	0.05 (0.14)	−0.04 (0.14)	0.22 (0.15)
Univ grad	0.17 (0.16)	0.39 (0.14)***	0.12 (0.14)	0.18 (0.15)	0.25 (0.15)*	0.00 (0.14)	0.15 (0.15)
Post grad	0.45 (0.18)***	0.42 (0.15)***	0.23 (0.15)	0.38 (0.17)**	0.24 (0.16)	0.21 (0.16)	0.40 (0.16)**
Income:							
$20,000–39,999	−0.26 (0.13)**	−0.14 (0.12)	−0.36 (0.11)***	0.05 (0.13)	0.04 (0.13)	−0.18 (0.12)	−0.08 (0.13)
$40,000–59,999	−0.22 (0.12)*	0.03 (0.11)	−0.11 (0.11)	0.06 (0.12)	−0.06 (0.11)	−0.12 (0.11)	−0.12 (0.12)

$60,000–79,999	−0.28 (0.13)**	−0.04 (0.12)	−0.07 (0.12)	0.13 (0.13)	−0.06 (0.12)	−0.13 (0.12)	0.06 (0.12)
$80,000–100,000	−0.11 (0.16)	−0.08 (0.14)	−0.03 (0.13)	0.07 (0.14)	−0.03 (0.14)	−0.01 (0.14)	−0.27 (0.14)**
Over $100,000	−0.27 (0.14)**	0.05 (0.13)	−0.04 (0.12)	0.01 (0.13)	−0.18 (0.13)	−0.18 (0.13)	−0.29 (0.13)**
Household size	−0.02 (0.02)	−0.03 (0.02)	−0.03 (0.02)	−0.03 (0.02)	−0.02 (0.02)	−0.02 (0.02)	−0.01 (0.02)
Head age:							
35–49	0.17 (0.13)	0.14 (0.12)	0.14 (0.12)	0.10 (0.13)	0.10 (0.12)	0.10 (0.12)	0.14 (0.13)
50–65	0.18 (0.13)	0.16 (0.12)	0.07 (0.12)	0.08 (0.13)	0.09 (0.13)	0.09 (0.13)	0.25 (0.13)**
Over 65	0.23 (0.15)	0.23 (0.14)*	0.01 (0.13)	−0.08 (0.14)	0.01 (0.14)	0.01 (0.14)	0.16 (0.14)
Number of observations	1403	1393	1404	1405	1407	1407	1220
Log likelihood	−976.32	−1259.35	−1465.51	−1080.69	−1114.49	−1233.75	−1026.60
χ^2 statistic	52.04***	45.97***	59.94***	61.63***	36.39***	43.86***	100.64***

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

4. Empirical Results

The results of the seven ordered probit regressions are presented in Table II. In all estimations except for toxic chemicals (which are not subject to the fee), the coefficient on the marginal price of waste disposal is positive and significant, indicating that user fees significantly increase the intensity of recycling. While it is impossible to make any direct inferences regarding illegal disposal, this effectiveness of user fees suggests that a majority of households increase recycling rather than resorting to illegal disposal. Other than sign and significance, the non-linearity of the procedure implies that the coefficients do not reflect marginal impacts on recycling probabilities. These marginal effects will be detailed below.

Among the other recycling policy variables, weekly recycling has a positive impact on the recycling of glass, aluminum, and toxic chemicals, but a negligible effect on the recycling intensity of newspaper, plastic bottles, tin cans and cardboard. This is consistent with the theory that making recycling more appealing (from fewer items to store from week-to-week and recycling at the same frequency as garbage collection) results in a higher recycling intensity.

Offering free units under a user fee program has a strong negative impact on recycling; in fact, in most cases the offering of free units completely offsets the benefits from the user fee program itself.[11] Mandatory recycling has the expected positive sign for most materials, with the exception of glass bottles where mandatory recycling is highly insignificant. Finally, limits on the number of units of garbage that can be placed at the curb (bag limits) generally have negligible impacts on the recycling, but have negative effects on the recycling of plastic bottles and toxic chemicals. As mentioned above, bag limits are expected to reduce garbage and increase recycling as households attempt to abide by the limit. The assumption underlying this is that the households would be over the limit otherwise. If this is not the case, then it is possible that households act strategically, increasing their garbage production to ensure that their limit is not reduced further.[12]

It should be noted that for three different policy options (recycling frequency, mandatory recycling, and bag limits), there is an effect on toxic chemicals despite the fact that these items are not collected in the weekly collections, and therefore are not directly affected by the policies. This suggests there may be indirect spillover effects of curbside recycling into depot recycling: policies that promote more household recycling at the curb also promote the recycling of non-curbside items.[13] As toxic chemicals have a potentially greater negative impact on environmental quality, the benefits of high recycling rates of particular non-hazardous materials generated by these policies may be augmented by significant benefits from spillovers into other materials.

Household characteristics have substantially different impacts, in both size and significance, depending on the material under consideration. For most materials, the highest education level attained is not a major factor in recycling intensity, except in terms of university undergraduate and/or post-graduate degrees for increased recycling of newspaper, aluminum, tin cans, and toxic chemicals. Glass is an exception, where education has positive impacts on recycling at all levels above a high school degree. Recycling generally decreases with income for newspaper (all levels of income), plastic (low levels only) and toxic chemicals (high levels only), and has no effect for the remaining materials.[14] As income increases, the value of time tends to increase, making recycling more costly. At the same time, some products (particularly newspapers) are more likely to be purchased by higher income households, which would then potentially increase their recycling.[15] Saltzman et al. (1993) suggests that the latter dominates the former, which is supported by the findings of Jenkins et al. (2000). Here we observe the opposite: the recycling time cost effect appears to be larger. Household size and age of the household head, included in other studies as well, has negligible impacts on the recycling of all variables. Jenkins et al. (2000) obtained the same results, except in the case of glass bottles where recycling increased with household size. Larger households imply more individuals who can potentially recycle, tending to increase recycling intensity. However, larger households result in more recyclable materials and therefore more effort necessary to recycle a given proportion. Finally, home ownership is positively (and strongly) related to recycling intensity. This may indicate that homeowners (as opposed to renters) are more attached to their community and/or are more concerned with the perceptions of their neighbors and recycle more as a result.

Again, the coefficients in the probit estimation do not represent the marginal effects of the independent variables on the recycling intensity probabilities. The non-linearity implies that the marginal effect of one variable is not independent of the levels of all other variables. Further, partial elasticities are not well defined for indicator variables. Accordingly, marginal effects are calculated for each significant policy variable by allowing one independent variable to change while holding the remaining independent variables at their respective means. For the continuous independent variable, the marginal price of garbage collection, this entails an increase of one unit from the mean, and finding the difference in predicted probabilities. For the indicator variables, the various probabilities are calculated with the indicator at a value of zero and at a value of one and differenced.

The marginal effects of the user fee (unit price) for each material are shown in Table III(a). The marginal effects are calculated only for those regressions where the price coefficient was significant, thereby excluding toxic chemicals (which was technically not permitted in curbside garbage collection and therefore not subject to the user fee). An increase of one dollar from the

Table III. Marginal effects

Variable	Newspaper	Glass	Plastic	Aluminum	Tin cans	Cardboard	Toxic chemicals
(a) Marginal effects of unit price variable in probit estimations, significant coefficients only							
Recycle 100%	0.042	0.065	0.101	0.082	0.077	0.052	–
Recycle 75%	−0.010	−0.012	−0.027	−0.012	−0.009	−0.010	–
Recycle 50%	−0.005	−0.006	−0.011	−0.007	−0.006	−0.005	–
Recycle 25%	−0.005	−0.013	−0.013	−0.008	−0.007	−0.007	–
Recycle 0%	−0.022	−0.034	−0.050	−0.055	−0.055	−0.031	–
(b) Marginal effects of weekly recycling indicator variable in probit estimations, significant coefficients only							
Recycle 100%	–	0.044	–	0.044	–	–	0.116
Recycle 75%	–	−0.007	–	−0.006	–	–	0.001
Recycle 50%	–	−0.004	–	−0.003	–	–	0.000
Recycle 25%	–	−0.008	–	−0.004	–	–	0.001
Recycle 0%	–	−0.024	–	−0.031	–	–	−0.118
(c) Marginal effects of free units indicator variable in probit estimations, significant coefficients only							
Recycle 100%	−0.069	−0.077	−0.134	−0.076	−0.092	−0.08421	−0.09274
Recycle 75%	0.014	0.012	0.025	0.009	0.008	0.0126	−0.001
Recycle 50%	0.008	0.006	0.012	0.005	0.005	0.008	−0.001

Recycle 25%	0.007	0.014	0.016	0.007	0.007	0.010	−0.001
Recycle 0%	0.040	0.045	0.081	0.055	0.071	0.054	0.095
(d) Marginal effects of bag limit indicator variable in probit estimations, significant coefficients only							
Recycle 100%	–	–	−0.130	–	–	–	−0.344
Recycle 75%	–	–	0.025	–	–	–	−0.005
Recycle 50%	–	–	0.012	–	–	–	−0.003
Recycle 25%	–	–	0.016	–	–	–	−0.010
Recycle 0%	–	–	0.078	–	–	–	0.362
(e) Marginal effects of mandatory recycling indicator variable in probit estimations, significant coefficients only							
Recycle 100%	0.064	–	0.131	0.075	0.076	0.090	0.297
Recycle 75%	−0.015	–	−0.032	−0.010	−0.008	−0.016	0.000
Recycle 50%	−0.008	–	−0.013	−0.006	−0.005	−0.009	0.000
Recycle 25%	−0.007	–	−0.017	−0.007	−0.007	−0.011	−0.001
Recycle 0%	−0.034	–	−0.069	−0.052	−0.056	−0.054	−0.296

mean[16] generates the largest impact on plastics (an over 10% increase in the probability that a household recycles approximately 100% of that material) and the smallest impact on newspaper (just over 4%). This tends to be true for the marginal effects of all policy variables. Overall, the impact of the unit price on recycling intensity is consistent with common waste management theory and Hong et al. (1993), and closely conform to the results of Callan and Thomas (1997).[17] This evidence differs, however, from the zero impact of unit pricing found in Fullerton and Kinnaman (1996), Reschovsky and Stone (1994) and Jenkins et al. (2000).

Table III(b) details the marginal effects of weekly recycling. Moving from biweekly recycling collection to weekly recycling collection increases the probability of recycling all of the potential material by 4.3% for glass, 4.4% for aluminum and 11.6% for toxic chemicals. Weekly recycling is insignificant for the remaining materials. More frequent recycling tends to reduce the amount of storage necessary for recycling and the disutility individuals may receive from having waste products on their premises. At the same time, more frequent collections may involve higher recycling time costs as the materials must be placed at the curb more frequently (although garbage is collected weekly in each community in the study). Recycling frequency has not been studied in this way prior to this investigation, and it is interesting to see that frequency does appear to have a positive impact.

Marginal effects of providing free units under a user fee program are indicated in Table III(c). Free units tend to have significantly negative impacts on recycling intensity, lowering the probability of recycling 100% by between 6.9% and 13.4% (depending on the material) and increasing the probability of not recycling by 4–9.4%. These changes are comparable to (or even slightly larger than) the user fee effects of Table III(a), suggesting that offering free units under a user fee is similar to having no user fee whatsoever. Fullerton and Kinnaman (1996) investigated the related issue of a bag minimum under unit pricing, suggesting that such a policy would slightly increase recycling through lower illegal dumping, relative to unit pricing with no bag minimum. However, no comparisons were made relative to the absence of unit pricing. Here, recycling decreases significantly with free units.[18] This is a new, and somewhat surprising (at least in magnitude), result as well.

Table III(d) shows the marginal impacts of a low bag limit on plastics and toxic chemicals. With respect to both materials, the negative effect on recycling intensity of imposing a bag limit is very large. For newspaper, glass, aluminum, tin, and cardboard, the regression coefficients were quite insignificant. Finally Table III(e) indicates the marginal effects of imposing mandatory recycling. Moving from a voluntary recycling program to a mandatory program increases the likelihood of recycling 100% by between 6.4% and 29.7%, and lowers the probability of recycling nothing by 3.4–29.6%. These results conform to expectations. However, Jenkins et al. (2000)

found that mandatory recycling has a negligible effect on the recycling intensity of all materials. It is possible that expected punishments (through stricter enforcement) were substantially lower in the communities in their study, making the programs in effect not mandatory.

To summarize, newspaper is most sensitive to mandatory recycling and user fees, and is unaffected by recycling frequency and bag limits. Glass recycling increases with user fees and more frequent recycling collection. Plastics are sensitive to all policy options except recycling frequency. Bag limits have a significant negative impact on the recycling of plastics. Aluminum recycling is affected by all options except bag limits, the greatest impact coming from user fees. Mandatory recycling and user fees significantly increase the recycling of tin cans. The same options affect cardboard recycling, although mandatory recycling generates larger increases than a $1 user fee. Offering free units with unit pricing reduces recycling for all materials.

5. Concluding Remarks

Despite a relatively unified theory of waste management, at least in terms of predictions of the impacts of various policies, substantial differences have been found when examining actual waste and recycling decisions of households and communities. Most theoretical papers on the topic in the past decade have suggested that user fees on waste disposal should be employed to reduce garbage and increase recycling intensities. The single most important obstacle to user fees has been the suggestion that illegal disposal effects may outweigh the potential recycling and waste reduction benefits of a positive user fee. If illegal behaviour could be taxed, a positive user fee would be optimal, and even without a illegal dumping tax, user fees remain positive in situations of high resource costs. Nonetheless, if illegal activity is an important household option, a positive user fee would not result in significantly more recycling without a corresponding consumption tax.[19] The purpose of this study was to gather information on recycling intensities under various recycling programs and waste management financing options to shed some light on issues such as unit disposal pricing, bag limits, and recycling frequency. Impacts on garbage production are left to future work, as the impacts appear clearer for that stream.

For all six materials studied that are permitted in the garbage stream, user fees are found to result in significant increases in recycling intensity. One caveat to this is that the provision of free units (x bags per collection) under such programs tends to entirely negate the positive effects of the user fee. More frequent recycling tends to increase recycling intensity, although not for all materials. Comparable effects to that of user fees can be achieved through instituting a mandatory recycling program as opposed to leaving recycling voluntary.[20] Bag limits, however, do not have the desired impact of increasing recycling intensity. In fact, the evidence presented here suggests that bag limits may actually reduce recycling intensity for some materials. A caveat here is that those municipalities with higher garbage production and lower recycling levels may be selecting bag limits as a policy, and not vice versa.

To be clear, this study examines only the impacts of various policies on recycling intensity. Overall, the total impacts on both garbage and recycling streams may be quite different than the evidence presented here suggests. Nonetheless, the recycling-specific conclusions drawn here could potentially be useful for waste management policymakers comparing the costs and benefits of a number of recycling and waste disposal policies.

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Notes

1. Some "subscription" programs, under which households commit in advance to a particular level over time and are charged accordingly, have existed for a very long time, but it has only recently that these and other unit pricing programs have become common.
2. Palmer et al. (1997) look at similar materials (paper, glass, plastic, aluminum and steel), but from the perspective of the firm rather than the household. Intervention levels necessary for waste reduction were estimated, with the finding that a deposit-refund system is more effective than advance disposal fees or recycling subsidies.
3. Previous studies, including Hong et al., have examined the frequency that individuals recycle, but not how the policy decision of how often to collect recyclables (the recycling pickup frequency) affects the amount individuals recycle.
4. The majority of deleted observations were the result of missing information on the family income level. Recycling program details were augmented and checked against known community information.
5. None of the recycling programs had been instituted in the previous 2 years.
6. Garbage collection frequency was identical across all households in the survey and therefore was excluded from the analysis.
7. One community limited the number of bags over a calendar year and not by week. The limit was 40 bags per year, thus the 0.77 bags per week figure.
8. All monetary figures are in Canadian dollars.

9. The breakdown for newspaper, from the highest category (100%) to the lowest (0%), was 81.3%, 5.5%, 2.5%, 2.2%, and 8.3% (all figures rounded); for glass bottles, 73.4, 7.1, 2.9, 5.5 and 11.1; for plastic bottles, 69.3, 11.0, 3.6, 4.1, 12.0; for aluminum cans, 77.0, 4.5, 2.2, 2.5, and 13.7; for tin cans, 75.8, 3.8, 2.2, 2.8, and 15.4; for cardboard, 74.1, 6.8, 3.3, 3.6, and 12.2; and for toxic chemicals, 43.3, 1.1, 0.8, 2.5 and 52.2.
10. Fullerton and Kinnaman note that a negative user fee would subsidize consumption and therefore a consumption tax would be required. The inability to tax illegal activity does not result in a second-best solution as, in general equilibrium, only relative taxes matter and the tax on illegal behaviour can be zero.
11. In most communities that offered free units, the limit was either two or three bags, which may exceed the average number of bags set out for collection by most households. If this is the case, the implciation is that the marginal price of garbage disposal is zero.
12. In fact, in one community with bag limits in the survey (Orillia), the number of bags permitted was reduced to below one per week as it was believed that households were putting out one bag of garbage at the curb every week despite not having one bag per week prior to implementation. There may be an endogeneity issue here as well as cities implement bag limits in response to low recycling rates.
13. Alternatively, there may be some other unobserved factors (such as personal environmental sentiment) that influence the recycling of these materials that could not be included in the analysis. Local government endogeneity problems of this type have been addressed in the aggregate study by Fullerton and Kinnaman (2000). However, the limited numbers of distinct municipalities in micro-data studies such as this one do not allow for such corrections.
14. The relatively high correlations between income and education may be obscuring the significance of these variables. The same could be said for home ownership, income and education.
15. The question remains whether this will in fact affect recycling rates.
16. Marginal effects of moving from a zero user fee to a positive user fee have the same general tendencies, with only slightly larger changes in the extreme category probabilities (that is, 0% and 100%).
17. Callan and Thomas found aggregate recycling would increase by 6.5% after the introduction of a user fee program.
18. This may, however, result in more illegal dumping.
19. Fullerton and Kinnaman note that consumption taxes are not generally the political jurisdiction of municipalities (which set user fees).
20. Presuming mandatory recycling is appropriately enforced.

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